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Lower Jurassic to lower Middle Jurassic succession at Kopy Sołtysie and Płaczliwa Skała in the eastern Tatra Mts (Western Carpathians) of Poland and Slovakia: stratigraphy, facies and ammonites

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Key words: stratigraphy, Lower to Middle Jurassic, ammonites, microfacies, correlations, Tatra Mts, Western Carpathians.

Abstract. The Lower Jurassic and the lower part of the Middle Jurassic deposits corresponding to the Sołtysia Marlstone Formation of the Lower Subtatric (Krížna) nappe in the Kopy Sołtysie mountain range of the High Tatra Mts and the Płaczliwa Skała (= Ždziarska Vidla) mountain of the Belianske Tatra Mts in the eastern part of the Tatra Mts in Poland and Slovakia are described. The work concentrates both on their lithological and facies development as well as their ammonite faunal content and their chronostratigraphy. These are basinal deposits which show the dominant facies of the fleckenkalk-fleckenmergel type and reveal the succession of several palaeontological microfacies types from the spiculite microfacies (Sinemurian–Lower Pliensbachian, but locally also in the Bajocian), up to the radiolarian microfacies (Upper Pliensbachian and Toarcian, Bajocian–Bathonian), and locally the *Bositra* (filament) microfacies (Bajocian–Bathonian). In addition, there appear intercalations of detrital deposits – both bioclastic limestones and breccias – formed by downslope transport from elevated areas (junction of the Sinemurian and Pliensbachian, Upper Toarcian, and Bajocian). The uppermost Toarcian – lowermost Bajocian interval is represented by marly-shaly deposits with a marked admixture of siliciclastic material. The deposits are correlated with the coeval deposits of the Lower Subtatric nappe of the western part of the Tatra Mts (the Bobrowiec unit), as well as with the autochthonous-parachthonous Hightatric units, but also with those of the Czorsztyn and Niedzica successions of the Pieniny Klippen Belt, in Poland. The character of the deposits in the sequences, and their biostratigraphical analysis, show that sedimentation during the Early Jurassic, and up to the Late Bajocian, was controlled by rifting phases which were active at the junction of the Sinemurian and Pliensbachian (Zliechov Phase), during the Late Pliensbachian and Toarcian (Devín Phase), and during the Bajocian (Krasín Phase). The onset of pelagic sedimentation overlying the rift strata took place during the latest Bajocian. Selected ammonite taxa are illustrated and discussed.

INTRODUCTION

The Jurassic succession of the Kopy Sołtysie mountain range area constitutes a fragment of the Lower Subtatric nappe stretching to the east of the Sucha Woda and Pańszczyca valleys, and north of the Koszysta and Wołoszyn massifs in the eastern part of the High Tatra Mts of Poland, which continues eastward into the Belianske Tatra Mts of Slovakia (Figs 1–5). The stratigraphical and tectonical interpretation of the Lower Jurassic and lower part of the Middle Jurassic succession was given by Iwanow (1973, 1979a–c, 1985) who recognized these deposits as representing a new

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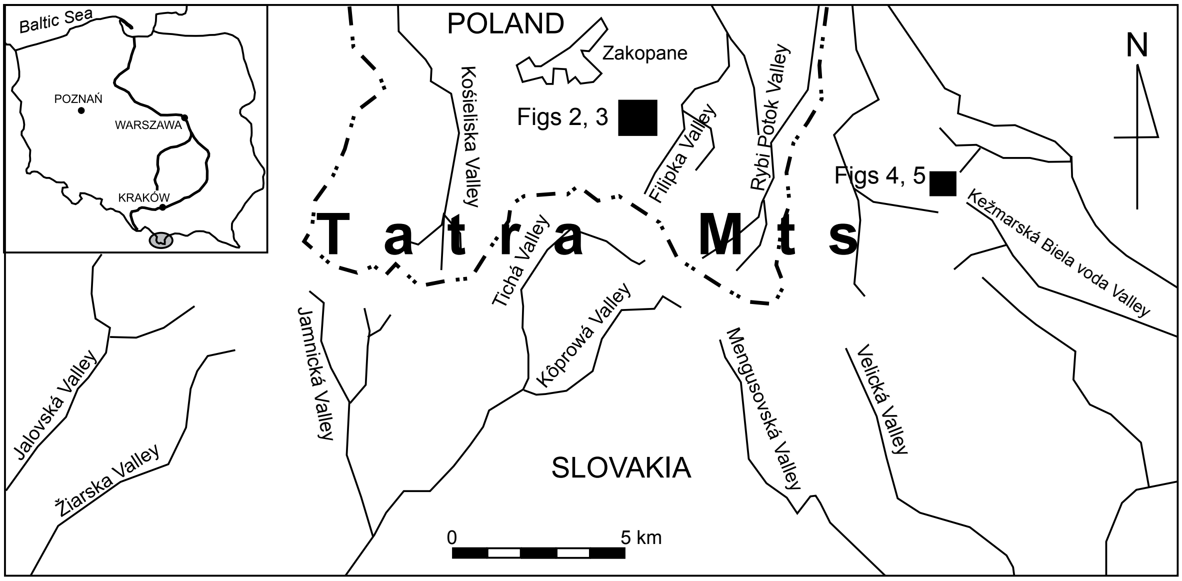

Fig. 1. Location map showing the positions of the investigated areas in the Tatra Mts

subdivision of the Lower Subtatric nappe called the Havran (Hawrań) sequence. This subdivision is characterized by the occurrence of white quartzitic sandstones (Baboš Quartzite Member) and a thick succession of basinal deposits represented by spotted limestones and marls of the Sołtysia Marlstone Formation of the dominant fleckenkalk – fleckenmergel facies. These deposits were subdivided into several formal lithostratigraphic units of member and bed rank within the proposed lithostratigraphic scheme (Iwanow, 1985). The succession is similar to that of the Lower Jurassic Janovky Formation of Gaździcki *et al.* (1972) which is based on the sequence about 300 meters in thickness exposed in the Janovky gully located on the southern slopes of Hawrań mountain (see Andrusov, 1959; Borza, 1959; Mišík, 1959) in the Belianske Tatra Mts in Slovakia. Another similar lithological unit is the Allgäu Formation which includes deposits of the fleckenkalk – fleckenmergel facies already distinguished by Gümbel (1856) in the Alps, but recognized also by some authors in the Western Carpathians. This lithostratigraphic classification has been modified recently by Birkenmajer (2013) who upgraded the Sołtysia Marlstone Formation into the Sołtysia Group, and proposed its subdivision into three newly erected formations. The proposal is not followed in the present study, however, and the relevant comments are given in the chapter "Conclusions".

The Lower Jurassic and lower Middle Jurassic deposits of the Lower Subtatric (Križna) nappe of the Fatricum megaunit in the Western Carpathians show a marked facies differentatiation corresponding to basinal and ridge areas. These include the Zliechov succession formed in the Zliechov basin which represents the dominating basinal deposits of the Lower Subtatric nappe, as well as the successions of the northern margin of the basin transitional to those of the Tatricum megaunit which show the presence of shallower and/or less complete sequences – such as the Vysoká type succession (Plašienka, 2003, 2012, and other papers cited therein). The same differentiation of coeval deposits may be observed in the Tatra Mts, in the Lower Subtatric nappe – where the basinal succession (the Havran sequence) of the Kopy Sołtysie area and of the Belianske Tatra Mts (Figs 2, 5) corresponds generally to the Zliechov succession, whereas those of the Czerwona Skałka–Holica units in the eastern part of the Tatra Mts, and of the Bobrowiec unit in the western part of the Tatra Mts, are similar to the Vysoká type succession. The formation of the deposits of the particular successions was controlled by the tectonic events, the rifting phases especially well pronounced during the Early and early Mid Jurassic (Plašienka, 2003, 2012).

Because of the monotonous development of the deposits of the Kopy Sołtysie area their detailed stratigraphical interpretation has to be based on ammonite findings. Early collections of ammonites described by Kuźniar (1908), including some specimens from the older collection of F. Bieniasz, as well as those described by Siemiradzki (1923) (specimens collected by V. Uhlig), gave the first information on the biostratigraphy of the younger part of the succession. The extensive field work and collecting by A. Iwanow during 1967–1973, offered the basis for the detailed chronostratigraphical interpretation of the whole succession (Iwanow, 1973, 1985; see also 1979d), but these ammonites have

Fig. 2. Kopy Sołtysie mountain range of the High Tatra Mts (eastward view)

been never described and/or illustrated, and corrections of some of the identifications are given herein. Moreover, this study includes newly gathered material by J. Iwańczuk which has not been presented so far. The specimens described by Myczyński (2004) supplemented the general knowledge on the stratigraphy of the youngest deposits of the succession studied. The preliminary results of these studies were presented recently in conference abstracts (Iwańczuk, 2009; Iwanow *et al.*, 2012; Iwańczuk *et al.*, 2012), but the full interpretation of the stratigraphy of the deposits studied, with descriptions of the most important ammonite findings, is given below.

FACIES AND STRATIGRAPHY

The oldest deposits of the Sołtysia Marlstone Formation which directly overly the quartzitic sandstones of the Med'odoly Sandstone Formation, are almost black, medium- and thick- bedded limestones, belonging to the Płaśnia Limestone Member (Iwanow, 1985). The lower part of the member consists of sandy limestones with the marked admixture (about 5–10%) of fine detrital quartz grains (0.1–0.4 mm in diameter), and some organogenic rests (sponge spicules, bivalves, and less commonly foraminifers of the family Nodosariidae, and fragments of unidentified echinoderms) (Pl. 1: 1). The sponge spicule content increases upwards, which results in the appearance of the spiculite microfacies in the upper part of the member, simultaneously the detrital quartz grains are decreasing.

The deposits of the Płaśnia Limestone Member are found on the Czerwone Brzeżki ridge and at Płaczliwa Skała mountain (Figs 3, 4, 7). The Czerwone Brzeżki locality is placed on the SE slope of the ridge (N49°16.093'; E20°03.134'); the Płaczliwa Skała locality is on the southern part of the mountain, and on its SE slope – in the old tourist trail, in the Belianske Tatra Mts of Slovakia (Fig. 5).

The Płaśnia Limestone Member yielded a few ammonites, found in a rubble possibly coming from the upper part of the unit. These ammonites include *Plesechioceras* cf. *delicatum* (Buckman)[1] * and "primitive" *Echioceras* sp. ex gr. *E. quenstedti* (Schafhäutl)[2] (Pl. 4: 1, 4). The occurrence of these ammonites indicates the Densinodulum Subzone, and the lower part of the Raricostatum Subzone of the Raricostatum Zone of the Upper Sinemurian ("Lotharingian")** (see Dommergues, 1982; Corna *et al.*, 1997; Blau, 1998).

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* Subscript members refer to the description of these specimens in the chapter "Comments on the ammonites"

** Use of the formal names for the substages such as "Lotharingian", "Carixian", "Domerian" is generally discouraged as not to multiply the list of names according to proposed objectives for ISJS (Morton, 2005); in fact they are still used, however, in a more or less informal way (*e.g.* Ogg *et al.*, 2012)

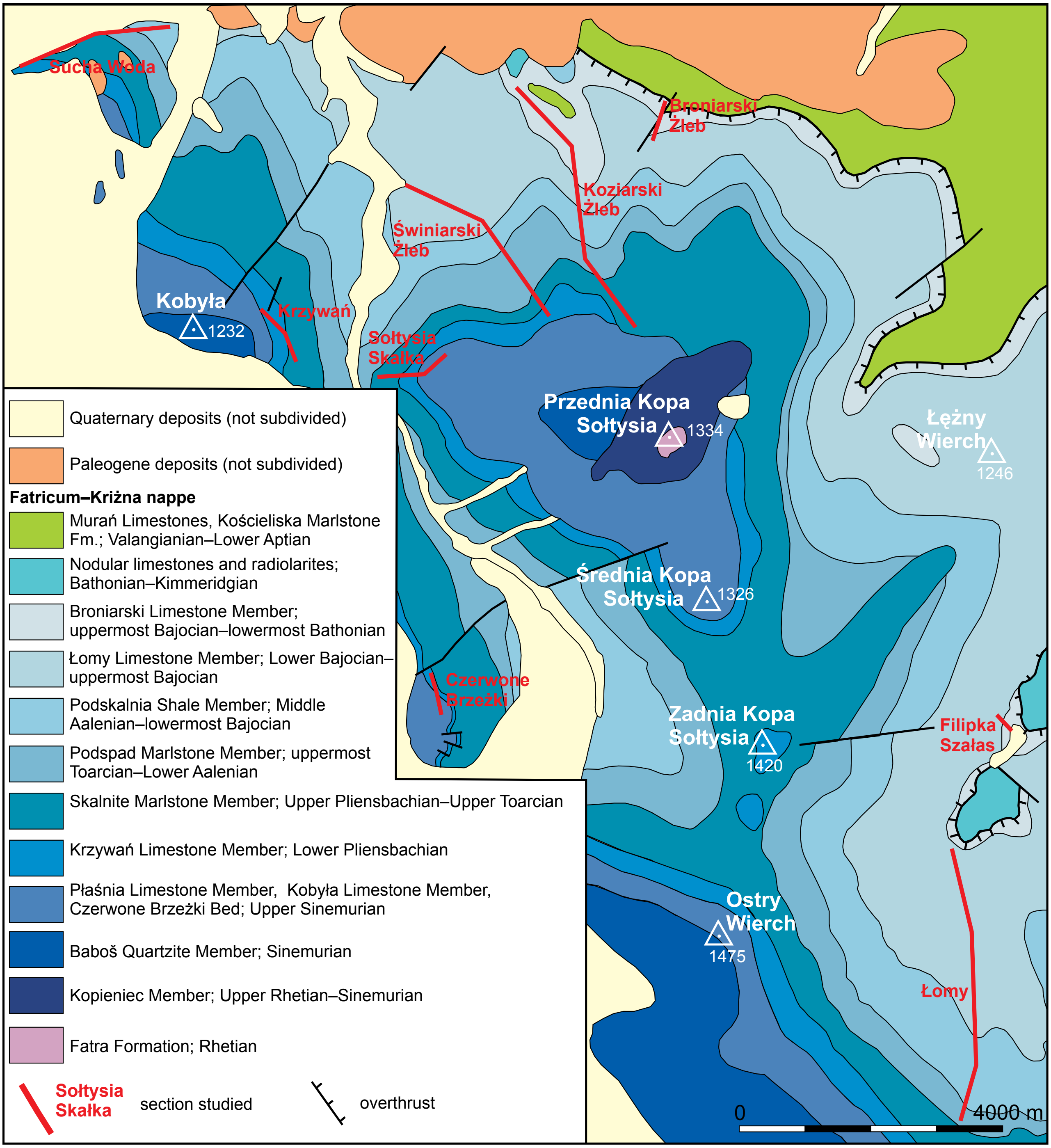


Fig. 3. Fragment of the geological map of the High Tatra Mts in Poland (Zakopane – Toporowa Cyrhla sheet, after Iwanow *et al.*, 2007b; and Łysa Polana sheet, after Iwanow *et al.*, 2007a; simplified), showing the Kopy Sołtysie area with the location of the sections studied

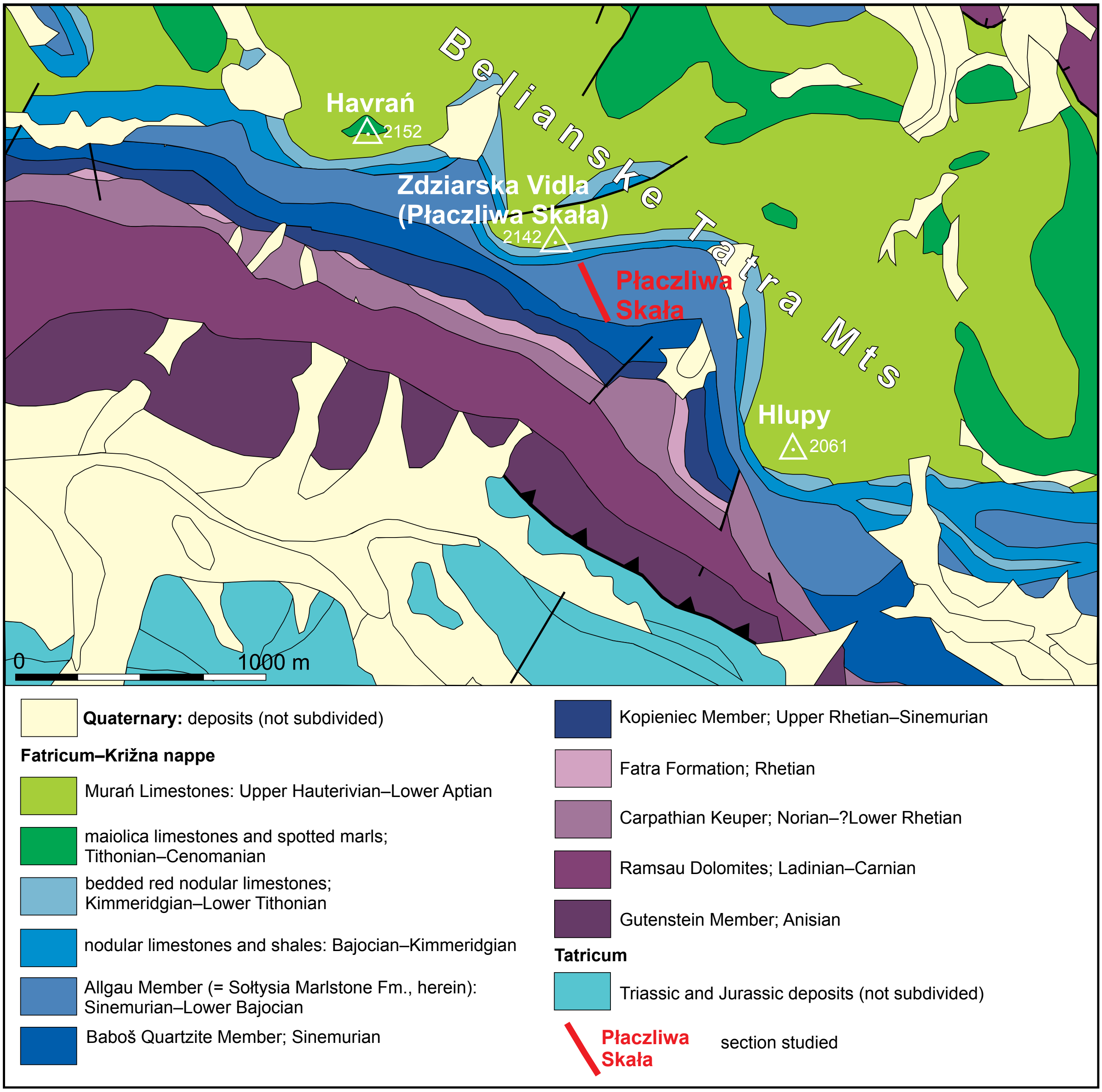


Fig. 4. Fragment of the geological map of the Belianske Tatra Mts in Slovakia (after Nemčok, 1986, simplified), showing the location of the section studied at Ždziarska Vidla (= Płaczliwa Skała) Mt.

The overlying beds are gray-brown, partly silicified spotty limestones and marly shales which represent the Kobyła Limestone Member (Iwanow, 1985). The limestones are thin-bedded, and individual beds attain up to 0.1–0.2 m in thickness, whereas the interstratified silicified marly shales are 0.01–0.02 m thick (Fig. 6A). The limestones show the presence of the spiculite wackestone – packstone microfacies (the most common of the spongy spicules are monaxons, but there occur also triaxons and tetraxons) (Pl. 1: 2); small belemnite rostra are occasionally found. Trace-fossils include: *Planolite*s, *Chondrites* and *Zoophycos*.

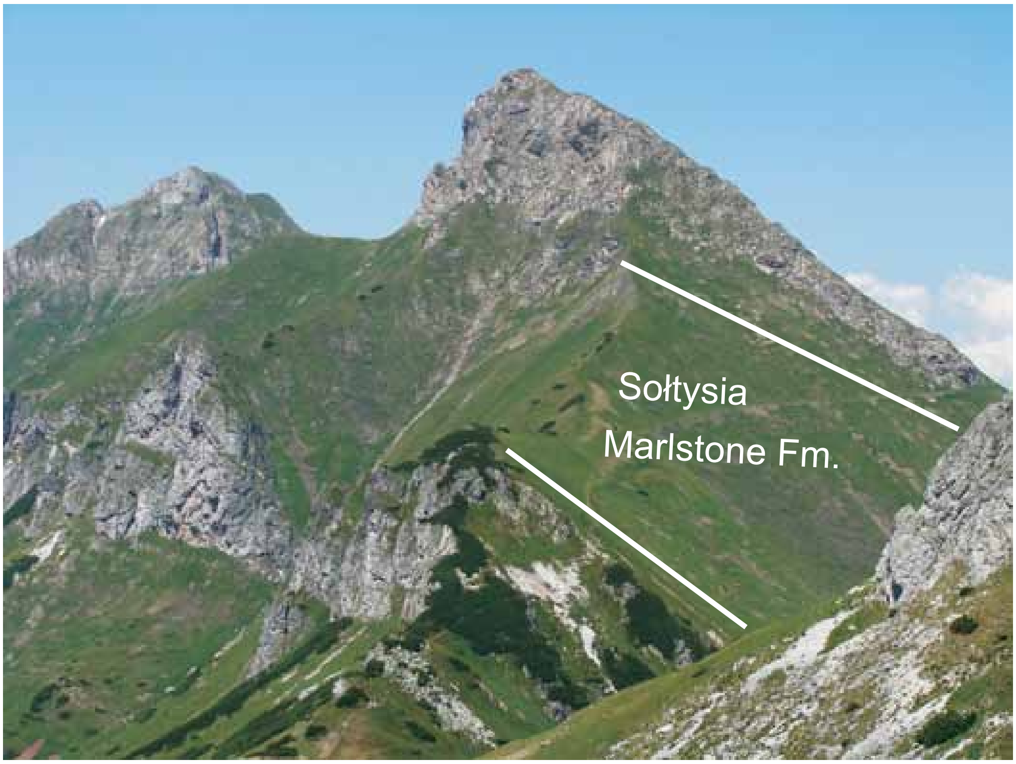


Fig. 5. Ždziarska Vidla (= Płaczliwa Skała) Mt. of the Belianske Tatra Mts (northern view) showing the position of the Sołtysia Marlstone Fm.

The Kobyła Limestone Member is found at Czerwone Brzeżki and Płaczliwa Skała as well as at Sołtysia Skałka (Figs 2–5). The latter locality (N49°16.572'; E20°02.977') is placed on the south-eastern and eastern slopes of the mountain.

The ammonites are represented by several fragments of *Echioceras*[2] – ex gr. *E. raricostatoides* (Vadasz) (Pl. 4: 3) – which are typical representatives of the genus with swollen ribs. These were found in a single piece of a rock from loose rubble – which suggests some condensation. These ammonites indicate the Raricostatum Subzone of the Raricostatum Zone of the Upper Sinemurian ("Lotharingian") – not including its lower part – as proved by occurrence of typical *Echioceras* (see Schlatter, 1991; Blau, 1998).

The Czerwone Brzeżki Bed (Iwanow, 1985), attaining a few metres in thickness (commonly from 2 to 3 m), consists of bioclastic limestones of the wackestone type with abundant bioclasts (echinoderms, bivalves and foraminifers) and fairly common belemnite rostra (Fig. 7; Pl. 1: 3–5). The bed commences with an intraformational breccia composed of clasts of dark limestones; the clasts show poorly marked boundaries and contain abundant fossil fragments of echinoderms, bivalves, brachiopods, as well as sponge spicules, juvenile ammonites, and foraminifers (*Involutina liassica* Jones, *I. turgida* Kristan, *Ophthalmidium laischneri* Kristan-Tollmann, *Nodosaria* sp.). The breccia matrix is a detrital limestone of the packstone/grainstone type containing also abundant bioclasts and foraminifers of the family Nodosariidae. The limestones representing the bulk of the bed are topped by marly limestones about 0.5 m in thickness (Fig. 6B).The bed is found at Czerwone Brzeżki and Sołtysia Skałka (Fig. 3).

No ammonites have been found within this bed, but its stratigraphical position near the junction of the Sinemurian and Pliensbachian is proved by ammonite findings in the underlying and overlying deposits. It should be noted, however, that the ammonite referred to here as *Ortechioceras recticostatum* Trueman et Williams[3] (Pl. 4: 2), found loose in the rubble, is preserved in a matrix of detrital limestone of the packstone/grainstone type – very similar to that of the Czerwone Brzeżki Bed. Assuming the ammonite comes from the Czerwone Brzeżki Bed, it indicates that the stratigraphical interval of this bed lies from the Raricostatum Subzone of the Raricostatum Zone of the Upper Sinemurian ("Lotharingian") – (not including its lower part) up to the somewhat younger parts of the Raricostatum Zone up to the Aplanatum

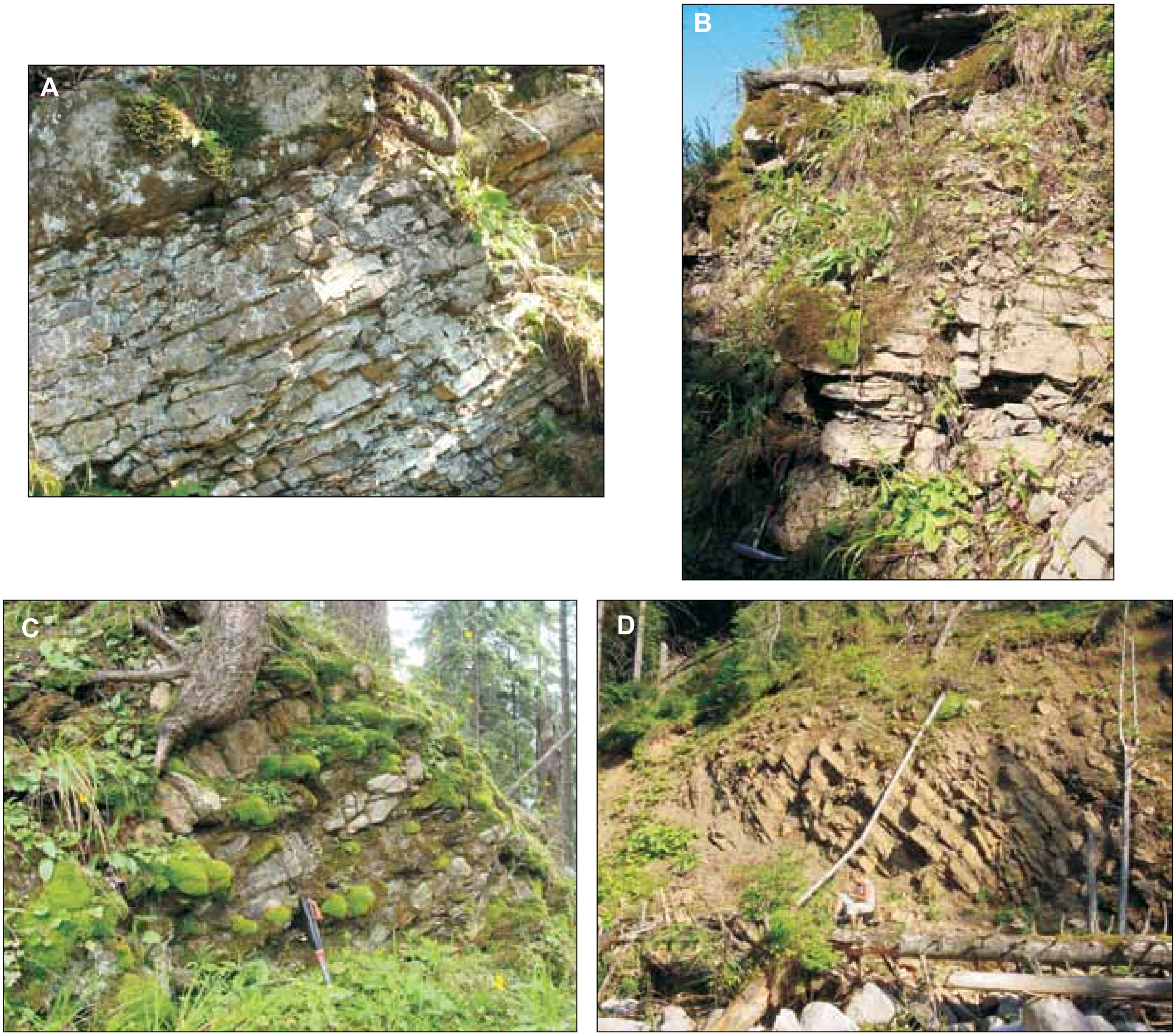
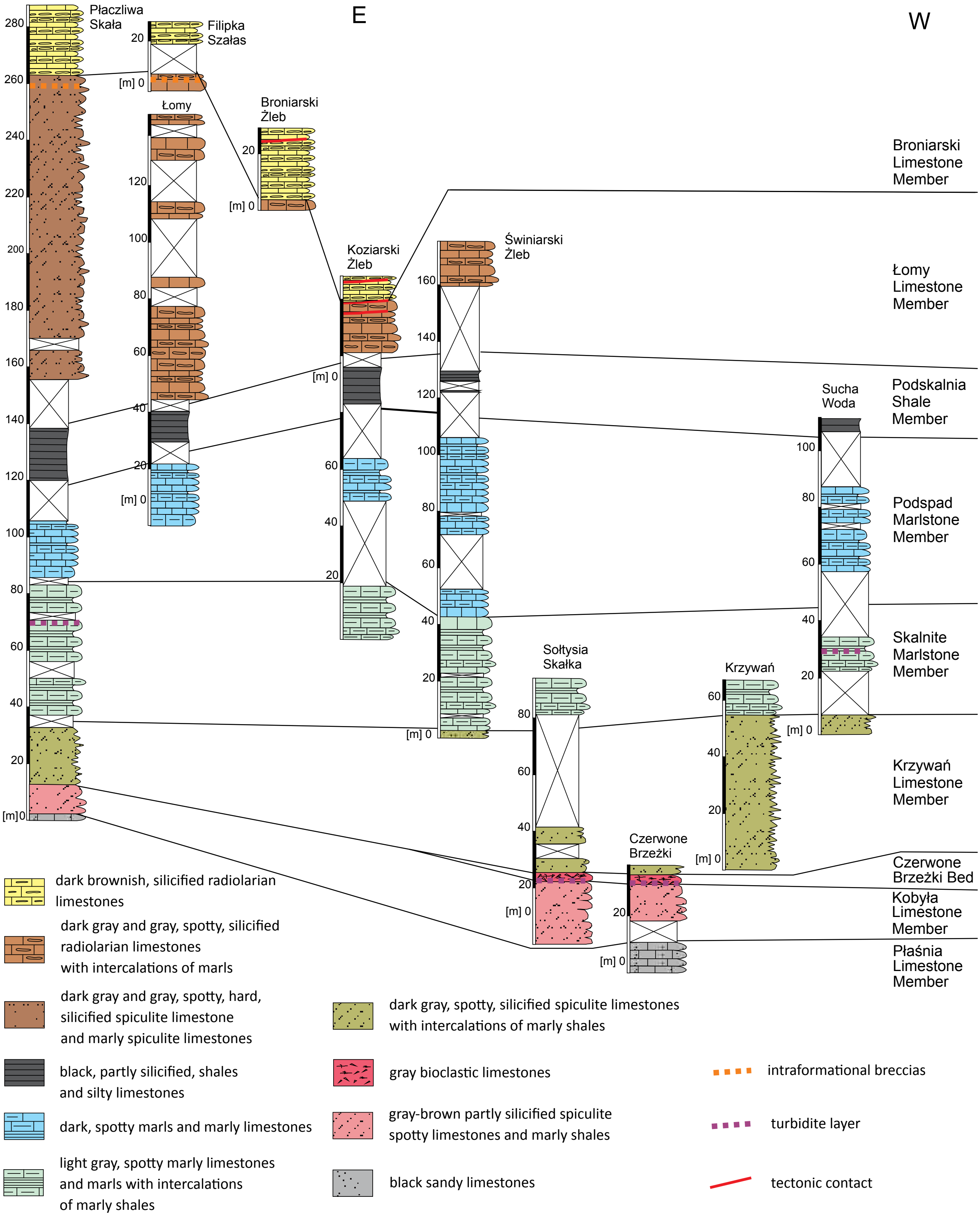


Fig. 6. Selected lithologies of various members of the Sołtysia Marlstone Fm. in the sections of the Kopy Sołtysie area studied (the beds are in an overturned position): A – Kobyła Limestone Member, Sołtysia Skałka; B – Czerwone Brzeżki Bed, Sołtysia Skałka; C – Krzywań Limestone Member, Sołtysia Skałka; D – Skalnite Marlstone Member, Sucha Woda

Subzone (see Schlatter, 1991; Blau, 1998). The foraminifers recognized in the Czerwone Brzeżki Bed suggest also the Sinemurian age of the deposits (Gaździcki, 1983).

Still younger are dark gray, spotty, strongly silicified, bedded limestones with a few belemnite rostra, and with cherts especially common in a middle part of the unit, and with intercalations of marly shales, representing the Krzywań Limestone Member (Iwanow, 1985; Figs 6C, 7). The common occurrence of sponge spicules results in the appearance of spiculite wackestones-packstones in some intervals of the succession (Pl. 1: 6). Some beds contain fragments of echinoderms, as well as foraminifers of the family Nodosariidae (*Nodosaria* sp., *Lenticulina* sp.). The thickness of particular beds ranges from 0.1–0.7 m, whereas that of the interstratified shales – from 0.02–0.1 m. One observes a general decrease in thickness of beds towards the top of the unit. Trace-fossils are commonly encountered and include: *Chondrites*, *Zoophycos* and *Planolites.*

The Krzywań Limestone Member is found at Krzywań, Sołtysia Skałka and Płaczliwa Skała mountains and in the


E
W
Płaczliwa Skała
Filipka Szałas
Łomy
Broniarski Żleb
Koziarski Żleb
Świniarski Żleb
Sucha Woda
Sołtysia Skałka
Krzywań
Czerwone Brzeżki
Broniarski Limestone Member
Łomy Limestone Member
Podskalnia Shale Member
Podspad Marlstone Member
Skalnite Marlstone Member
Krzywań Limestone Member
Czerwone Brzeżki Bed
Kobyła Limestone Member
Płaśnia Limestone Member
[m] 0
dark brownish, silicified radiolarian limestones
dark gray and gray, spotty, silicified radiolarian limestones with intercalations of marls
dark gray and gray, spotty, hard, silicified spiculite limestone and marly spiculite limestones
black, partly silicified, shales and silty limestones
dark, spotty marls and marly limestones
light gray, spotty marly limestones and marls with intercalations of marly shales
dark gray, spotty, silicified spiculite limestones with intercalations of marly shales
gray bioclastic limestones
gray-brown partly silicified spiculite spotty limestones and marly shales
black sandy limestones
intraformational breccias
turbidite layer
tectonic contact

Sucha Woda valley (Figs 2–5). It usually forms steep cliffs such as that of the 50 metre high cliff of Krzywań, representing one of the most spectacular and inaccessible localities of the study area (N49°16.628'; E20°02.795'). The Sucha Woda locality (N49°17.036'; E20°02.373') is found on the eastern slope of the Sucha Woda valley, near the black tourist trail.

Ammonites are not common in the Krzywań Limestone Member. The occurrence of *Tropidoceras* sp.[4] (Pl. 4: 5) indicates the Lower Pliensbachian ("Carixian"), especially the Jamesoni and Ibex zones (see *e.g.* Meister, 1986; Dommergues *et al.*, 1997; Géczy, Meister, 2007).

The overlying light gray, bedded, spotty marly limestones and marls with intercalations of marly shales belong to the Skalnite Marlstone Member (Iwanow, 1985; Figs 6D, 7). The thickness of particular limestone and marl beds ranges from 0.1 m to 0.7 m, whereas that of the intercalations of shales is from 0.02 to 0.3 m. Radiolarian wackestones/packstones constitute the dominating microfacies (Pl. 2: 1), but subordinately filament (*Bositra*) packstones are also encountered. The deposits are usually highly bioturbated, and the assemblage of ichnofossils differs in particular beds (from one composed entirely of *Chondrites*, through ones composed of *Zoophycos*-*Chondrites* or *Planolites*-*Chondrites*, up to ones of *Planolites*-*Chondrites*-*Zoophycos*) (see Iwańczuk, Tyszka, 2009; Iwańczuk, Sobień, 2011). Some rare limestone beds (0.2–0.3 m in thickness) are devoid of bioturbation and differ markedly from the dominating lithology of the unit also in other features. They contain a characteristic succession of microfacies – from spiculite packstone/grainstone with ferrugineous concretions (from 0.02–0.1 m in diameter) up to graded and laminated spiculite packstone/wackestone (Pl. 2: 2) or of the crinoidal packstone/grainstone (Pl. 2: 3). According to these features – the beds may be interpreted as distal turbidites (Iwańczuk, Tyszka, 2009). These limestone beds have been found in the Sucha Woda and Płaczliwa Skała localities where they occur in deposits attributed to the Upper Toarcian.

The Skalnite Marlstone Member is found at the Sucha Woda, Świniarski Żleb, Koziarski Żleb, Krzywań, Płaczliwa Skała, Sołtysia Skałka localities (Figs 2–5). The Koziarski Żleb locality (N49°16.978'; E20°03.266') exposes beds at the bottom of a stream on the NW slopes of Przednia Kopa Sołtysia mountain; another locality – the Świniarski Żleb, is placed more towards the west of the former.

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Fig. 7. Lithostratigraphical units of the Lower to lower Middle Jurassic sections of the Kopy Sołtysie mountain range (High Tatra Mts), and the Ždziarska Vidla (= Płaczliwa Skała) Mt. (Belianske Tatra Mts)

Ammonites are numerous, occurring mostly in lenses in marly limestones; they represent several ammonite faunas different in age. The oldest fauna consists of (Pl. 4: 6–9): *Fuciniceras* ex gr. *F. lavinianum* (Fucini) – *F. portisi* (Fucini)[5], *Fuciniceras* ex gr. *F. cornacaldense* (Tautsch)[6], *Protogrammoceras* ex gr. *P. celebratum* (Fucini)[7], and *Paltarpites* sp.[8] These characterize the Margaritatus Zone of the Upper Pliensbachian ("Domerian") (Wiedenmayer, 1977; Géczy, Meister, 1998; Bendík, 2012). Although the Lower Toarcian has not been faunistically proved, the occurrence of the next ammonite fauna (Pl. 4: 10; Pl. 5: 1–3) of the Bifrons and the Variabilis zones of the Middle Toarcian (*Hildoceras bifrons* (Bruguière)[9] and *H.* ex gr. *H. sublevisoni* Fucini[10], *Haugia* sp.) is well documented (*cf.* Elmi *et al.*, 1997; Rulleau, Elmi, 2001). A younger ammonite fauna (Pl. 5: 4–7; Pl. 6: 1–6), consisting of *Pseudogrammoceras bingmanni* (Denckmann), *P. struckmanni* (Denckmann)[11], and *Pseudogrammoceras* ex gr. *P. doerntense* (Denckmann)[12], abundantly represented in the collections studied, belongs to the Bingmanni Subzone, and a lower part of the Thouarsense Subzone, thus representing a lower part of the Thouarsense Zone of the lower Upper Toarcian (Guex, 1975; Gabilly, 1976; Elmi *et al.*, 1997). Ammonites of the same ammonite fauna such as the *Grammoceras* cf. *thouarsense* (d'Orbigny) of Kuźniar (1908, p. 79, pl. 1: 7) and of Siemiradzki (1923, p. 23–24, pl. 4: 5), as well as *Pseudogrammoceras* including the *P. bingmanni* of Myczyński (2004, p. 54–56, fig. 21: 1–4, 5; fig. 22: 1–2; fig. 24: 2) were previously reported from the area of study. The ammonite *Polyplectus discoides* (Zieten) described by Myczyński (2004, p. 53–54, fig. 23:1; fig. 24: 3) from the Skalnite Marlstone Member is somewhat younger, because it indicates a higher part of the Thouarsense Zone and a lower part of the Dispansum Zone of the Upper Toarcian (Guex, 1975; Elmi *et al.*, 1997). Also a poorly preserved ammonite referred to as *Hammatoceras* sp.[13] in the collection studied (Pl. 7: 7), may indicate the presence of the Dispansum Zone (possibly the Insigne Subzone) of the Upper Toarcian.

Dark, in places almost black, spotty marls and marly limestones with common intercalations of marly shales, showing a marked admixture of fine siliciclastic material (quartz grains and mica flakes) represent the Podspad Marlstone Member (Iwanow, 1985). The marls and marly limestones are medium to thick bedded (Figs 7, 8A). They show some similarity to deposits of the Skalnite Marlstone Member, but differ in a marked admixture of siliciclastic material (which is easily visible macroscopically) and in being more dark-coloured, and may be classified as muddy allochem limestones after Mount (1985). Except for the presence of siliciclastic material, radiolarians (Pl. 2: 4) as well as some rare benthic foraminifers and single bioclasts may be seen in thin sections. Ammonites and belemnites are rare.

Fig. 8. Selected lithologies of various members of the Sołtysia Marlstone Fm. in the sections of the Kopy Sołtysie area studied (the beds are in an overturned position): A – Podspad Marlstone Member, Sucha Woda; B – Podskalnia Shale Member, Koziarski Żleb; C – Łomy Limestone Member, Łomy; D – Broniarski Limestone Member, Filipka Szałas

The Skalnite Marlstone Member is found at the Świniarski Żleb, Sucha Woda, Koziarski Żleb, and Płaczliwa Skała localities (Figs 2–5).

The youngest Toarcian ammonites come from the Podspad Marlstone Member: here belong such forms as the "*Harpoceras* sp. *opalinum-primordiale*" of Kuźniar (1908, p. 74, pl. 1: 1) which is possibly a densely ribbed *Dumortieria*, as well as the "*Harpoceras aalensis*" of Kuźniar (1908, p. 78–79, pl. 1: 8) which is a *Pleydellia*. The occurrence of these genera indicates the Pseudoradiosa Zone and the Aaalenis Zone of the uppermost Toarcian (Elmi *et al.*, 1997). Still younger are specimens of *Leioceras opalinum* (Reinecke)[14] (Pl. 7: 1) and *Bredyia* sp.[15] (Pl. 8: 1) whose co-occurrence is indicative of the lowermost Aalenian – the Opalinum Zone of the English subdivision, corresponding to the lower and middle parts of the Opalinum Subzone of the Opalinum Zone of the French-German subdivision (Contini, 1969; Callomon, Chandler, 1990; Goy *et al.*, 1994; Contini *et al.*, 1997; Chandler, Callomon, 2009).

The overlying Podskalnia Shale Member (Iwanow, 1985; Figs 7, 8B) consists of black, partly silicified, indistinctly spotty shales and silty limestones rich in siliciclastic material (quartz grains and mica flakes). The limestone beds attain about 0.2 m in thickness. Bivalve shells of *Bositra buchi* (Roemer) are commonly encountered on bed surfaces. Sections of thin *Bositra* shells (filaments) are commonly recognized also in the rock (Pl. 2: 5); moreover pyritized tests of foraminifers (Nodosariidae), and pyrite framboids are commonly seen; sponge spicules sometimes have also been found (Pl. 2: 6). The microfacies is the allochemic mudrock of Mount (1985), rich in siliciclastic material.

The Podskalnia Shale Member is found at the Świniarski Żleb, Koziarski Żleb, Sucha Woda and Płaczliwa Skała localities (Figs 2–5).

The Podskalnia Shale Member yields generally poorly preserved ammonites of the genera *Ludwigia* – *L.* aff. *obtusiformis* (Buckman) – see Myczyński (2004, p. 85–86, fig. 34: 2, 4) and *Ludwigia* (*Pseudographoceras*) sp. – see Kuźniar (1908, pl. 1: 3), *Brasilia* – *B.* cf. *bradfordensis* (Buckman), and *Graphoceras* [16] (Pl. 7: 2–6) – including *G. concavum* (Sowerby) (see also Myczyński, 2004, p. 99–100, fig. 33: 1) and *G.* cf./aff. *cornu* (Buckman) (see also Myczyński, 2004, p. 103–104, fig. 33: 3, 5; fig. 34: 5). The presence of these ammonites is indicative of the Middle to Upper Aalenian – from the Murchisonae Zone, through the Bradfordensis Zone up to the Concavum Zone (Contini *et al.*, 1997). The youngest ammonites referred to this lithostratigraphic unit are *Fontannesia concentrica* Buckman, and *Sonninia* (*Euhoploceras*) cf. *polyacantha* (Waagen) described by Myczyński (2004, p. 109–111, fig. 33: 2, fig. 35: 3). The former is indicative of the lowermost Bajocian – the Discites Zone (Rioult *et al.*, 1997), whereas the latter, recently treated as a variety of the species *Sonninia* (*Euhoploceras*) *adicra* (Waagen), occurs in the Trigonalis Subzone of the Laeviuscula Zone of the Lower Bajocian (Dietze *et al.*, 2005). These data indicate that the Podskalnia Shale Member ranges in its upper part into lower part of the Lower Bajocian.

Younger deposits are dark gray and gray, spotty, hard, well bedded, silicified limestones with some intercalations of soft marl representing the Łomy Limestone Member (Iwanow, 1985; Figs 7, 8C). The limestone beds range from 0.2 m to 1 m in thickness, whereas the intercalations of marl are about 0.02 m thick. The trace fossils *Chondrites*, *Planolites*, and *Zoophycos* are common. The limestones show the presence of the radiolarian wackestone microfacies; moreover thin *Bositra* bivalve shells (filaments) are sometimes encountered (Pl. 3: 2–3). At the top of the unit radiolarites may appear locally. A lateral variation of the Łomy Limestone Member composed of spiculite limestone and marly spiculite limestone (marly spiculite wackestone – packstone, marly bioclastic filament wackestone microfacies, Pl. 3: 1) is found in the Płaczliwa Skała locality.

In the upper part of the Łomy Limestone Member, a well defined bed originally distinguished as the Łężny Encrinite Bed is recognized (Iwanow, 1985). A detailed study of the rock in the Filipka Szałas and the Płaczliwa Skała localities shows, however, its somewhat different lithological character – which is dominated by breccias. The thickness of the bed attains usually about 0.2 m; the bed is an intraformational breccia (Pl. 3: 4), consisting of sharp-edged small clasts (up to about 0.01 m in diameter) of several types of rocks: (1) spiculite wackestone/packstone, (2) crinoidal packstone, (3) marly wackestone, containing fragments of sponge spicules, unidentified echinoderm fragments, and ? plant debris; the matrix is marly wackestone with abundant pyrite grains. At the Płaczliwa Skała section the breccias contain fragments of still older breccias composed of similar clasts (Pl. 3: 5), and showing at least two episodes of clast formation.

The Łomy Limestone Member is found at the Łomy locality as well as at the Filipka Szałas, Broniarski Żleb, Koziarski Żleb, Świniarski Żleb and Płaczliwa Skała localities (Figs 2–5). The locality Łomy (N49°15.917'; E20°04.178') exposes hard limestones of the unit forming steep steps in the upper part of the Filipka valley. The locality Filipka Szałas (N49°16.113'; E20º04.302') is found on the eastern slopes of Zadnia Kopa Sołtysia mountain, whereas the Broniarski Żleb locality (N49°16.938'; E20°03.569') exposes the beds of the unit at the bottom of a stream on the northern slopes of Przednia Kopa Sołtysia mountain.

Ammonites in the Łomy Limestone Member are rare. These include: *Bradfordia* sp. (Pl. 7: 9), *Nannolytoceras tripartitum* (Raspail) (Myczyński, 2004, p. 52–53, fig. 20: 1–3), and *Cadomites* (*Polyplectites*) sp. (Myczyński, 2004, p. 119–120, fig. 35: 2). The former is indicative of the Lower Bajocian, whereas the two latter indicate the uppermost Bajocian–lowermost Bathonian (see Sadki, 1994; Wierzbowski *et al.*, 1999).

The youngest part of the succession studied is the Broniarski Limestone Member (Iwanow, 1985) – dark brownish (yellowish when weathered), indistinctly spotty, well bedded, hard silicified limestones with thin, rare radiolarite chert intercalations, occurring in the topmost part of the unit (Figs 7, 8D). The limestone beds attain usually from 0.1–0.2 m in thickness. The deposits show the presence of the *Bositra* (filament) wackestone microfacies (Pl. 3: 6); radiolarians as well as small planktonic and benthic foraminfers (*Involutina* sp.) have been recognized, moreover, in thin sections. Different types of deposit belonging to this member are recognized at the Płaczliwa Skała locality: these are silicified bioclastic limestones (bioclastic spiculite radiolarian packstones/wackestones.

The Broniarski Limestone Member is found at the the Broniarski Żleb, Koziarski Żleb, Filipka Szałas and Płaczliwa Skała localities (Fig. 2). Rare ammonite findings include *Nannolytoceras tripartitum* (Raspail)[17] (Pl. 7: 8) which indicates the uppermost Bajocian and/or lowermost Bathonian (*cf.* Wierzbowski *et al.*, 1999).

COMMENTS ON THE AMMONITES

The following abbreviations are used in the descriptions of the ammonites: D – diameter of specimen in milimetres; Wh – whorl height in relation to diameter of specimen; Wb – whorl breadth in relation to diameter of specimen; Ud – umbilical diameter in relation to diameter of specimen; PR – number of primary ribs per whorl.

[1] A single specimen (Pl. 4: 1), about 50 mm in diameter. The coiling is strongly evolute, and the ribbing is dense, consisting of weakly prorsiradiate simple ribs (at D = 30–50 mm, PR = 50); the venter is widely rounded, and bears a poorly preserved keel. The specimen resembles very much the forms referred to as *Plesechioceras delicatum* (see *e.g.* Dommergues, 1982, pl. 1: 1–4; Schlatter, 1991, pl. 3: 6–7; Corna *et al.*, 1997, pl. 5: 3ab; Géczy, Meister, 2007, pl. 29: 2–4, 6). The specimen in question was referred to previously (Iwanow, 1973; Iwanow *et al.*, 2012) as *Paltechioceras boehmi* (Hug), but it differs from representatives of the latter species and its allies in its more dense ribbing, and a lack of accentuation of the ribs at the ventrolateral shoulders (see *e.g.* Schlatter, 1991, p. 45–46, pl. 6: 4–6; Géczy, Meister, 2007, p. 186–187, pl. 29: 7, 9).

[2] The specimens of the genus *Echioceras* belong to two separate groups (1) an older fragmentarily preserved specimen (Pl. 4: 4) showing the presence of uniformly developed ribs which do not become swollen at the ventral margin which is a typical feature of the "primitive" *Echioceras* of the *E. quenstedti* (Schafthäutl) group as interpreted by Blau (1998, p. 205–206, pl. 4: 1–2), as well as (2) the specimens (Pl. 4: 3) showing well developed swellings of the ribs at the ventrolateral shoulders and moderately dense ribbing which are referred to as *E. ex* gr. *E. raricostatoides* (Vadasz) (see *e.g.* Schlegelmilch, 1976, pl. 21: 11; Schlatter, 1991, pl. 2: 5–6).

[3] A single specimen (Pl. 4: 2) showing strongly evolute coiling (at D = 50 mm, Ud = 0.56); whorl section is subquadrate; the ribs are rectiradiate, protruding and sparsely placed (at D = 25 mm, PR = 19; at D = 50 mm, PR = 22). The venter bears a keel bordered by shallow ventral sulci. The features indicate a close relation with the genus *Ortechioceras*, and the specimen in question seems very close to *Ortechioceras recticostatum* Trueman et Williams as interpreted by Schlatter (1991, p. 40–41, pl. 4: 1–4). The specimen has been referred to as *Echioceras* ex gr. *E. raricostatoides* (Vadasz) by Iwanow *et al.* (2012) but the presence of ventral sulci indicates its close affinity with *Ortechioceras.*

[4] A fragmentarily preserved specimen (Pl. 4: 5) about 45 mm in diameter showing weakly evolute coiling and the presence of loosely spaced ribs (at D = 30 mm, PR = 22) which become thinner and strongly inclined forwards near the ventral side. The features suggest affinity with the genus *Tropidoceras* (see *e.g.* Meister, 1986; *cf.* also Iwanow, 1973).

[5] A specimen about 60 mm in diameter (Pl. 4: 6) shows falcate ribbing represented by a short prorsiradiate periumbilical stem, and a much longer rursiradiate outer part of the rib (about 22 ribs per half a whorl). The coiling is evolute. The venter bears a keel bordered by ventral sulci. Although fragmentarily preserved, compares closely to the closely related forms – *Fuciniceras lavinianum* and *F. portisi*, and it is referred to as *Fuciniceras* ex gr. *F. lavinianum* (Fucini) – *F. portisi* (Fucini) according to the interpretation of Géczy and Meister (1998, p. 111–112, pl. 7: 7; pl. 8: 1–11, pl. 9: 1–3, 5).

[6] A small specimen (Pl. 4: 7), about 30 mm in diameter, covered with dense falcate ribbing represented by a short prorsiradiate periumbilical stem, which splits into a much longer outer part of the rib consisting of two–three rursiradiate branches. The specimen is very close to *Fuciniceras* ex gr. *F. cornacaldense* (Tautsch) according to the interpretation of Géczy and Meister (1998, p. 113, pl. 13: 6, 10, 11). A fairly narrow umbilicus in the specimen studied resembles somewhat that of representatives of the genus *Paltarpites*, but such a narrow umbilicus is encountered also in some specimens referred to as *Fuciniceras* gr. *cornacaldense* by Blau and Meister (1991, pl. 6: 12–13) and Géczy and Meister (1998, pl. 13: 10).

[7] The specimens consisting of fragments of whorls (Pl. 4: 8) are covered with dense falcate ribs which fade on the keel sides at the venter. The specimens are referred to as *Protogrammoceras* ex gr. *P. celebratum* (Fucini) according to the interpretation of Géczy and Meister (1998, p. 108–109, pl. 12: 7–9; pl. 13: 1–3, 5). They differ from the very close *Protogrammoceras* gr. *mariani* (Fucini) in the absence of flat surfaces bordering the keel, and the weaker backward course of the outer parts of the ribs (Géczy, Meister, 1998).

[8] The fragments of whorls (Pl. 4: 9) show dense, strongly falcate ribbing with a long prorsiradiate part of the rib, and markedly rursiradiate and concave its outer part. These features along with the involute coiling of the whorls enable the identification of the specimens as representing the genus/subgenus *Paltarpites* (*cf.* Géczy, Meister, 1998). The specimens are, however, too badly preserved for closer identification.

[9] Two specimens (Pl. 4: 10) show ornamentation consisting of weakly developed inner ribs, and strongly developed, rursiradiate, falcoid outer ribs, separated by a well marked

lateral groove which is placed somewhat below half of the whorl height. These enable the identification of the specimens as *Hildoceras bifrons* (Bruguière). The species is interpreted according to Rulleau and Elmi (2001, pl. 6: 4; pl. 8: 1–5; pl. 9: 2–3, 5, 8) who included in it a number of morphotypes differing in the character of coiling, density of ribbing and final shell size.

10 A quarter of whorl (Pl. 5: 1) about 20–25 mm in whorl height shows the presence of strong weakly falcoid ribs without a lateral groove, but having a smooth indistinct belt above the umbilical wall. The specimen is closely related to the earliest representative of the genus *Hildoceras* – *H. sublevisoni* Fucini (see *e.g.* Schlegelmilch, 1976, pl. 43: 6; Rulleau, Elmi, 2001, pl. 6: 2) and it is referred to as *H.* ex gr. *sublevisoni* Fucini.

11 Several specimens (Pl. 5: 7; Pl. 6: 1–6) from about 45 mm – 90 mm in diameter represent macroconchs, with a single small microconch (Pl. 5: 6). The macroconch specimens are densely ribbed (at D = 50–60 mm, PR = 39–45). The ribs are single, falcate and wide – typical of the genus *Pseudogrammoceras.* The venter bears a keel which may be bordered by poorly marked ventral sulci. The coiling is variable – from weakly involute (Wh = 0.34–0.38, Ud = 0.36–0.40) to moderately evolute (Wh = 0.30–0.33, Ud = 0.42–0.44) – but there is no sharp boundary between the two groups of specimens. Although the former are close to *Pseudogrammoceras bingmanni* (Denckmann), and the latter to *P. struckmanni* (Denckmann) – the differentiation of these very close species is not always possible (*cf.* Gabilly, 1976). A single small specimen (Pl. 5: 6) about 28 mm in diameter shows weakly evolute coiling (at D = 28 mm, Wh = 0.37, Ud = 0.39) and fading of the ribbing at the end of the last whorl, which indicates the proximity of the final peristome – the specimen is a microconch similar to that of *P. struckmanni* as illustrated by Gabilly (1976, pl. 23: 11–12).

12 Two specimens about 50–65 mm in diameter (Pl. 5: 4–5) show evolute coiling (at D = 50–65 mm, Wh = 0.28–0.32, Ud = 0.42–0.44). The ribbing is fairly dense (at D = 50–65 mm, PR = 41–43). The ribs are single, strongly falcoid, and wide. The ventral side of the whorl is narrow with the median keel bordered by smooth bands. The specimens are similar, especially in the presence of wide, strongly falcoid ribs, to *Pseudogrammoceras doerntense* (Denckmann) which occupies a somewhat transitional position between the genus *Pseudogrammoceras* and the genus *Grammoceras* – especially the species *Grammoceras thouarsense* (d'Orbigny) (*cf.* Guex, 1975, p. 103, pl. 4: 13–14, 16; and p. 104, pl. 2: 5, pl. 4: 15, and pl. 5: 1; Schlegelmilch, 1976, pl. 42: 7, and pl. 43: 4; Gabilly, 1976, p. 115–118, pl. 18: 1–2, 7–8, and p. 146–149, pl. 20: 8–10, pl. 27: 3–4, pl. 28: 1–2). The specimens in question have been previously attributed to the species *G. thouarsense* by Iwanow *et al.* (2012a), and Iwańczuk *et al.* (2012) but they are referred now to as *Pseudogrammoceras* ex gr. *P. doerntense* (Denckmann).

13 A fragment of whorl (Pl. 7: 7) about 50 mm in diameter, showing strongly developed short periumbilical tubercles, and long fairly thick secondary ribs typical of the genus *Hammatoceras* (see *e.g.* Schlegelmilch, 1976).

14 A single specimen (Pl. 7: 1) about 75 mm in diameter consists of the phragmocone, and about half a whorl of body chamber. Marked uncoiling of the last whorl is observed which shows the specimen is fully grown. The final peristome is fragmentarily preserved in its dorsal part. The coiling is strongly involute (at D = 55 mm, Wh = 0.19, Ud = 0.49). The ribbing is very weak, consisting of groups of striae. The venter bears a sharp keel. The specimen corresponds well to *Leioceras opalinum* (Reinecke), being very similar to larger specimens of the species such as those illustrated by Rulleau and Elmi (2001, pl. 19: 4–6).

15 A large, strongly flattened specimen (Pl. 8: 1) about 165 mm in diameter; at this diameter the form is involute (Wh = 0.39, Ud = 0.29), but on its inner whorls it is evolute. The poorly preserved innermost whorls show loosely spaced umbilical tubercles. The umbilical ribs are weakly developed on the outer whorl and disappear at about 120 mm diameter. The outer ribs number two or three per umbilical rib and occur up to the end of the last whorl. The venter bears a high keel bordered on both sides by smooth areas. The specimens studied is similar to representatives of the genus *Bredyia* (including the genus *Pseudoammatoceras* which is at least partly its macroconch counterpart – see *e.g.* Rulleau, Elmi, 2001, p. 58; *cf.* also Goy *et al.*, 1994; Schweigert, 1996), but due to its poor preservation cannot be identified at the species level.

16 Several specimens including larger, strongly involute forms (Pl. 7: 2–3), attaining about 50 mm in diameter (at D = 48, Wh = 0.25, Ud = 0.41) with the strongly falcate and rursiradiate ribbing, as well as a deep umbilicus with a steep umbilical wall (still well visible although specimens are badly flattened). These specimens show marked similarity to *Graphoceras* (*Graphoceras*) *concavum* (Sowerby) as widely interpreted by Contini (1969, p. 61–67, pl. 21: 1–9, pl. 22: 1–3). A very close form referred to as *Harpoceras concavum* Sowerby was described and illustrated from the area of study by Kuźniar (1908, p. 77, pl. 1: 4). Other specimens (Pl. 7: 4) are smaller, attaining about 23–33 mm in diameter and weakly evolute (Wh = 0.33–0.37, Ud = 0.48): these are referred to as *Graphoceras* (*Ludwigella*) cf. *cornu* (Buckman).

17 A strongly evolute, about 35 mm in diameter, corroded specimen represented by the phragmocone and the body chamber, showing the presence of the characteristic S-shaped constrictions (Pl. 7: 8) compares well with *Nannolytoceras tripartitum* (see *e.g.* Wierzbowski *et al.*, 1999, pl. 16: 2–3).

CORRELATION WITH OTHER JURASSIC SUCCESSIONS OF THE POLISH CARPATHIANS

The deposits studied representing the Lower Jurassic to lower Middle Jurassic succession at the Kopy Sołtysie mountain range and the Belianske Tatra Mts in the eastern part of the Tatra Mts may be compared with coeval deposits of the Bobrowiec unit of the Lower Subtatric nappe in the western part of the Tatra Mts between the Kościeliska valley and the Chochołowska valley in Poland. These deposits show, however, some marked differences in the development of the younger deposits – beginning in the Upper Pliensbachian. Also there are marked differences between the succession studied and those of the Hightatric (Tatricum) megaunit – from the autochthonous unit up to the directly overlying parautochthonous units. Additionally the correlation of the succession studied in the Lower Subtatric (Križna) nappe in the eastern part of the Tatra Mts with those of the Pieniny Klippen Belt – especially the faunistically best documented, the Niedzica and the Czorsztyn successions, are also discussed (Fig. 9).

The Lower Jurassic succession of the Lower Subtatric nappe in the western part of the Tatra Mts begins with the siliciclastic deposits of the dominant gresten facies of the Kopieniec Formation, attributed to the Hettangian, and possibly also to the lowermost Sinemurian (Gaździcki, 2006, and earlier papers cited therein). Younger are the marly limestones with marly intercalations of the dominating fleckenkalk-fleckenmergel facies, generally attributed to the Sołtysia Marlstone Formation. They are subdivided in their lower part into “dull black limestones” of the Przysłop Marlstone Member, and the overlying spotty limestones and marls of the Poslednia Luka Marlstone Member (Iwanow, 1985). The distinction between the two units is sometimes difficult, and the deposits have yielded ammonites indicative of the junction of the Bucklandi Zone and the Semicostatum Zone of the Lower Sinemurian, such as *Arnioceras falcaries* (Quenstedt) and *A. ceratitoides* (Quenstedt), as well as of the Raricostatum Zone of the Upper Sinemurian – *Echioceras raricostatum* (Zieten) and *E. raricostatoides* (Vadasz) (see Myczyński *in*: Uchman, Myczyński, 2006, and earlier papers cited therein). These deposits correspond jointly to the Płaśnia Limestone Member and the Kobyła Limestone Member from eastern part of the Tatra Mts (Iwanow, 1985).

A thin, a few metres in thickness, sequence of light-gray limestones, locally containing belemnite rostra, of the Pośrednia Kopka Limestone Member, and the overlying dark-gray to brownish siliceous limestones with cherts of the Parządczak Limestone Member, are the youngest deposits of the Sołtysia Marlstone Formation of the Lower Subtatric nappe in the western part of the Tatra Mts (Iwanow, 1985). The deposits have not yielded any stratigraphically valuable ammonites, but they are usually correlated with the Czerwone Brzeżki Limestone Bed, and the Krzywań Limestone Member from the eastern part of the Tatra Mts (Iwanow, 1985), and thus should not range stratigraphically higher than the lowest Pliensbachian (Fig. 9).

The overlying deposits of the Lower Subtatric nappe in the western part of the Tatra Mts between the Kościeliska valley and the Chochołowska valley (the Bobrowiec unit) belong to the Huciska Limestone Formation (Lefeld, 1985a). The lowermost part is represented by grayish to dark-gray spongiolites of the Świńska Turnia Spongiolite Member (Lefeld, 1985a). These deposits contain large amounts of siliceous sponge spicules, mostly Hexactinellidae, replaced in the uppermost part of the member by Demospongiae spicules; intercalations of crinoidal limestones appear already in the middle part of the member, but become more coarse and thicker at the top of the member (Jach, 2006, and earlier papers cited therein). The Świńska Turnia Spongiolite Member is possibly of Late Pliensbachian age according to the age position of the directly overlying deposits – the Długa Encrinite Member – in the succession (*cf.* Krajewski *et al.*, 2001).

The Długa Encrinite Member is represented by white and pinkish crinoidal grainstones. Although the deposits did not yield any ammonites, their stratigraphical position was established on the basis of chemostratigraphical data – distinct positive carbon values in the middle part of the member indicate the presence of the Falcifer (= Falciferum) Subzone of the Serpentinum Zone of the Lower Toarcian (Krajewski *et al.*, 2001; *cf.* Jach, 2002, 2005, 2006). The occurrence of Mn-bearing deposits of the Banie Ore Bed (Lefeld, 1985a) which occurs directly above the Długa Encrinite Member, locally forming lenses up to 2 metre thick, has been related to hydrothermal activity; this was controlled by synsedimentary tectonics and a special bottom-water chemistry depleted in oxygen which was particularly pronounced for the Falcifer Subzone of the Lower Toarcian (Krajewski *et al.*, 2001; Jach, Dudek, 2006). Thus, the deposits of the Długa Encrinite Member may be ascribed to the Lower Toarcian – possibly the Tenuicostatum Zone in their lower part, and the Falcifer Subzone of the Serpentinum Zone in their upper part, together with overlying Banie Ore Bed.

Younger deposits of the Huciska Limestone Formation in the western part of the Tatra Mts between the Kościeliska valley and the Chochołowska valley are the variable red limestones of the Kliny Limestone Member (Lefeld, 1985a). These deposits attain about 7 metres in thickness in the type section of this unit. They are developed in their lower part, about 4 metres in thickness, as adnet facies type deposits: these non-nodular and nodular crinoidal wackestones con-

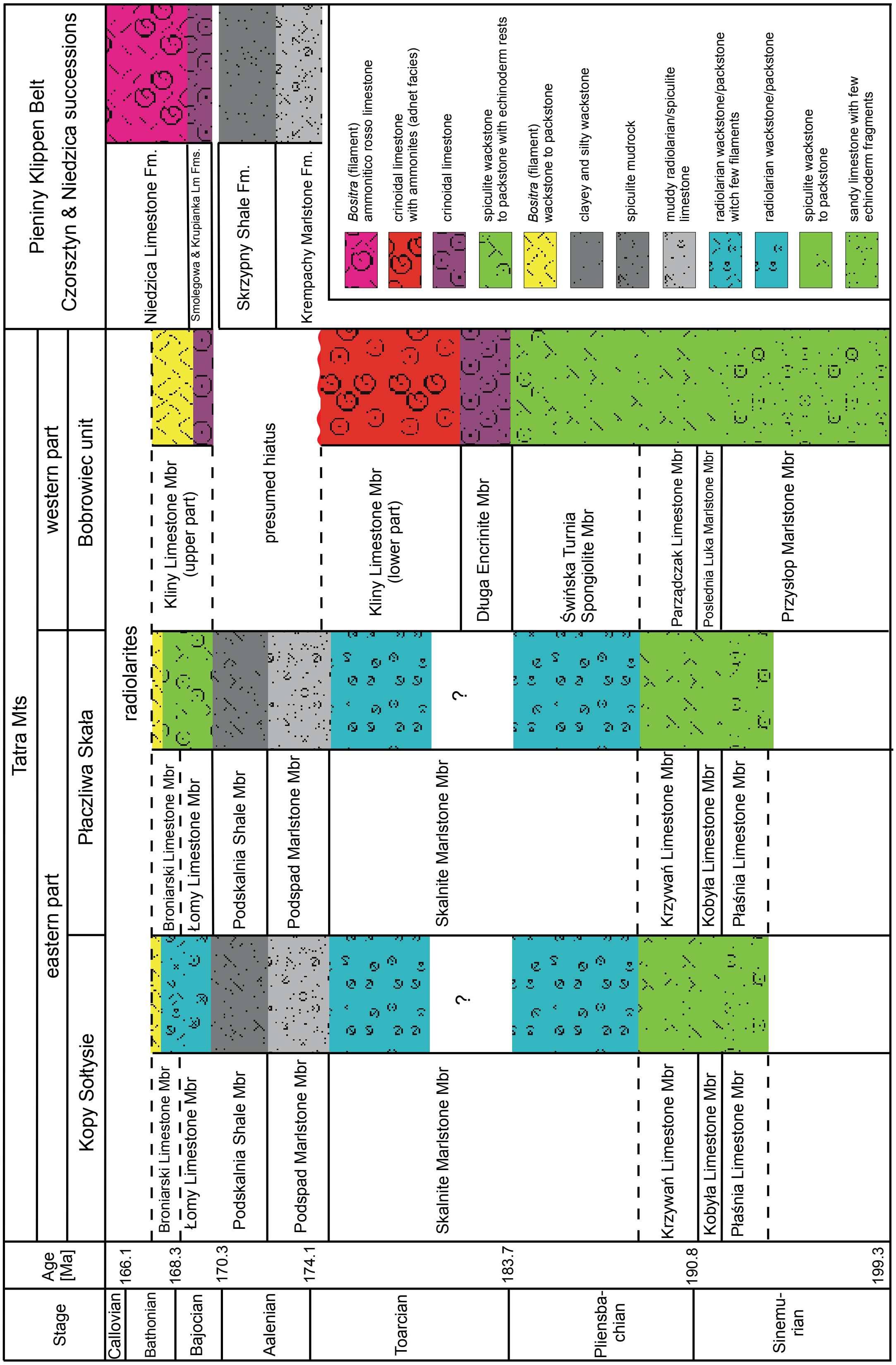

Fig. 9. Correlation of the main lithostratigraphic units between the eastern and western areas of the Lower Subtatric (Križna) nappe in the Tatra Mts, and the Pieniny Klippen Belt, showing the distribution of the microfacies, and given on the background of the stratigraphical time scale (after Ogg *et al.*, 2012)

tain locally abundant ammonites, with common discontinuity surfaces, and are topped by a stromatolite level with large microbial-foraminiferal oncoids occurring above, indicating an extremely low deposition rate (Gradziński *et al.*, 2004; Gradziński *et al.*, 2006). Although the stromatolites and microbial-foraminiferal oncoids are not encountered in every section of the Kliny Limestone Member in the western part of the Tatra Mts, the top of the red limestones of the adnet facies of that unit is everywhere very sharp, and the contact with the overlying crinoidal packstones/grainstones and various *Bositra* limestones " most probably displays the character of an omission surface" (Jach, 2007, p. 164). These red limestones have yielded two ammonite assemblages in their lower and middle parts, and a third one whose detailed location in the deposits remains unknown (Myczyński, Lefeld, 2003; Gradziński *et al.*, 2006; Myczyński, Jach, 2009; see also Sokołowski, 1925; and other earlier papers cited therein): (1) *Harpoceras serpentinum* (Schlotheim), *Harpoceras* ex gr. *falcifer* (Sowerby), *Cleviceras elegans* (Sowerby), and *Nodicocoeloceras* cf. *crassoides* (Simpson) indicative of the upper part of the Serpentinum Zone, *i.e.* the uppermost part of the Lower Toarcian; (2) *Hildoceras sublevisoni* Fucini, *H.* cf. *lusitanicum* Meister, *H. bifrons* (Bruguière) and others, indicative of the whole Bifrons Zone of the Middle Toarcian; (3) *Cattuloceras* cf. *dumortieri* (Thiollière) of the Levesquei Subzone of the Pseudoradiosa Zone of the Upper Toarcian. These data indicate the wide stratigraphical interval represented by the red limestones of the adnet type of the Kliny Limestone Member – from the upper part of the Lower Toarcian up to (at least) the upper part of the Upper Toarcian (Myczyński, Jach, 2009).

Resulting from the aforegoing, it is clear that the deposits of the Huciska Limestone Formation in the western part of the Tatra Mts, from the Świńska Turnia Spongiolite Member through the Długa Encrinite Member up to the red limestones of the adnet type of the lower part of the Kliny Limestone Member, may be interpreted as the lateral equivalents of the Skalnite Limestone Member, and possibly in part of the Podspad Marlstone Member of the Sołtysia Marlstone Formation at Kopy Sołtysie in the eastern part of the Tatra Mts (Fig. 9).

The upper part of the Kliny Limestone Member, a few meters in thickness, of the western part of the Tatra Mts between the Kościeliska valley and the Chochołowska valley, consists of a variety of *Bositra* limestones (*Bositra* packstones/grainstones, *Bositra* crinoidal packstones, *Bositra* radiolarian wackestones), as well as crinoidal packstones/grainstones which contain also crushed *Bositra* shells (Jach, 2007, and earlier papers cited therein). Crinoidal material is especially common in the lower part of these deposits (especially in more expanded sections), whereas towards the top, and possibly laterally, the *Bositra* packstones/grainstones forming the bulk of the succession are replaced by *Bositra* radiolarian wackestones, and then by radiolarites (Jach, 2007, figs 2, 4). These deposits did not yield any stratigraphically important fossils, but their age may be theoretically estimated to be from the latest Toarcian up to the Aalenian or even Early Bathonian as based on their relation to the directly underlying and overlying strata (*cf.* Lefeld, 1985a, 1999; Jach, 2007, and other papers cited therein); the succession is, however, neither uniform nor complete, and undoubtedly contains marked stratigraphical hiatuses. All these make the detailed correlation of the deposits in question with coeval deposits of the Sołtysia Marlstone Formation at Kopy Sołtysie in eastern part of the Tatra Mts difficult. It should be remembered, however, that the lithological character of the *Bositra* limestones and the underlying crinoidal grainstones/packstones of the upper part of the Kliny Limestone Member makes possible correlation of these deposits with some of the Early Bajocian to Early Bathonian members from the eastern part of the Tatra Mts, namely the Łomy Limestone Member and especially the Broniarski Limestone Member which show the presence of the filament (*Bositra*) microfacies. If these correlations are correct – the succession referred to the Kliny Limestone Member may contain a marked stratigraphical hiatus at the junction of its lower part (adnet facies) and its upper part (*Bositra* limestones and crinoidal limestones). The hiatus may explain the total absence of deposits rich in siliciclastic material in the sections studied, corresponding at least to the Podskalnia Shale Member from the eastern part of the Tatra Mts – which range in age from the Middle Aalenian to the earliest Bajocian. Such an interpretation suggests additionally the necessity of the subdivision of the Kliny Limestone Member as currently interpreted (*cf.* Lefeld, 1985a) into two separate lithostratigraphic units possibly of member rank: a lower one corresponding to deposits of the adnet facies, and an upper one including a variety of *Bositra* limestone and crinoidal limestone (Fig. 9).

Undoubtedly more difficult is the correlation of the succession studied here of the Sołtysia Marlstone Formation at Kopy Sołtysie in the eastern part of the Tatra Mts with those of the Hightatric (Tatricum) megaunit. The Hightatric autochthonous Lower Jurassic deposits consist predominantly of sandstones with intercalations of crinoidal limestones and other biogenic limestones (with sponge spicules, brachiopods and bivalves) and spongiolites which represent together the Dudziniec Formation (Wójcik, 1985). The smaller rank lithostratigraphic units (members, beds) are generally poorly characterized faunistically which makes their detailed chronostratigraphical interpretation difficult. An exception is the Smytnia Limestone Member (Wójcik, 1985) which is composed of limestones containing abundant brachiopods (*Spiriferina* and *Rhynchonella*) as well as bivalves indicative of the Upper Sinemurian (Horwitz, Rabowski, 1922). This indicates that the member corresponds at least partly to the Płaśnia Limestone Member and/or the Kobyła Limestone Member of the Sołtysia Marlstone Formation in the eastern part of the Tatra Mts.

The younger Hightatric autochthonous deposits are crinoidal limestones of the Smolegowa Limestone Formation and the Krupianka Limestone Formation (Lefeld, 1985b). The Smolegowa Limestone Formation, developed as white to light grey or pinkish coarse crinoidal limestones, occurs also in the parautochthonous High Tatric units (the Giewont nappe and the Czerwone Wierchy nappe); these are here the oldest Jurassic deposits which penacordantly cover the Middle Triassic (Anisian) limestones and dolomites – forming laterally discontinuous lenticular bodies or the infillings of neptunian dykes (Łuczyński, 2001, 2002). These deposits have yielded brachiopods indicating their Bajocian age (Horwitz, Rabowski, 1922; Lefeld, 1985b). The deposits of the Krupianka Limestone Formation should consist of "fine to medium-grained crinoid limestone, usually distinctly bedded, sometimes shaly with red colours predominating"... – which is the typical development of the formation (*cf.* Birkenmajer, 1977, p. 53); some of the deposits attributed to that formation in the Tatra Mts by Lefeld (1985b) do not fit this definition, however. This is the case of the strongly condensed horizon of red biomicrites with numerous macrofossils – especially ammonites and belemnites, containing patches of stromatolites, ferruginous crusts and concretions; these deposits, occurring mostly in the Czerwone Wierchy nappe, represent lithologically a very variable group called "the ferrugineous limestones" by Łuczyński (2002, p. 370). This horizon well known especially at the Wielka Świstówka locality has yielded numerous ammonites especially of Bathonian age (mostly of the Bremeri Zone of the upper Middle Bathonian) (see Passendorfer, 1936, 1938; Galácz, Matyja, 2006); a single specimen referred to as *Parkinsonia* sp. (Passendorfer, 1936, p. 96, pl. 3: 8) suggests, however, the presence of fragmentarily preserved older deposits at the junction of the Bajocian and Bathonian. This strongly condensed horizon resting on "white to red crinoid limestones, or even directly on more or less eroded pre-rift Middle Triassic carbonate sediments", and below expanded pelagic carbonate deposits, is well distinguished in the parautochthonous sequences of the Hightatric nappes (Wieczorek, 2001, p. 201); it should be recognized as a separate lithostratigraphic unit different from the underlying typical crinoidal limestones. It seems thus highly probable that the crinoidal limestone units – the Smolegowa Limestone Formation, and the Krupianka Limestone Formation of the Hightatric successions – show a similar stratigraphic position as the same lithostratigraphic units in the Pieniny Klippen Belt (see below). Consequently, they could be treated as the lateral equivalent of the Łomy Limestone Member of the Sołtysia Marlstone Formation in the eastern part of the Tatra Mts.

The uppermost Lower Jurassic to Middle Jurassic deposits in the Pieniny Klippen Belt are well recognized both in their lithology and chronostratigraphical position in the Czorsztyn and Niedzica successions. These are marls and marly limestones with fine mica flakes containing fairly common radiolarians and benthic foraminifers attributed to the Krempachy Marl Formation of the Upper Toarcian (at least Dispansum to Aalensis zones) and the Lower Aalenian (Opalinum Zone), followed by dark shales and clays with abundant siliciclastic material of the Skrzypny Shale Formation of the Middle–Upper Aalenian (Murchisonae to Concavum zones) and the lowermost Bajocian (Discites Zone) (see Birkenmajer, 1977; Myczyński, 2004; Wierzbowski *et al*., 2004; Barski *et al.*, 2012, with earlier papers cited therein). The deposits in question may be easily correlated with the similarly developed and nearly coeval deposits of the Sołtysia Marlstone Formation in the eastern part of the Tatra Mts, *viz.* the Podspad Marlstone Member, and the Podskalnia Shale Member, respectively (Fig. 9). It should be remembered, however, that a marked stratigraphical hiatus covering a lower part of the Lower Bajocian exists at the top of the Skrzypny Shale Formation in the Czorsztyn and Niedzica successions of the Pieniny Klippen Belt. This hiatus precedes the appearance of the crinoidal limestones – the Smolegowa Limestone Formation, and the Krupianka Limestone Formation – which range stratigraphically here from the upper part of the Lower Bajocian (upper part of the Propinquans Zone, and the Humphriesianum Zone) up to the upper part of the Upper Bajocian (Garantiana Zone) (Wierzbowski *et al.*, 1999; Wierzbowski *et al.*, 2004; Krobicki, Wierzbowski, 2004; Barski *et al.*, 2012). As indicated above, these crinoidal limestone units are possibly coeval with those known from the Hightatric nappes, and have their time-equivalent in the Łomy Limestone Member of the Sołtysia Marlstone Formation in the eastern part of the Tatra Mts. The overlying pelagic deposits in the Czorsztyn and Niedzica successions of the Pieniny Klippen Belt are nodular limestones showing the presence of the filament (*Bositra*) microfacies belonging to the lower part of the Czorsztyn Limestone Formation, and to the Niedzica Limestone Formation, which have yielded ammonites from the topmost part of the Bajocian (Parkinsoni Zone) up to the Bathonian (Wierzbowski *et al.*, 1999). These deposits correspond to the Broniarski Limestone Member of the Sołtysia Marlstone Formation in the eastern part of the Tatra Mts (Fig. 9).

CONCLUSIONS

The deposits of the Sołtysia Marlstone Formation in the Kopy Sołtysie mountain range in the High Tatra Mts, as well as those of the sections studied of the Belianske Tatra Mts (mostly the Płaczliwa Skała section) of the Lower Subtatric nappe in eastern part of the Tatra Mts of Poland and Slovakia, constitute the most expanded succession of the Lower Jurassic to lower part of the Middle Jurassic in the whole Tatra Mts. In addition these deposits have yielded abundant ammonites making possible their detailed chronostratigraphical interpretatation. The dominant deposits, generally corresponding to the Zliechov Succession (Plašienka, 2012), are those of the flekenkalk-flekenmergel facies which show the presence of the following palaeontological microfacies (Fig. 9): (1) the sandy limestones passing upwards into the spiculite wackestones of the Płaśnia Limestone Member (Sinemurian); (2) the spiculite wackestones to packstones of the Kobyła Limestone Member (Sinemurian) and the Krzywań Limestone Member (Lower Pliensbachian), but appearing once more in the succession in the Łomy Limestone Member at Płaczliwa Skała (upper part of the Lower Bajocian up to the uppermost Bajocian – lowermost Bathonian); (3) the radiolarian wackestones/packstones of the Skalnite Marlstone Member (Upper Pliensbachian to the Thouarsense and Dispansum zones of the lower part of the Upper Toarcian; but note that the presence of the Lower Toarcian has not been recognized), and of the Łomy Limestone Member (in the Kopy Sołtysie area) (upper part of the Lower Bajocian up to the uppermost Bajocian–lowermost Bathonian); (4) the *Bositra* (filament) microfacies (uppermost Bajocian–lowermost Bathonian) of the Broniarski Limestone Member (and to a lesser degree the Łomy Limestone Member). Markedly different type of deposits with the common admixture of siliciclastic material are represented by the Podspad Marlstone Member (muddy allochem limestones), and especially the Podskalnia Shale Member (allochemic mudrocks) which represent the upper part of the Upper Toarcian – through the Aalenian – up to the lower part of the Lower Bajocian.

In accordance with aforegoing, the Sołtysia Marlstone Formation may be informally subdivided into four different rock units (from the base): (1) spotty limestones and marls/marly shales of the spiculite wackestones/packstones (Płaśnia Limestone Mbr, Kobyła Limestone Mbr, and Krzywań Limestone Mbr); (2) spotty marly limestones and marls with thick intercalations of marly shales of the radiolarian wackestones/packstones (Skalnite Marlstone Mbr) showing upwards a marked admixture of fine siliciclastic material (Podspad Marlstone Mbr); (3) shales and silty limestones rich in siliciclastic material (quartz grains and mica flakes) of the dominating spiculite mudrock type (Podskalnia Shale Mbr); (4) spotty often silicified limestones and marls either of the radiolarian, locally also filamentous wackestone/packstone type, or the spiculite wackestone/packstone type, as well as of the filamentous wackestone/packstone type (Łomy Limestone Mbr and the Broniarski Limestone Mbr). The subdivision of the Sołtysia Marlstone Fm. presented differs from that proposed recently by Birkenmajer (2013, table 1) who subdivided the corresponding stratigraphical interval into three new formations (from the base): (1) the Kopy Fm. (including the Kobyła Limestone Mbr and the Krzywań Limestone Mbr), (2) the Skalnite Fm. (including the Skalnite Marlstone Mbr), and (3) the Filipka Fm. (including the Podspad Marlstone Mbr, the Podskalnia Shale Mbr, the Łomy Limestone Mbr and the Broniarski Limestone Mbr). Because the proposed new classification scheme of Birkenmajer (2013) does not take into account the differences in the lithological development of the deposits of the Sołtysia Marlstone Formation discussed above – it is not accepted in the present study.

In addition, there occur some subordinate deposits in the succession studied which show "unusual" development when compared with surrounding deposits. These include: (I) the bioclastic wackestones composed of different organic fragments (foraminifers, bivalves, belemnites, echinoderms) and the breccias of the Czerwone Brzeżki Bed at the junction of the Sinemurian and Pliensbachian; (II) the graded and laminated spiculite packstone/grainstones with ferruginеous concretions (from 0.02–0.1 m in diameter), as well as the crinoidal packstone/grainstone in the Skalnite Marlstone Members (Upper Toarcian) – see Iwańczuk, Tyszka (2009); (III) the breccia intercalations containing spiculite limestone and crinoidal limestone clasts representing the Łężny "Encrinite" = Breccia Bed in the Łomy Limestone Member (Bajocian). These "unusual" deposits sandwiched in between the generally dominated fleckenkalk-fleckenmergel facies may be considered as forming during sudden tectonically induced events. Their formation was possibly related to the rifting phases which also disturbed the sedimentation in the basinal environment (Plašienka, 2003, 2012). The rifting resulted in the occurrence of narrow highs with special condensed deposits, whose slopes may be also a source of detrital material transported towards wide surrounding basins.

The origin of the Czerwone Brzeżki Bed formed at the junction of the Sinemurian and Pliensbachian may be referred to the Zliechov rifting phase, which is generally well recorded in the autochthonous-parachthonous (Tatricum) and the allochthonous (Fatricum) domains (Plašienka, 2003, 2012). The Pośrednia Kopka Limestone Member in the western part of the Lower Subtatric (Križna) nappe in the Tatra Mts possibly had a similar origin.

The Devín rifting phase was interpreted by Plašienka (2003, p. 89) as being "indicated by an increasing contrast between the hemipelagic, partly anoxic sedimentation in half grabens (Allgäu Fm.) and the deposition of well aerated 'ammonitico rosso' limestones (Adnet Fm.) on the edges of domino blocks". The occurrence of highly diversified deposits, well dated by ammonite faunas, and attributed to the Janovky (Allgäu) Formation and the Adnet Formation, resepectively, of the Late Pliensbachian – Toarcian from the Križna nappe of the Velká Fatra "core mountains" of Slovakia (Mišík, 1964; Rakús, 1964; Mišík, Rakús, 1964; Bendík, 2012) is fully consistent with such an interpretation of this rifting phase. This picture also fits well with the appearance of the radiolarian microfacies during the Late Pliensbachian and Toarcian in the basinal deposits of the Skalnite Marlstone Member of the Sołtysia Marlstone Formation of the eastern part of the Lower Subtatric nappe in the Kopy Sołtysie mountain range. It is also consistent with the occurrence at the same time of the sponge spiculites of the Świńska Turnia Spongiolite Member, and the crinoidal grainstones of the Długa Encrinite Member followed by the red limestones of the adnet type of the lower part of the Kliny Limestone Member of the Huciska Limestone Formation in the Bobrowiec unit in western part of Tatra Mts (see also Jach, 2005, 2006), but also in the Czerwona Skała–Holica units in eastern part in Tatra Mts (Lefeld, 1985a, 1999), both corresponding to ridge areas.

The occurrence of distal turbidites composed of sponge spicules and of crinoid fragments in the Upper Toarcian deposits of the Skalnite Marlstone Member of the Sołtysia Marlstone Formation of the eastern part of the Lower Subtatric nappe in the Sucha Woda valley, and on Płaczliwa Skała Mt., seems to be related to the existence of a topographic ridge inhabited by siliceous sponges, and may be the source of the deposits similar to those of the Świńska Turnia Spongiolite Member of the Bobrowiec unit (*cf.* Jach, 2006).

The next stage in basinal sedimentation in the succession studied in the Lower Subtatric (Križna) nappe in the eastern Tatra Mts shows the re-appearance of limestones of the radiolarian microfacies laterally replaced by the spiculite and filament (*Bositra*) microfacies (Płaczliwa Skała) which contains, however, intercalations of breccias (Łężny Encrinite =Breccia Bed) in the Bajocian (Łomy Limestone Member). These intercalations were possibly the distal "tails" of mass-movement deposits including the spiculite and crinoidal sediments developed along the elevated areas, such as that placed close to the Płaczliwa Skała area in the Belianske Tatra Mts, but also that between the Kościeliska valley and the Chochołowska valley in the western part of the Tatra Mts. The existence of a possible stratigraphical gap at the base of the crinoidal limestones in the latter area (Jach, 2007), corresponding at least partly to the Aalenian, could result from uplift and non deposition. The existing contrast between sedimentation of the limestones with radiolarian microfacies (basinal), and the appearance of crinoidal limestones and spiculite limestone (elevated areas) could be related to the Krasín rifting phase of Plašienka (2003). The same phase was also active in the autochthonous and parautochthonous Hightatric (Tatricum) units where the presence of crinoidal limestones marks the syn-rift to early post-rift episode (Wieczorek, 2001). The stratigraphical hiatus related to the Krasín rifting phase at the base of the crinoidal limestones of the Bajocian age in the Pieniny Klippen Belt, is especially well developed in the Czorsztyn Succession and the Niedzica Succession, and is documented by ammonite faunas and sedimentological features (Krobicki, Wierzbowski, 2004; Wierzbowski *et al.*, 2004). The hiatus, and the formation of thick crinoidal limestone formations (the Smolegowa Limestone Fm. which is replaced laterally by the Flaki Limestone Fm., and both overlain in places by the Krupianka Limestone Fm.), were related to the Early Bajocian uplift of the Czorsztyn Ridge (Barski *et al.*, 2012, and earlier papers cited therein).

The Lower Jurassic of the autochthonous Hightatric unit shows the alternation of detrital deposits composed predominantly of sandy facies mostly of quartz grains, and with clasts of Triassic carbonate rocks, with deposits of the crinoid facies, as well as spongiolites. The sedimentation of the detrital deposits could be related to the uplift of neighbouring source areas (Wójcik, 1981), and hence could be related to the rifting phases – but unfortunately the poor faunistic documentation of the deposits precludes the chronostratigraphical interpretation and detailed correlation. It may be suggested *e.g.*, that the Iwanówka Limestone Member, composed of crinoidal limestones and spongiolites, is at least partly of Early Pliensbachian age (see Wójcik, 1985) – representing a more "quiet" stratigraphical time-interval between two rifting phases.

The deposits such as marly limestones, marls, and clays rich in siliciclastic material from the uppermost Toarcian to the Lower Aalenian (Podspad Marlstone Member), and especially from the Middle Aalenian to the lower part of the Lower Bajocian (Podskalnia Shale Member) of the succession studied in the Lower Subtatric nappe in the eastern Tatra Mts, find their nearly coeval equivalents in the Pieniny Klippen Belt in the Krempachy Marl Formation and the Skrzypny Shale Formation (*cf.* also Guzik, 1959). The siliciclastic material came from erosion of older deposits on land, and this phenomenon was possibly related to uplift and/or change of climatic conditions, but deposits rich in siliciclastic material are unknown from such elevated areas as the Bobrowiec unit between the Kościeliska valley and the Chochołowska valley in the western part of the Tatra Mts.

The youngest deposits of the succession studied are the pelagic limestones, showing the presence of the *Bositra* microfacies, of the Broniarski Limestone Member. These deposits correspond to the limestones of similar microfacies of the uppermost part of the Kliny Limestone Member in the western part of the Tatra Mts (*cf.* Jach, 2007). The nodular limestones of the ammonitico-rosso facies, with the filament (*Bositra*) microfacies, in the Pieniny Klippen Belt are also their facies and time-counterparts. All these deposits began to form at the end of the Bajocian and continued during the Bathonian. Their development corresponded well with general subsidence and the development of a more uniform pelagic facies pattern over a wide area from the Pieniny Klippen Basin in the north, down to the autochthonous -parautochthonous Tatricum to the south – as well as the adjoining southern Fatricum such as the Lower Subtatric nappe.

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PLATE 1

Fig. 1. Sandy limestone with echinoderm fragments; Płaśnia Limestone Member, Czerwone Brzeżki locality

Fig. 2. Spiculite packstone; Kobyła Limestone Member, Sołtysia Skałka locality

Fig. 3. Bioclastic wackestone, A – *Nodosaria* sp., B – bivalve shell; Czerwone Brzeżki Bed, Czerwone Brzeżki locality

Fig. 4. Bioclastic wackestone, A – gastropod shell, B – echinoderm fragments; Czerwone Brzeżki Bed, Czerwone Brzeżki locality

Fig. 5. Bioclastic wackestone, A – *Involutina liassica* Jones; Czerwone Brzeżki Bed, Czerwone Brzeżki locality

Fig. 6. Spiculite wackestone/packstone; Krzywań Limestone Member, Krzywań locality

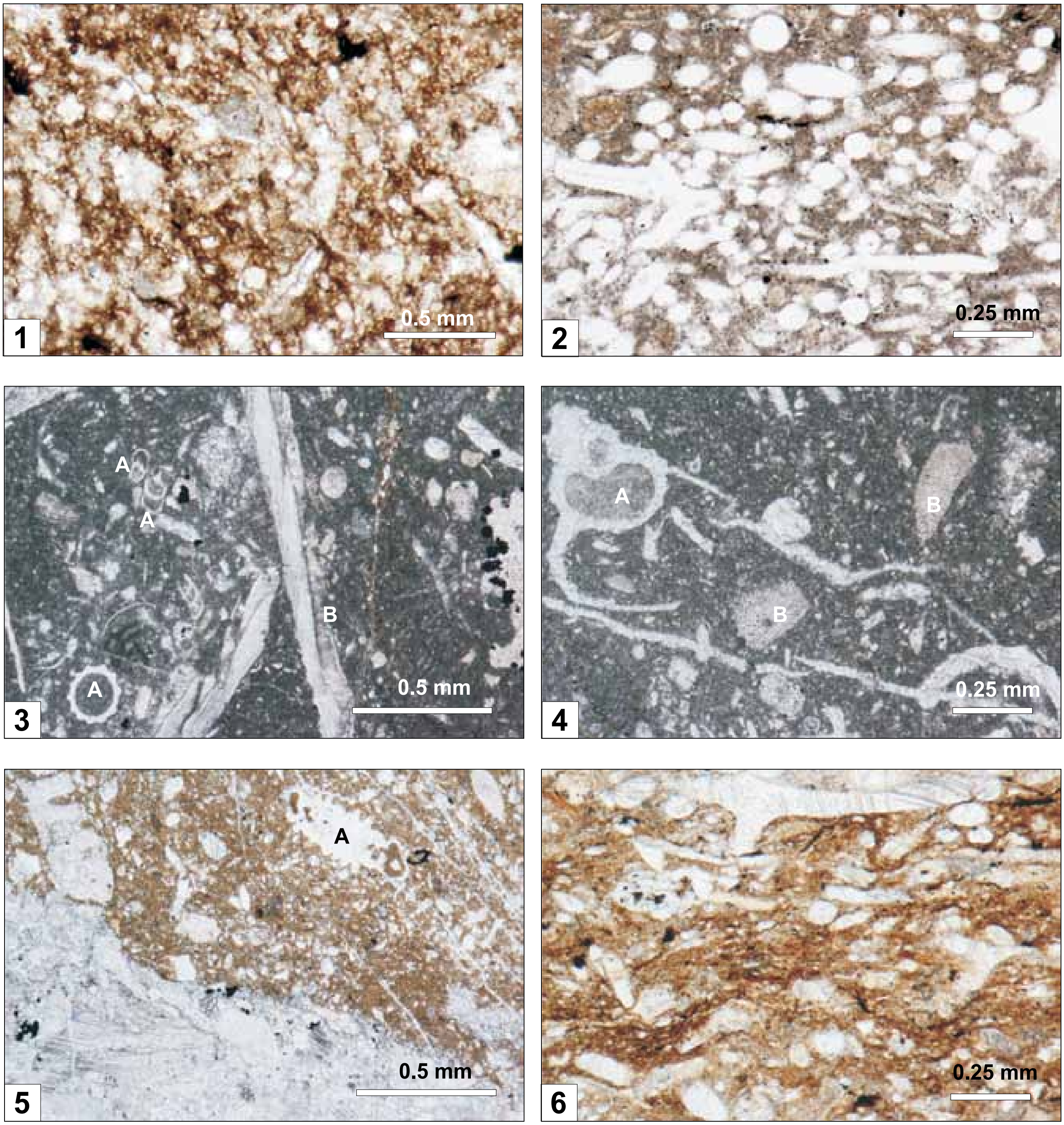
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PLATE 2

Fig. 1. Radiolarian wackestone; Skalnite Marlstone Member, Sucha Woda locality

Fig. 2. Spiculite packstone/grainstone of the turbidite layer; Skalnite Marlstone Member, Sucha Woda locality

Fig. 3. Crinoidal packstone/grainstone of the turbidite layer, A – echinoderm fragments, B – lithoclast; Skalnite Marlstone Member, Ždziarska Vidla (Płaczliwa Skała) locality

Fig. 4. Muddy radiolarian limestone with silt admixture; Podspad Marlstone Member, Świniarski Żleb locality

Fig. 5. *Bositra* (filament) wackestone with silt admixture (filament mudrock); Podskalnia Shale Member, Sucha Woda locality

Fig. 6. Spiculite mudrock; Podskalnia Shale Member, Sucha Woda locality

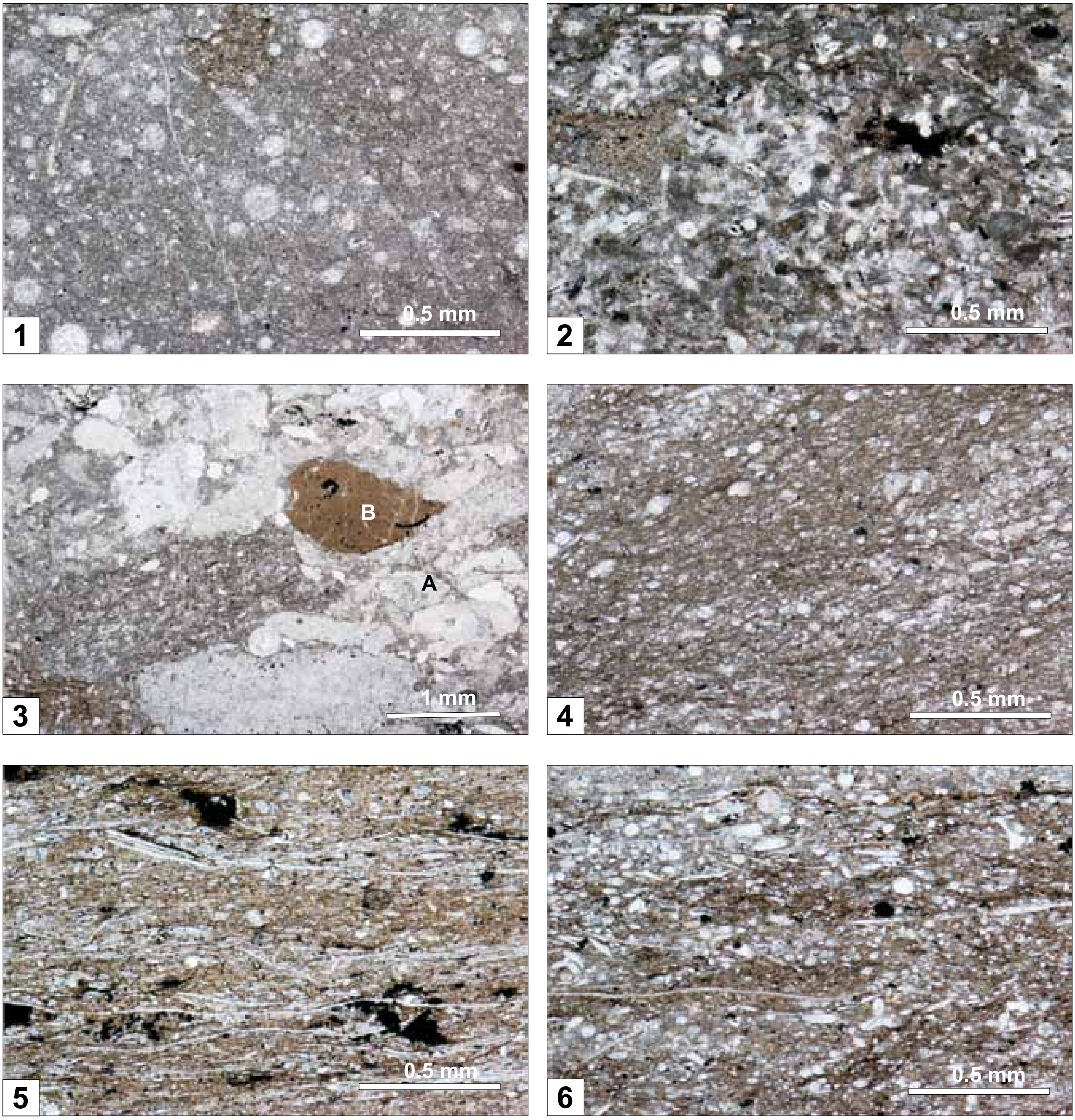
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PLATE 3

Fig. 1. Spiculite packstone; Łomy Limestone Member, Ždziarska Vidla (Płaczliwa Skała) locality

Fig. 2. Radiolarian wackestone; Łomy Limestone Member, Świniarski Żleb locality

Fig. 3. Radiolarian wackestone with some *Bositra* (filaments); Łomy Limestone Member, Koziarski Żleb locality

Fig. 4. Intraformational breccia composed of several types of clasts, A – sponge spiculite packstone, B – sponge spiculite wackestone; Łężny Breccia ("Encrinite") Bed, Filipka Szałas locality

Fig. 5. Intraformational breccia containing fragments of still older breccia; Łężny Breccia ("Encrinite") Bed, Płaczliwa Skała locality

Fig. 6. *Bositra* (filament) wackestone/packstone; Broniarski Limestone Member, Koziarski Żleb locality

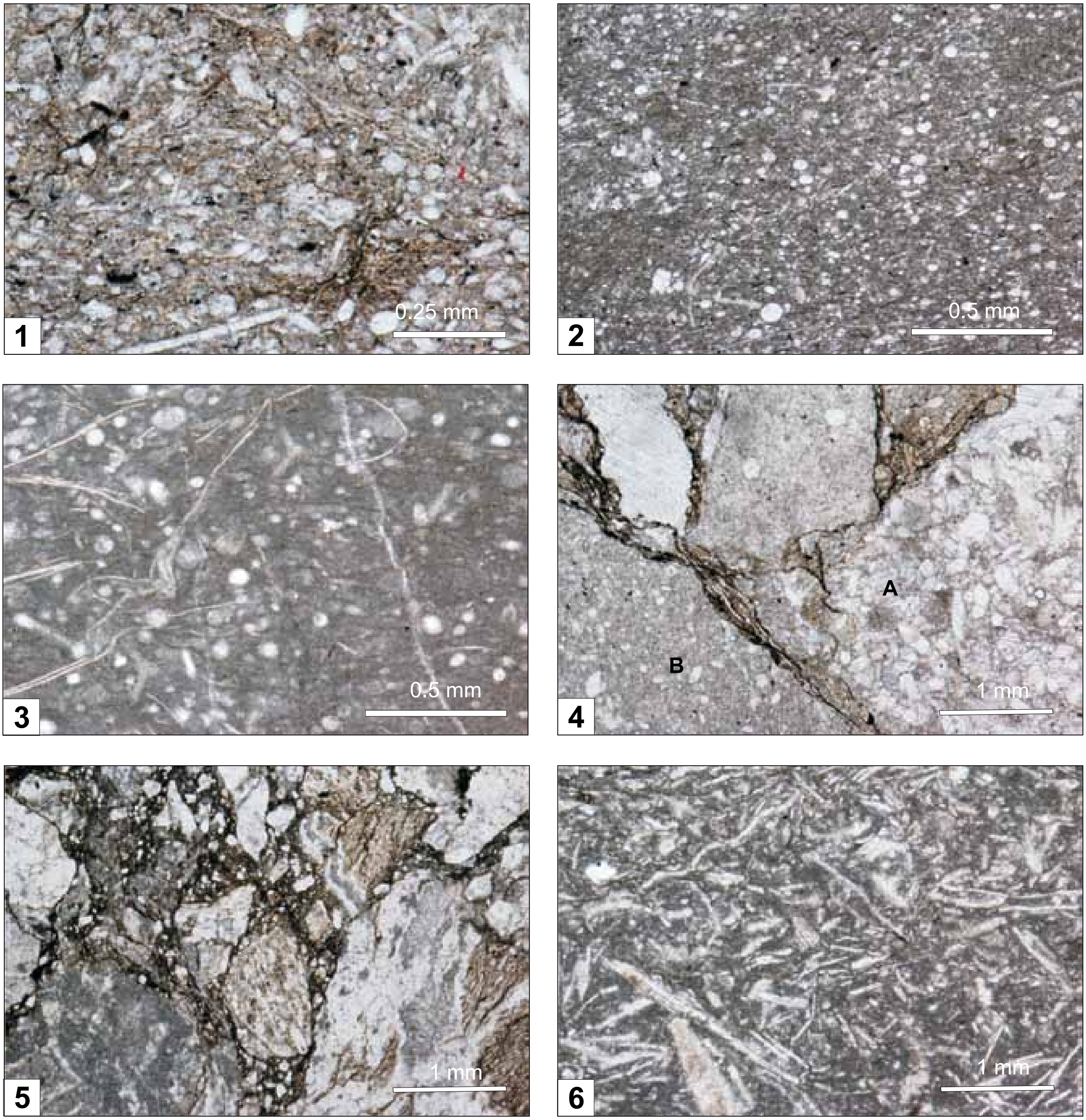
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PLATE 4

Fig. 1. *Plesechioceras* cf. d*elicatum* (Buckman); ZI/48/024,40; Płaśnia Limestone Member, Upper Sinemurian, Raricostatum Zone

Fig. 2. *Ortechioceras raricostatum* Trueman et Williams; ZI/48/023; phragmocone; Czerwone Brzeżki Bed, northern slopes of Krzywań Mt., Upper Sinemurian, Raricostatum Zone

Fig. 3. *Echioceras* ex gr. *E. raricostatoides* (Vadasz); ZI/48/048; Kobyła Limestone Member, northern slopes of Krzywań Mt., rubble, Upper Sinemurian, Raricostatum Zone

Fig. 4. *Echioceras* sp. ex gr. *E. quenstedti* (Schafhäutl); ZI/48/036; fragment of body chamber; Płaśnia Limestone Member, Upper Sinemurian, Raricostatum Zone

Fig. 5. *Tropidoceras* sp.; ZI/48/028; Krzywań Limestone Member, Lower Pliensbachian

Fig. 6. *Fuciniceras* ex gr. *F. lavinianum* (Fucini) – *portisi* (Fucini); ZI/48/022; Skalnite Marlstone Member, old road to Kobyła Mt., rubble, Upper Pliensbachian, Margaritatus Zone

Fig. 7. *Fuciniceras* ex gr. *F. cornacaldense* (Tautsch); ZI/48/020; Skalnite Marlstone Member, old road to Kobyła Mt., rubble, Upper Pliensbachian, Margaritatus Zone

Fig. 8. *Protogrammoceras* ex gr. *P. celebratum* (Fucini); ZI/48/016; Skalnite Marlstone Member, Filipka Valley (Filipka Szałas locality); Upper Pliensbachian, Margaritatus Zone

Fig. 9. *Paltarpites* sp.; ZI/48/019; Skalnite Marlstone Member, Sołtysia Skałka locality, Upper Pliensbachian, Margaritatus Zone

Fig. 10. *Hildoceras bifrons* (Bruguière); ZI/48/025; Skalnite Marlstone Member, Sołtysia Skałka locality, Middle Toarcian, Bifrons Zone

The specimens in natural size. The phragmocone/body chamber boundary is arrowed

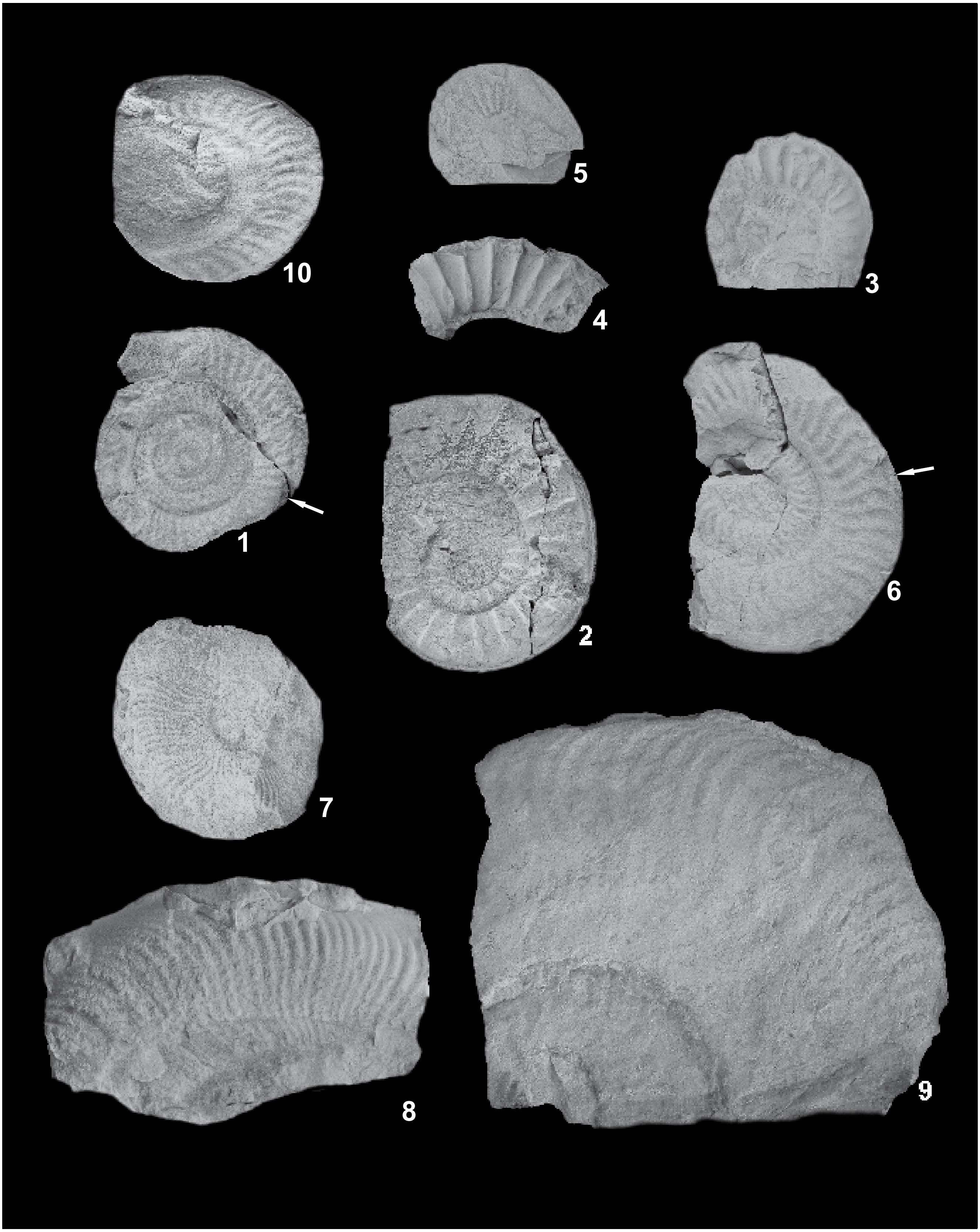
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PLATE 5

Fig. 1. *Hildoceras* ex gr. *H. sublevisoni* Fucini; ZI/48/017; Skalnite Marlstone Member, northern slope of Przednia Kopa Mt., rubble, Middle Toarcian, Bifrons Zone

Fig. 2. *Haugia* sp.; ZI/48/021; Skalnite Marlstone Member, northern slope of Przednia Kopa Mt., rubble, Middle Toarcian, Variabilis Zone

Fig. 3. *Haugia* sp.; 1740.II.18; Skalnite Marlstone Member, Świniarski Żleb locality, Middle Toarcian, Variabilis Zone

Fig. 4. *Pseudogrammoceras* ex gr. *P. doerntense* (Denckmann); ZI/48/015; Skalnite Marlstone Member, Kobyła Mt. or Krzywań Mt., rubble, Upper Toarcian, Thouarsense Zone

Fig. 5. *Pseudogrammoceras* ex gr. *P. doerntense* (Denckmann); 1740.II.02; Skalnite Marlstone Member, Sucha Woda locality, Upper Toarcian, Thouarsense Zone

Fig. 6. *Pseudogrammoceras bingmanni* (Denckmann) – *P. struckmanni* (Denckmann), microconch; 1740.II.11; Skalnite Marlstone Member, Sucha Woda locality, Upper Toarcian, Thouarsense Zone

Fig. 7. *Pseudogrammoceras bingmanni* (Denckmann); 1740.II.10; Skalnite Marlstone Member, Sucha Woda locality, Upper Toarcian, Thouarsense Zone

The specimens in natural size. The phragmocone/body chamber boundary is arrowed

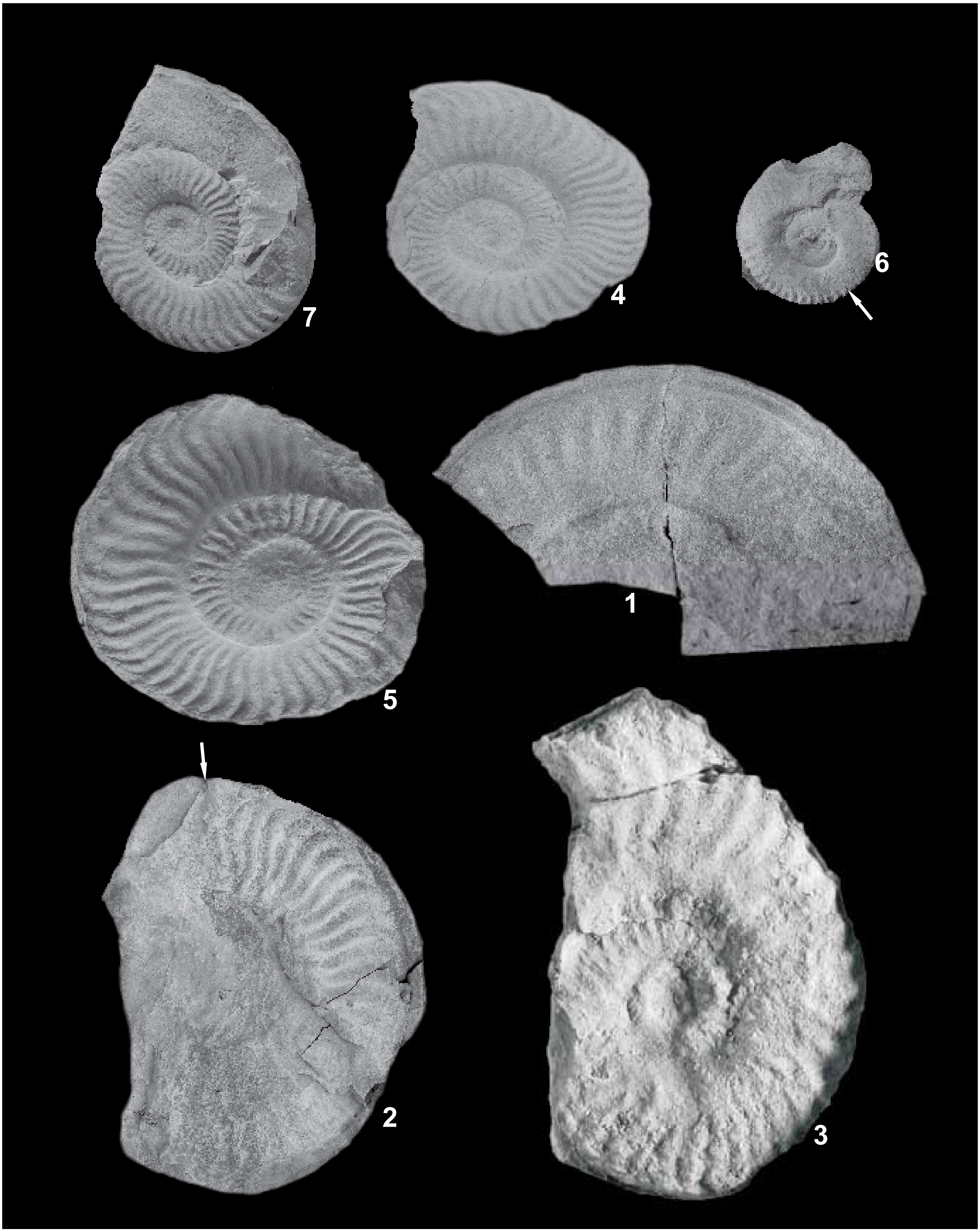
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PLATE 6

Fig. 1. *Pseudogrammoceras bingmanni* (Denckmann); ZI/48/006; Skalnite Marlstone Member, Sołtysia Skałka locality, Upper Toarcian, Thouarsense Zone

Fig. 2. *Pseudogrammoceras bingmanni* (Denckmann); 1740.II.05; Skalnite Marlstone Member, Sucha Woda locality, Upper Toarcian, Thouarsense Zone

Fig. 3. *Pseudogrammoceras bingmanni* (Denckmann); 1740.II.07-08; Skalnite Marlstone Member, Sucha Woda locality, Upper Toarcian, Thouarsense Zone

Fig. 4. *Pseudogrammoceras bingmanni* (Denckmann); 1740.II.03; Skalnite Marlstone Member, Sucha Woda locality, Upper Toarcian, Thouarsense Zone

Fig. 5. *Pseudogrammoceras struckmanni* (Denckmann); 1740.II.01; Skalnite Marlstone Member, Sucha Woda locality, Upper Toarcian, Thouarsense Zone

Fig. 6. *Pseudogrammoceras struckmanni* (Denckmann); 1740.II.09; Skalnite Marlstone Member, Sucha Woda locality, Upper Toarcian, Thouarsense Zone

The specimens in natural size


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PLATE 7

Fig. 1. *Leioceras opalinum* (Reinecke); ZI/48/001; Podspad Marlstone Member, Lower Aalenian, Opalinum Zone

Fig. 2. *Graphoceras* (*Graphoceras*) *concavum* (Sowerby); 1740.II.12; Podskalnia Shale Member, Świniarski Żleb locality, Upper Aalenian, Concavum Zone

Fig. 3. *Graphoceras* (*Graphoceras*) cf. *concavum* (Sowerby); 1740.II.21; Podskalnia Shale Member, Świniarski Żleb locality, Upper Aalenian, Concavum Zone

Fig. 4. *Graphoceras* (*Ludwigella*) cf. *cornu* (Buckman); 1740.II.14; Podskalnia Shale Member, Świniarski Żleb locality, Upper Aalenian, Concavum Zone

Fig. 5–6. *Graphoceras* sp.; 1740.II.22-23; Podskalnia Shale Member, Świniarski Żleb locality, Upper Aalenian, Concavum Zone

Fig. 7. *Hammatoceras* sp.; 1740.II.17; Podspad Marlstone Member, Sucha Woda locality, Upper Toarcian, Dispansum Zone

Fig. 8. *Nannolytoceras tripartitum* (Raspail); 1740.II.16; Broniarski Limestone Member, Koziarski Żleb locality, uppermost Bajocian or lowermost Bathonian

Fig. 9. *Bradfordia* sp.; ZI/48/012; Łomy Limestone Member, Rogova above Javorova Valley, Slovakia; Lower Bajocian

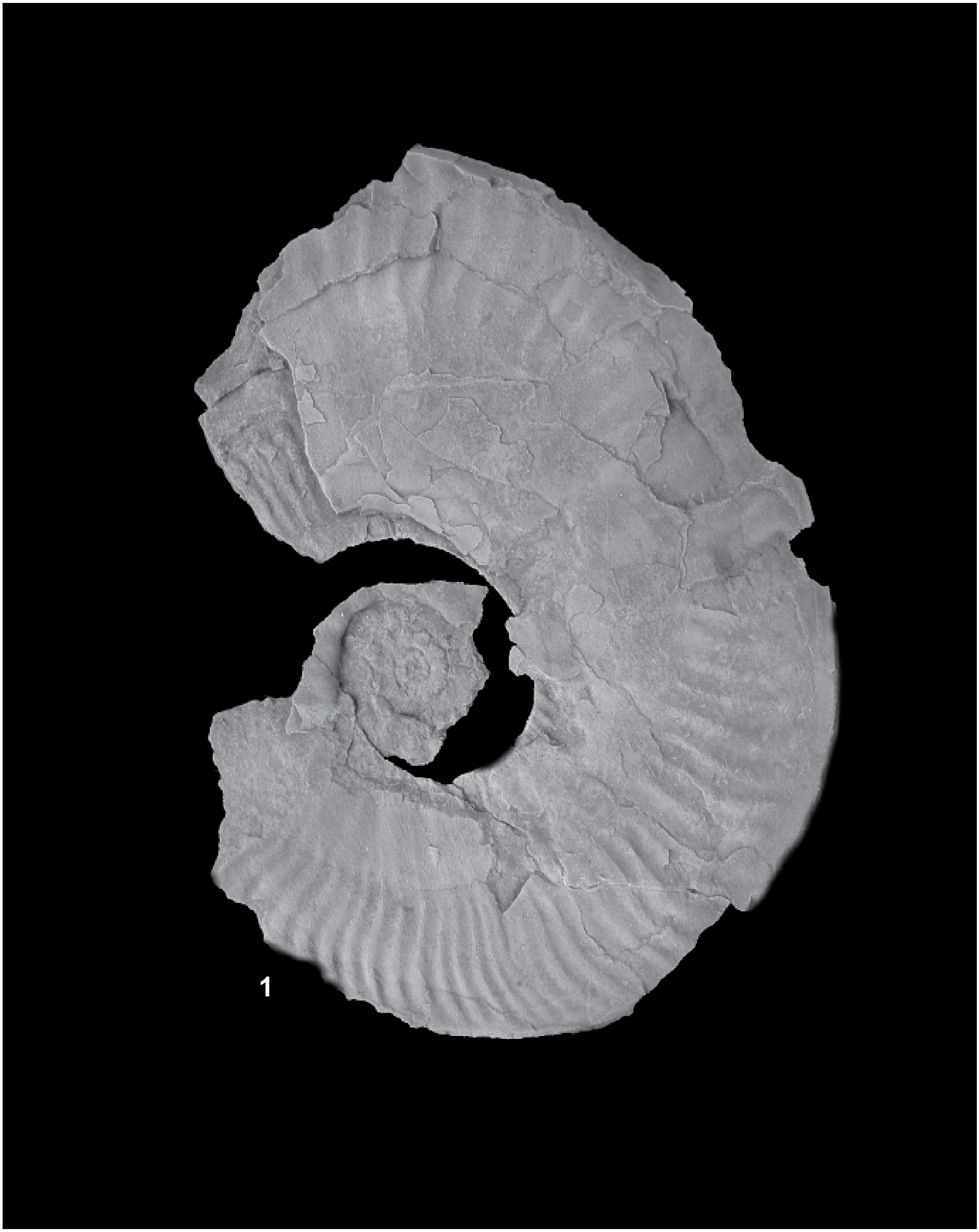
The specimens in natural size. The phragmocone/body chamber boundary is arrowed


3
9
5
6
2
4
7
8
1

PLATE 8

Fig. 1. *Bredyia* sp.; ZI/48/009; Podspad Marlstone Member, Sucha Woda locality, Lower Aalenian, Opalinum Zone

The specimen in natural size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