Annales Societatis Geologorum Poloniae (2009), vol. 79: 27–39.

CEPHALOPOD FAUNA AND STRATIGRAPHY OF THE ADNET TYPE RED DEPOSITS OF THE KRÍŽNA UNIT IN THE WESTERN TATRA MOUNTAINS, POLAND

Ryszard MYCZYŃSKI[1] & Renata JACH[2]

[1] *Institute of Geological Sciences, Polish Academy of Sciences, Twarda 51/55, 00-818 Warszawa, Poland, e-mail: rmyczyns@wp.pl*
[2] *Institute of Geological Sciences, Jagiellonian University, Oleandry 2a, 30-063 Kraków, Poland, e-mail: renata.jach@uj.edu.pl*

Myczyński, R. & Jach, R., 2009. Cephalopod fauna and stratigraphy of the Adnet type red deposits of the Krížna unit in the Western Tatra Mountains, Poland. *Annales Societatis Geologorum Poloniae*, 79: 27–39.

Abstract: The Lower Jurassic Adnet type red limestones and marlstones (Kliny Limestone Member, Huciska Limestone Formation) of the Krížna unit in the Tatra Mountains comprise cephalopod fauna represented by ammonites, belemnites and rarely by nautiloids. Ammonites belong to the families Phyloceratidae, Lytoceratidae, Hildoceratidae and Dactylioceratidae and indicate Early Toarcian *Serpentinum* Zone, Middle Toarcian *Bifrons* Zone (most probably *Sublevisoni* and *Bifrons* Subzones) and Late Toarcian *Pseudoradiosa* Zone. Hence, the age of Adnet type deposits may be estimated as Early Toarcian–Late Toarcian. Relatively moderate diversity of ammonite assemblage is noticed. Ammonites and nautiloids are preserved mainly as internal moulds, only some specimens display preserved calcified shells. Part of this macrofauna has resedimented character. Studied ammonite assemblage is closely related to that of the Mediterranean Province.

Key words: ammonites, nautiloids, Toarcian, Western Tethys.

Manuscript received 24 September 2008, accepted 18 March 2009

INTRODUCTION

The ammonites and nautiloids described here derived from the Lower Jurassic red limestones and marlstones of the Krížna unit in the Western Tatra Mountains. Studied red deposits are traditionally compared to the Adnet limestones due to the facies type and age covering the span of Early Jurassic, therefore in this paper they will be called as Adnet type deposits. However, such deposits are also ranked among *Ammonitico Rosso* type deposits, since this name is widely used to describe red nodular carbonate facies of Jurassic age (*cf.* Wieczorek, 1983; Tucker & Wright, 1990; Martire, 1996; Böhm *et al.*, 1999). This facies especially widespread in the Mediterranean realm is known to contain rich ammonite assemblages.

The described Adnet type deposits represent one of a few levels within Jurassic succession of the Krížna unit in the Western Tatra Mountains, which contain biostratigraphically important fauna. Macrofauna from these deposits has been the subject of research by numerous authors (*e.g.*, Zejszner, 1852; Uhlig, 1897; Myczyński & Lefeld, 2003). On the basis of these findings, Adnet type deposits were assigned for long time as Middle Toarcian. Nonetheless, the published data on ammonites contain scarce information concerning precise location of the specimens in the sections. Recently, several sections through these deposits were investigated in detail; however, cephalopod fauna within the sections were found almost exclusively at the Huciański Klin locality. The main reason for this phenomenon is the insufficient state of the other outcrops.

The main purpose of this study is to present previously undescribed ammonite collections from the Huciański Klin and Czerwona Skałka sections which are classic localities of the Krížna unit in the Western Tatra Mountains. Moreover, this paper describes the ammonite and nautiloid assemblage within Adnet type deposits from the taphonomic point of view and discuses the age of host deposits, improving the knowledge of Jurassic biostratigraphy in the Tatra Mountains.

GEOLOGICAL SETTING

The studied Adnet type red deposits crop out in the Polish part of the Western Tatra Mountains. These deposits belong to the Krížna unit, which in the Western Tatra Mountains is represented by a large slab called the Bobrowiec unit (Fig. 1; Bac, 1971). This unit comprises Lower Triassic through Lower Cretaceous deposits.

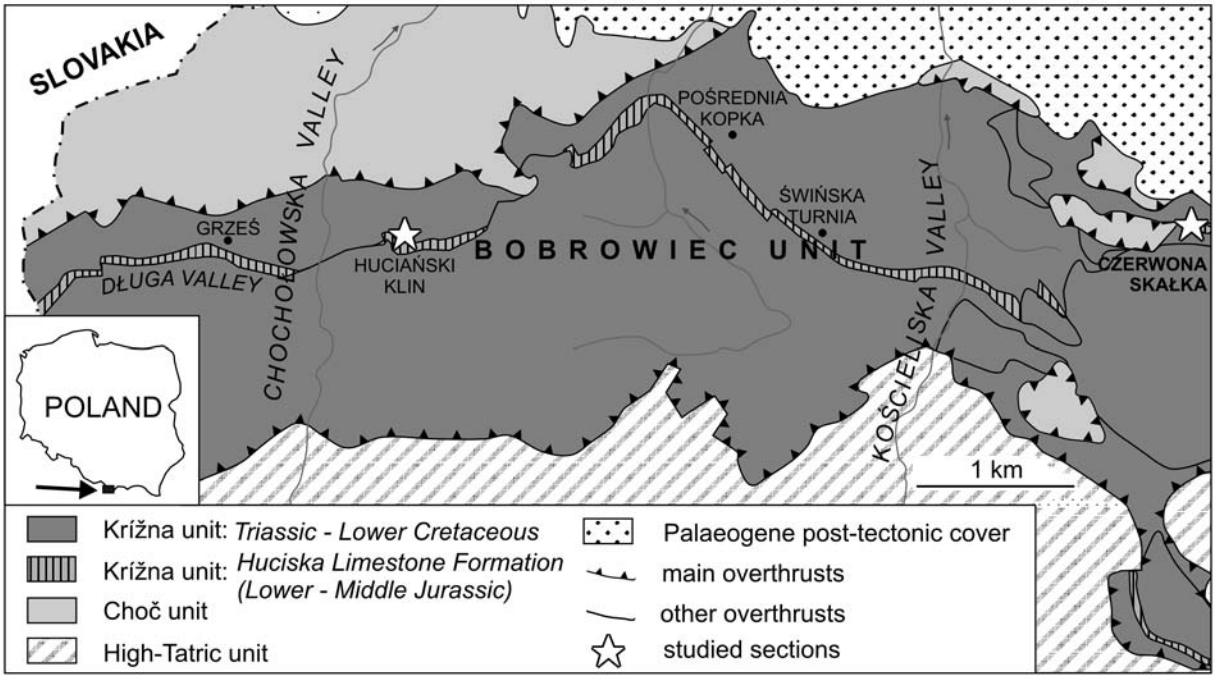


Fig. 1. Geological sketch map of Polish part of the Western Tatra Mountains (after Bac-Moszaszwili *et al.* 1979, simplified) showing location of the Huciański Klin and Czerwona Skałka sections

The Adnet type deposits form the lower part of the Kliny Limestone Member belonging to Huciska Limestone Formation (Lefeld *et al.*, 1985). The member is 7 m thick in the stratotype section at the Huciański Klin crest, north-east of the Polana Huciska alp in the Chochołowska Valley in the Western Tatra Mountains (Figs 2, 3; Lefeld *et al.*, 1985). Deposits of this member have been regarded as Middle Toarcian–Aalenian in age (Lefeld *et al.*, 1985; Myczyński & Lefeld, 2003). The Adnet type deposits, represented by limestones and marlstones, are up to 4 m thick and belong to the lower part of the Kliny Limestone Member (Lefeld *et al.*, 1985). These deposits overlie crinoidal limestones (Długa Encrinite Member) and locally, at Huciański Klin crest, Mn-bearing deposits (Banie Ore Bed; Lefeld *et al.*, 1985; Jach & Dudek, 2005). The age of crinoidal limestones is estimated as Early Toarcian on the basis of their location in the section and chemostratigraphic data (Krajewski *et al.*, 2001). The Adnet type deposits are covered by *Bositra* limestones, up to 3 m thick. These limestones belong to the upper part of the Kliny Limestone Member (Lefeld *et al.*, 1985). Their age is not precisely determined due to the lack of diagnostic fossils; however, this facies in the Krížna unit is estimated as Aalenian–Early Bathonian in age (Bujnovský & Polák, 1979; Jach, 2007). The *Bositra* limestones are covered by nodular limestones and radiolarites of Upper Bathonian–Lower Kimmeridgian age (Polák *et al.*, 1998).

During Early Jurassic time the Krížna Basin was disintegrated into several local basins and structural elevations. Adnet type limestones and marlstones were formed mainly at elevated parts of the basin. These deposits are partly nodular (Fig. 2). Gradziński *et al.* (2004) distinguished six microfacies within these deposits: crinoidal-ostracod packstone, crinoidal packstone, crinoidal wackestone, marly mudstone, *Bositra* packstone and *Bositra*-crinoidal packstone. These deposits display finning-upward trend which is accompanied by upward increasing abundance of microborings. Structures such as stromatolites and ferruginous microbial-foraminiferal macrooncoids, being the most unique feature of these deposits, are abundant in the upper part of the section (Gradziński *et al.*, 2004). These features are typical of condensed deposits (*cf.* Jenkyns, 1971).

PREVIOUS WORK

Adnet type deposits of the Krížna unit became famous mainly because of the iron ores, exploited in the 19th century. Zejszner (1852) was the first who described fauna from several localities of the Adnet type deposits in the Western Tatra Mountains. He listed several ammonite species from the Czerwona Skałka section. They are as follows: *Ammonites walcoti* (Sowerby) (=*Hildoceras bifrons* (Bruguière); Uhlig, 1897), *A. serpentinus* Schlotheim, *A. bucklandii* (Sowerby), *A. fimbriatus* (Sowerby), *A. heterophyllus numismalis* (Quenstedt), and *Nautilus arratus* (Schlotheim). However, determination and localization of *Ammonites bucklandii* (Sowerby) was later questioned by Sokołowski (1925). Uhlig (1897) noted *Harpoceras radians* (Reinecke) from the same outcrop. Moreover Sokołowski (1925) reported from there: *Hildoceras bifrons* (Bruguière), *H. laevisoni* (Simpson), *Coeloceras commune* (Sowerby), *Lytoceras* aff. *francisci* (Oppel) and belemnite *Passaloteuthis paxillosus tripartitus* (Schlotheim). From the Świńska Turnia section Zejszner (1852) mentioned *Ammonites capellinus* (Schlotheim) and *A. variabilis* (d'Orbigny). From the some locality Sokołowski (1925) noticed *Lioceras* sp. and

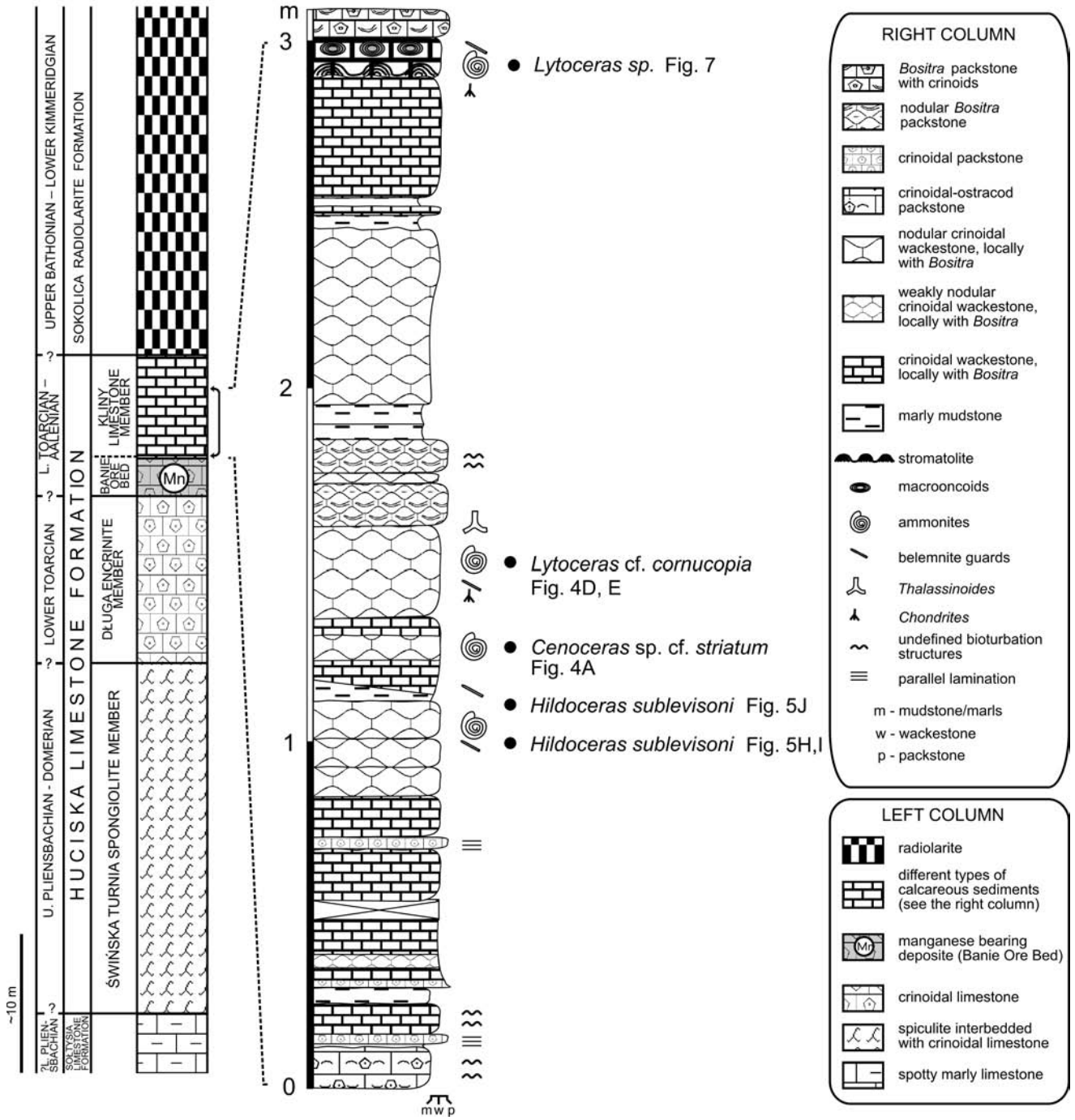


Fig. 2. Lithostratigraphic log of the Lower-Middle Jurassic deposits of the Krížna unit and chronostratigraphic interpretation (after Lefeld *et al.*, 1985; left); lithological section of the cephalopod-bearing deposits at the Huciański Klin crest (after Gradziński *et al.*, 2004; right)

Hildoceras saemanni Dumortier. On the basis of those findings, he estimated the age of Adnet type deposits as lowermost Upper Liassic. Uhlig (1897) listed from the Huciański Klin section the following taxa: *Ammonites lilli* Hauer, *A. bifrons* (Bruguière), *A. serpentines* (Reinecke), *A. fimbriatus* (Sowerby), *A. variabilis* (d'Orbigny), *A. tatricus* (Pusch) and *Nautilus semistriatus* (d'Orbigny). Unfortunately, detailed location of the above listed ammonites within sections became unknown. Moreover, it is difficult to estimate quality of these determinations. It seems to be necessary to revise the 19th century diagnosis of ammonites assembled by Zejszner (1852) and Uhlig (1897), as well as ammonites assembled later by Siemiradzki (1923).

The latest description of ammonites of the Adnet type red limestones and marlstones was given by Myczyński and Lefeld (2003). They described ammonites collected by the second author and by Sokołowski (1925) and reported several forms belonging to Phyloceratidae, Lytoceratidae and Hil- doceratidae families. From the Huciański Klin section they described the following specimens: *Calliphylloceras*

nilssoni (Hébert), *Cenoceras* aff. *striatum* (Sowerby), *Pachylytoceras* sp. gr. *P. wrighti* Buckman, additionally *Harpoceras serpentinum* (Schlotheim) from the Świńska Turnia section and *Cenoceras* sp., *Phylloceras* cf. *baconicum* Prinz, *Lytoceras fimbriatum* (Sowerby) and *Catulloceras dumortieri* (Thiollière) from Czerwona Skałka at the Przysłop Miętusi. Moreover, from the Holica section (Eastern Tatra Mountains), where Adnet type deposits also crop out, following specimens were described: *Calliphylloceras nilssoni* (Hébert), *Calliphylloceras* sp. gr. *C. supraliasicum* (Pom- peckj), *Lytoceras* cf. *cornucopia* (Young et Bird), *Pachy- lytoceras* sp. gr. *P. wrighti* Buckman.

MATERIAL AND METHODS

The studied macrofauna assemblage includes 22 specimens. The described ammonites derived from two localities, that is Huciański Klin and Czerwona Skałka at the Przysłop Miętusi pass (Fig. 2). Generally, due to exploitation of Mn-bearing deposits and ferruginous macrooncoids in the 19th century the Adnet type deposits are relatively well exposed, however, the collapsing of adits caused that the sections are not complete. Macrofauna within these deposits has been mainly found in the small rock cliffs located in the vicinity of the adits at the Huciański Klin crest and the Czerwona Skałka. Adits numeration at the Huciański Klin locality presented in this paper is after Jach (2002). Other sections of the Adnet type deposits can be regarded as reference sections (*e.g.*, sections at Świńska Turnia, Pośrednia Kopka and Grześ in the Długa Valley).

Macrofauna from the Huciański Klin section were collected by the second author (R.J.). This collection is kept in the Geological Museum of the Institute of Geological Sciences, Jagiellonian University (collection number 201P). The major part of this material was collected directly from the outcrop and hence the fossils have precise location in the section (Fig. 2). The stratigraphic position of the samples is shown in Fig. 2. Only minor part of specimens from this collection comes from the debris. The second collection described here contains specimens assembled at the Czerwona Skałka section by an anonymous collector. This collection is housed in the Geological Museum of the Institute of Geological Sciences, Polish Academy of Sciences in Kraków (collection number ZNG PAN B-I-74). Specimens from this collection are not accompanied by precise location in the section.

Classification of the ammonites is based on the papers by Arkell (1950) and Arkell *et al.* (1957). The synonymy list for particular species includes reference to the figured type specimens and to more recent papers which present a wider list of references.

The following measurements are used in the description of ammonites: D – maximum diameter, Wh – whorl height, Wb – whorl width; U – umbilical diameter, Wh/D – whorl height/shell diameter, U/D – umbilical diameter/shell diameter, Wb/Wh – whorl width/whorl height.

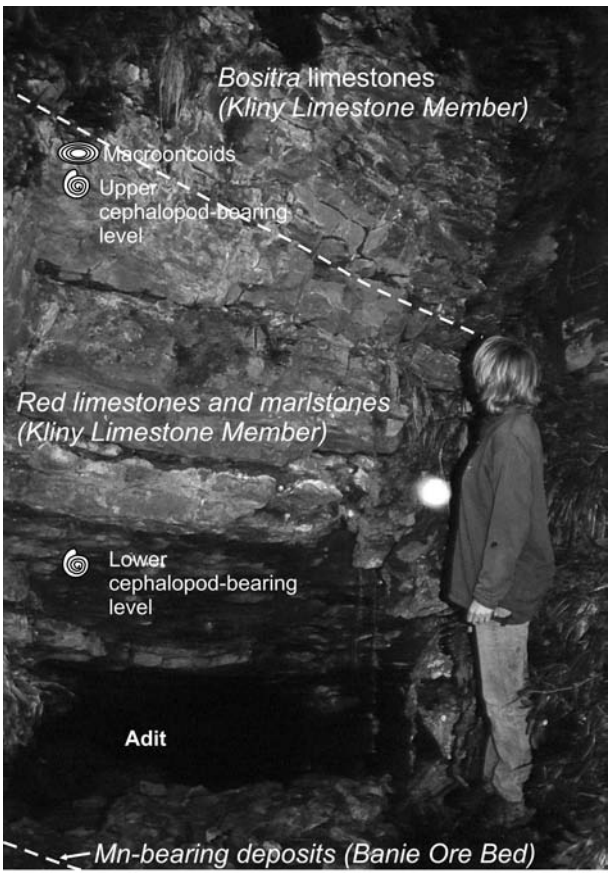


Fig. 3. Field view of the Huciański Klin locality. Section of the Adnet type deposits visible in the entrance to the adit no. 7

RESULTS

Systematic description of cephalopod fauna

Class CEPHALOPODA Cuvier 1798
Subclass NAUTILOIDEA Agassiz 1847
Family NAUTILIDAE d'Orbigny 1840
Genus *Cenoceras* Hyatt 1883
Type species *Nautilus orbigny* Prinz 1906

Cenoceras (*Cenoceras*) sp. cf. *striatum* (Sowerby 1817)
(Fig. 4A, B)

1956. *Cenoceras stratus* (Sowerby): Kümmel, p. 362, pl. 3, figs 1, 2
1964. *Cenoceras stratum* (Sowerby): Rakús, p. 95, pl. 16, figs 1, 2

Material: Two compressed fragments of whorl (201P/RJ5; Wb – 40 mm; ZNG PAN B-I-74/RJ14; Wh – 13 mm; Wb – 50 mm).
Description and remarks: Two ventrally compressed fragments of the last whorl (Wb – 40 mm and 50 mm). Ventral side rounded. Suture line is weakly visible, as not very diversified but have sinuses lobes (7 on the half whorl). Our specimens show similarity in whorl shape and the character of suture line to *Cenoceras striatum* (Sowerby), illustrated and described by Kümmel (1956, p. 362, pl. 3, figs 1, 2) and the specimen from the Pliensbachian (*Jamesoni* Zone) of Rovne pod Krížnou (Veľka Fatra, Slovak Republic), depicted by Rakús (1964, p. 95, pl. XVI, figs 1, 2). Poor preservation of the specimens does not permit identification with the Sowerby's species without reservation.

Occurrence: Our specimens were found in Adnet type deposits at the Huciański Klin section (specimen 201P/RJ5, adit no. 7, position in section see Fig. 2) and Czerwona Skałka (specimen ZNG PAN B-I-74/RJ14), Krížna unit, Western Tatra Mountains. *Cenoceras striatum* (Sowerby) is well known from Liassic deposits of Europe (Rakús, 1964).

Order AMMONOIDEA Zittel 1884
Suborder PHYLLOCERATINA Arkell 1950
Super family PHYLLOCERATINAE Zittel 1884
Family PHYLLOCERATIDAE Zittel 1884
Genus *Phylloceras* Suess 1865
Type species *Ammonites heterophyllus* Sowerby 1819

Phylloceras ex gr. *heterophyllum* (Sowerby 1819)
(Fig. 4C)

1819. *Ammonites heterophyllus* Sowerby: p. 119, pl. 266
1976. *Phylloceras* (*Phylloceras*) *heterophyllum* (Sowerby): Schlegelmilch, p. 25, pl. 1, figs 1, 2
1998. *Phylloceras heterophyllum* (Sowerby): Rulleau, p. 21, pl. 1, figs 1-3; pl. 2, fig. 3; text-fig. 5-1

Material: One fragment of whorl ZNG PAN B-I-74/RJ28, Wh – 88 mm.
Description and remarks: One fragment of whorl with high-oval whorl section, weakly convex sides and narrow rounded ventral side. Maximal shell width is at half of the whorl height. No constrictions. These features are similar to the ammonites presented by the authors cited in the synonymy list. Poorly preserved suture line is similar to the suture presented by Neumayr (1871, p. 12, fig. 1). Incomplete preservation of the specimen makes it impossible to identify it unquestionably.
Occurrence: Czerwona Skałka, Krížna unit, Western Tatra Mountains. *Phylloceras heterophyllum* (Sowerby) is known from the *Serpentinum* Zone to *Bifrons* Subzone (see Rulleau, 1998).

Suborder LYTOCERATINA Hyatt 1889
Superfamily LYTOCERATACEAE Neumayr 1875
Family LYTOCERATIDAE Neumayr 1875
Subfamily LYTOCERATINAE Neumayr 1875
Genus *Lytoceras* Suess 1865
Type species *Ammonites fimbriatus* Sowerby 1817

Lytoceras cf. *cornucopia* (Young et Bird 1822)
(Fig. 4D–G)

1968. *Lytoceras cornucopia* (Young et Bird): Pinna, p. 6, pl. 1, fig. 20; text-fig. 2.n.t., fig. 1
1976. *Lytoceras cornucopia* (Young et Bird): Schlegelmilch, p. 29, pl. 2, fig. 4
1998. *Lytoceras cornucopia* (Young et Bird): Rulleau, p. 38

Material: Three incomplete specimens (201P/RJ1; 201P/RJ3; 201P/RJ7) and one fragment of whorl (201P/RJ4), preserved as internal mould.
Dimensions:

Measurements Specimen	D (mm)	Wh (mm)	Wb (mm)	U (mm)	Wh/D (%)	Wb/D (%)	Wb/Wh (%)	U/D (%)
201P/RJ1	80	30	27	31	37	34	90	39
201P/RJ3	112	44	32	44	39	29	94	39
201P/RJ4		35						
201P/RJ7	118	47	?35	51	39	29	?74	43

Description and remarks: The specimens are middle-sized with obliterated sculpture. Whorls grow quickly. Whorl section is oval, slightly broader than higher. Ventral side slightly flattened and rounded. Whorl side is narrow and convex. Thicker megastriae occur cyclically. Shell surface uneven, with depressions and elevations, most probably remnants of primary morphology. In whorl section, general shape and dimensions of the specimens are similar to the ammonites illustrated by Géczy (1967, p. 72, pl. 19, fig. 1; pl. 64, fig. 26) as *Lytoceras* cf. *cornucopia* (Young et Bird), to those of Schlegelmilch (1976, p. 29, fig. 4) described as *Lytoceras cornucopia* (Young et Bird), as well as those described by Rulleau (1998, p. 39, figs 1-3; pl. 10, figs 1-3; pl. 11, figs 1-3; text-fig. 6 (3-5)) as *Lytoceras cornucopia* (Young et Bird). Due to poor state of preservation, the studied specimens have been classified to this species with reservation.
Occurrence: The specimens have been found in the debris and in the section of the Adnet type deposits at the Huciański Klin section (specimens 201P/RJ1 – RJ4, adit no. 7, position in the section see Fig. 2; specimen 201P/RJ7, adit no. 5, collected in debris), Krížna unit, Western Tatra Mountains. The species *Lytoceras cornucopia* (Young et Bird), to which our specimen has been classified, is known mainly from the *Bifrons* Zone of Europe (see Rulleau, 1998, p. 39).

Lytoceras cf. *L. verpillierense* Rulleau 1998
(Fig. 4H, I)

1998. *Lytoceras verpillierense* Rulleau: Rulleau, p. 42, pl. 12, figs 4-6; pl. 35, figs 5-6; text-fig. 6-2

Material: two fragments of whorl (201P/RJ10; Wh – 51 mm; Wb – 33 mm; ZNG PAN B-I-74/RJ13, Wh – 50 mm).
Description and remarks: Whorl section is highly oval. Whorl side is slightly convex. Ventral side is rounded. Weakly marked constriction is visible on whorl side. The suture line is poorly preserved. Incompleteness of the specimen makes its exact determination impossible. In its transverse section, and with the presence of constriction, it seems to stand close to *Lytoceras verpillierense* Rulleau (see Rulleau, 1998).
Occurrence: Specimen 201P/RJ10 was found at the Huciański Klin section (adit no. 7, collected in debris) and specimen ZNG PAN B-I-74/RJ13 at the Czerwona Skałka, Krížna unit, Western Tatra Mountains. The species *Lytoceras verpillierense* Rulleau is known from the *Bifrons* Zone of France (Rulleau, 1998).

Superfamily EODEROCERATACEAE Arkell 1950
Family DACTYLIOCERATIDAE Hyatt 1867
Subfamily DACTYLIOCERATINAE Hyatt 1867
Genus *Nodicoeloceras* Buckman 1926
Type species *Ammonites crassoides* Simpson 1855

Nodicoeloceras cf. *crassoides* (Simpson 1855)
(Fig. 5A)

1963. *Nodicoeloceras* cf. *crassoides* (Simpson): Zanzzuchi, p. 117, pl. 14, figs 8, 8a
1976. *Nodicoeloceras* cf. *crassoides* (Simpson):Schlegelmilch, p. 78, pl. 39, fig. 4

Material: One incomplete specimen (ZNG PAN B-I-74/RJ18; Wh = 17 mm).
Description and remarks: Shell serpenticone, with elipsoidal cross section of the whorl. Whorl side convex. Ventral side rounded, slightly flattened. Umbilical margin rounded. Umbilical wall inclined. Umbilicus moderately wide and deep. Ornamentation consists of the moderately robust, slightly backward inclined, simple, primary ribs bifurcated on the ventro-lateral margin. Secondary bifurcate ribs are slightly weaker then the primary ones.

Small tubercles occur in the bifurcation point. The shape of the shell and ornamentation of specimen is very similar to the species *Nodicoeloceras crassoides* (Simpson), which was described and illustrated by Zanzzuchi (1963) and Schlegelmilch (1976). However, the incomplete preservation of it makes unquestionable determination to this species impossible.

Occurrence: Czerwona Skałka section, Krížna unit, Western Tatra Mountains. Species *Nodicoeloceras crassoides* (Simpson) is known from the *Exaratum* Zone (actual *Serpentinum* Zone) of England (Schlegelmilch, 1976).

Superfamily HILDOCERATACEAE Hyatt 1867
Family HILDOCERATIDAE Hyatt 1867
Subfamily PHYMATOCERATINAE Hyatt 1867
Genus *Phymatoceras* Hyatt 1867
Type species *Phymatoceras robustum* Hyatt 1867 = *Ammonites tirolensis* Dumortier 1874

Phymatoceras cf. *robustum* Hyatt 1867
(Fig. 5B)

1957. *Phymatoceras robustum* Hyatt: Arkell, p. L265, fig. 302
1966. *Phymatoceras robustum* Hyatt: Géczy, p. 16, pl. 1, fig. 2; pl. 37, fig. 1
1968. *Phymatoceras robustum* Hyatt: Pelosio, p. 156, pl. 21, fig. 1 a-c
1975. *Phymatoceras robustum* Hyatt: Gabilly,1975, p. 45, pl. 1, figs 6-8, 12 = *Phymatoceras* cf. *robustum* Hyatt

Material: One specimen (201P/RJ19).
Dimensions:

Measurements Specimen	D (mm)	Wh (mm)	Wb (mm)	U (mm)	Wh/D (%)	Wb/D (%)	Wb/Wh (%)	U/D (%)
201P/RJ19	?110	30	–	55	?27	–	–	?50

Description and remarks: Shell evolute with slowly growing whorls. It has a subtrapezoidal cross section. Whorl side is slightly convex. Ventral side wide, slightly flattened and rounded with keel. Umbilical margin rounded. Umbilical wall almost vertical. Umbilicus wide and shallow. Ornamentation consists of the retroverse, simple and united ribs (about 10 on the 1/4 of the whorl). The points of the ribs union are marked by presence of massive tubercles projected on the umbilical margin. Deep constriction is present. Shape and ornamentation of the specimen well respond to the characteristic features of the species *Phymatoceras robustum* Hyatt (see Arkell, 1957; Géczy, 1966; Pelosio, 1968 and Gabilly,1975) but incomplete preservation of specimen does not permit admittedly to refer it to Hyatt's species.

Occurrence: Specimen 201P/RJ19 was collected in debris at the Huciański Klin section, Krížna unit, Western Tatra Mountains. Species is known from the *Bifrons* Zone of NW Europe and Mediterranean area (Gabilly, 1975; Elmi *et al.*, 1997).

Superfamily HILDOCERATACEAE Hyatt 1967
Family HILDOCERATIDAE Hyatt 1867
Subfamily HARPOCERATINAE Neumayr 1875
Genus *Cleviceras* Howarth 1992
Type species *Ammonites exaratum* Young & Bird 1828

Cleviceras elegans (Sowerby 1815)
(Fig. 5C)

1815. *Ammonites elegans* Sowerby: p. 213, pl. 94
1976. *Harpoceras elegans* (Sowerby): Schlegelmilch, p. 87, pl. 45, fig. 6
1992. *Cleviceras elegans* (Sowerby): Howarth, p. 100, pl. 12, figs 6-19; pl. 13, fig. 3; pl. 14, figs 1-17; pl. 15, figs 1, 2; text-figs 16, 18D, 19D, 21, 22

Material: One specimen (ZNG PAN B-I-74/RJ17).
Dimensions:

Measurements Specimen	D (mm)	Wh (mm)	Wb (mm)	U (mm)	Wh/D (%)	Wb/D (%)	Wb/Wh (%)	U/D (%)
ZNG PAN B-I-74/RJ17	55	29	9	10	52	16	31	18

Description: Specimen is involute, small-sized microconch (D = about 60 mm) with compressed whorl section, higher whorls, sloping umbilical walls and small umbilicus. Ventral side narrow with keel. Ornamentation preserved only on the body-chamber which consists of the weak falcoid ribs. Suture line is poorly preserved.

Remarks: General shape of the specimen and its characteristics such as dimensions, sloping umbilical walls, narrow umbilicus, and weak ornamentation well justify classification of it to *Cleviceras elegans* (Sowerby). The described specimen corresponds well to the descriptions and illustrations of this species shown in the papers given in the synonymy list.

Occurrence: Czerwona Skałka section, Krížna unit, Western Tatra Mountains. Species *Cleviceras elegans* (Sowerby) is known from the *Falciferum* Subzone (*Serpentinum* Zone) of England, Germany and Switzerland (Howarth, 1992).

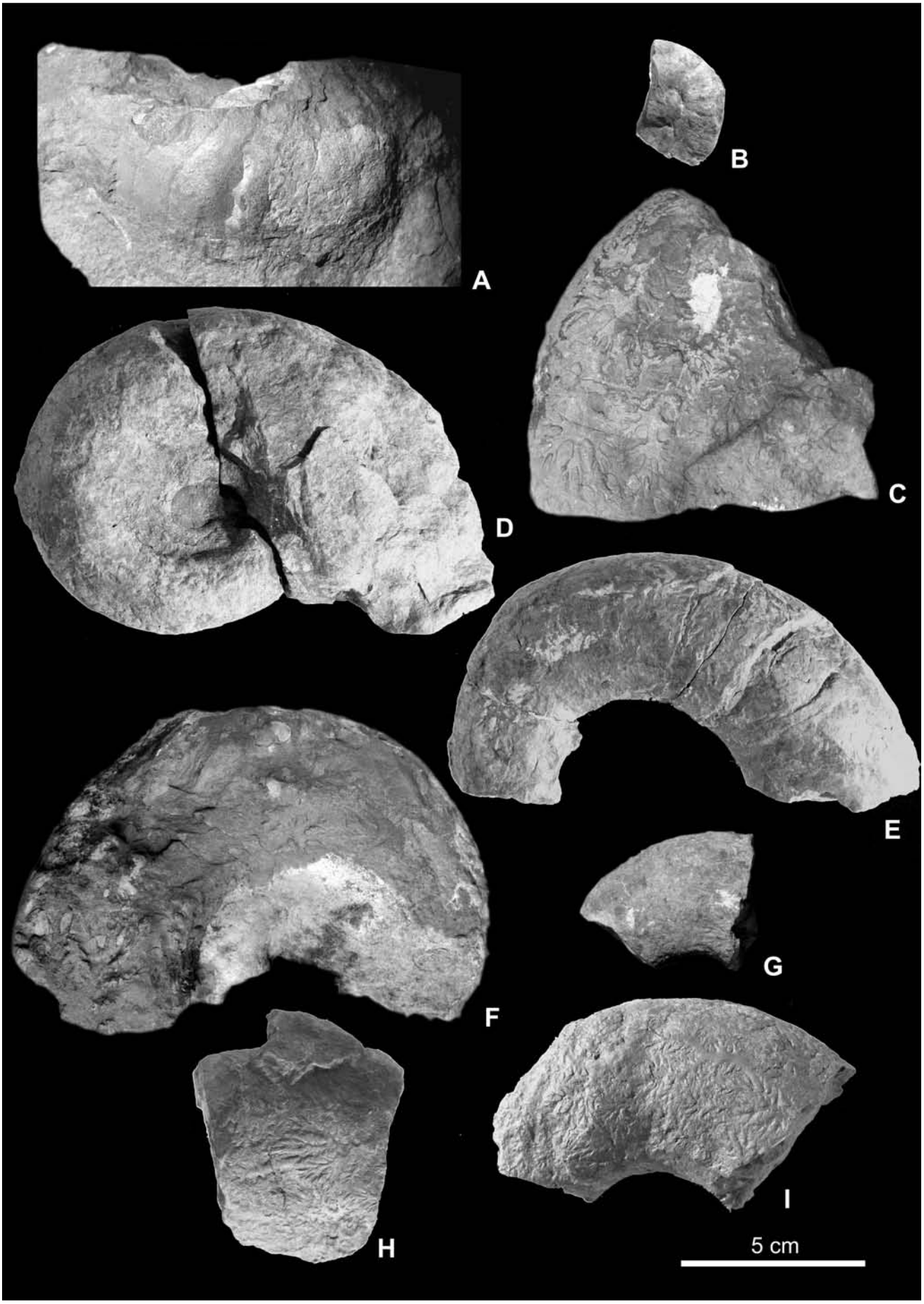
Genus *Harpoceras* Waagen, 1869
Type species *Ammonites falcifer* Sowerby 1820

Harpoceras ex gr. *falciferum* (J. Sowerby 1820)
(Fig. 5D–F)

1820. *Ammonites falcifer* Sowerby: p. 99, pl. 254, fig. 2
1885. *Harpoceras lythensis gigas* Quenstedt: p. 353, pl. 43, figs 10, 11
1976. *Harpoceras falciferum* (Sowerby): Schlegelmilch, p. 86, pl. 45, fig. 4
1992. *Harpoceras falciferum* (Sowerby): Howarth, p. 119, pl. 18, fig. 3; pl. 19, figs 2-4; pl. 20, figs 1-11; text-figs 18F, 19B, 27-34 (with given synonymy list)

Material: Three fragments of whorl (ZNG PAN B-I-74/RJ24, Wh

Fig. 4. **A** – *Cenoceras* sp. cf. *striatum* (Sowerby, 1817). Huciański Klin section, adit no. 7, specimen 201P/RJ5; **B** – *Cenoceras* sp. cf. *striatum* (Sowerby, 1817); lateral and ventral view of the specimen. Czerwona Skałka, specimen ZNG PAN B-I-74/RJ14; **C** – *Phylloceras* ex gr. *heterophyllum* (Sowerby, 1817). Czerwona Skałka, specimen ZNG PAN B-I-74/RJ28; **D**, **E** – *Lytoceras* cf. *cornucopia* (Young et Bird, 1822). Huciański Klin section, adit no. 7, specimens 201P/RJ1 and 201P/RJ3; **F** – *Lytoceras* cf. *cornucopia* (Young et Bird, 1822). Huciański Klin, adit no. 5, specimen 201P/RJ7; **G** – *Lytoceras* cf. *cornucopia* (Young et Bird, 1822). Huciański Klin, adit no. 7, specimen 201P/RJ4; **H** – *Lytoceras* sp. cf. *L. verpillierense* Rulleau, 1998. Czerwona Skałka, specimen ZNG PAN B-I-74/RJ13; **I** – *Lytoceras* sp. cf. *L. verpillierense* Rulleau, 1998. Huciański Klin, adit no. 7, specimen 201P/RJ10


A
B
C
D
E
F
G
H
I
5 cm

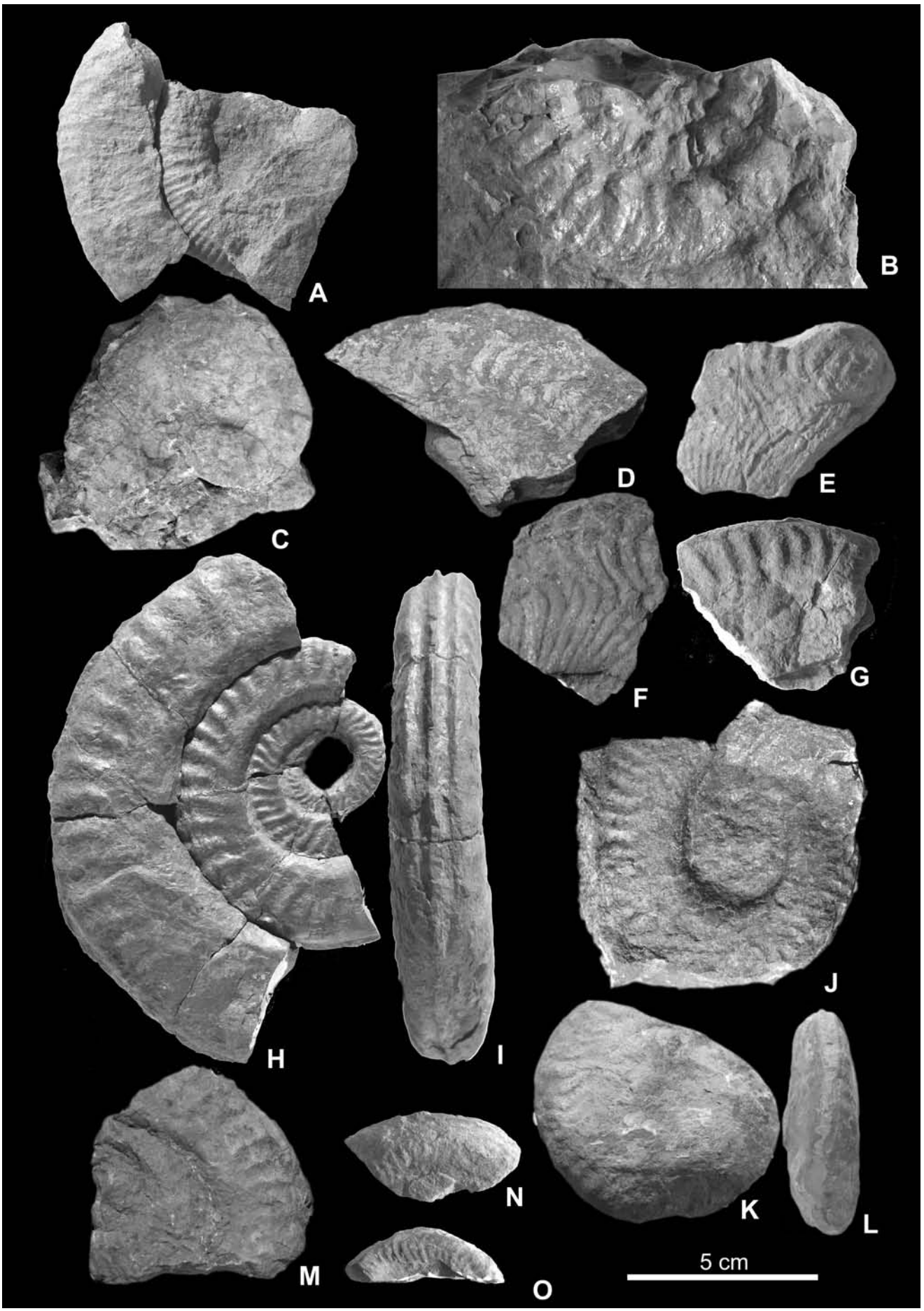

A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
5 cm

Fig. 5. **A** – *Nodicoeloceras* cf. *crassoides* (Simpson, 1855). Czerwona Skałka, specimen ZNG PAN B-I-74/RJ18; **B** – *Phymatoceras* cf. *robustum* Hyatt, 1867. Huciański Klin, adit no. 5, specimen 201P/RJ19; **C** – *Cleviceras elegans* (Sowerby, 1815). Czerwona Skałka, specimen ZNG PAN B-I-74/RJ17; **D-F** – *Harpoceras* ex gr. *falciferum* (Sowerby, 1820). Czerwona Skałka, specimens ZNG PAN B-I-74/RJ24, ZNG PAN B-I-74/26 and ZNG PAN B-I-74/27; **G** – *Hildoceras sublevisoni* Fucini, 1919; Czerwona Skałka, specimen ZNG PAN B-I-74/RJ16; **H**, **I** – *Hildoceras sublevisoni* Fucini, 1919; lateral (H) and ventral (I) view of the specimen. Huciański Klin, adit no. 7, specimen 201P/RJ6; **J** – *Hildoceras sublevisoni* Fucini, 1919; Huciański Klin, adit no. 7, specimen 201P/RJ8; **K**, **L** – *Hildoceras sublevisoni* Fucini, 1919; lateral (K) and ventral (L) view of the specimen. Huciański Klin, adit no. 4, specimen 201P/RJ9; **M–O** – *Hildoceras sublevisoni* Fucini, 1919; Czerwona Skałka, specimens ZNG PAN B-I-74/RJ20, ZNG PAN B-I-74/RJ11 and ZNG PAN B-I-74/RJ12

– 48 mm; ZNG PAN B-I-74/RJ26, Wh – 41 mm; ZNG PAN B-I-74/RJ27, Wh – 40 mm).

Description and remarks: Three fragments of whorl with flattened transverse section and weakly convex sides. Ribs wavy and dense, robust on the ventro-lateral part of the whorl. Character of ornamentation agrees well with that of *Harpoceras falciferum* (Sowerby) as given in the papers cited in the synonymy list.

Occurrence: The specimens come from Czerwona Skałka section, Krížna unit, Western Tatra Mountains. The species *Harpoceras falciferum* (Sowerby) is known from the *Falciferum* Subzone of *Serpentinum* Zone and *Bifrons* Zone of Great Britain, France, Luxembourg, Germany, Switzerland, Greece, Caucasus, NE Siberia and New Zealand (Howarth, 1992).

Subfamily HILDOCERATINAE Hyatt 1867
Genus *Hildoceras* Hyatt 1867
Type species *Ammonites bifrons* Bruguière 1789

Hildoceras sublevisoni Fucini 1919
(Fig. 5G–O; Fig. 6)

1972. *Hildoceras sublevisoni* (Fucini): Guex, pl. VI, fig. 2
1976. *Hildoceras* (*Hildoceras*) *sublevisoni* Fucini: Schlegelmilch, p. 85, pl. 43, fig. 6
1990. *Hildoceras sublevisoni* (Fucini): Goy et Martinez, p. 23, pl. 2, fig. 1
2002. *Hildoceras sublevisoni* Fucini: Neige et Rouget, p. 772, figs 4 C-E; 8 D-F

Material: Four specimens preserved as internal moulds (201P/RJ6; 201P/RJ8; 201P/RJ9; ZNG PAN B-I-74/RJ20) and three fragments of the whorl (ZNG PAN B-I-74/RJ11, Wh – 23; ZNG PAN B-I-74/RJ12, Wh – 24 mm; ZNG PAN B-I-74/RJ16).

Dimensions:

Measurements Specimen	D (mm)	Wh (mm)	Wb (mm)	U (mm)	Wh/D (%)	Wb/D (%)	Wb/Wh (%)	U/D (%)
201P/RJ6	125	36	24	69	28	19	66	55
201P/RJ8	65	24	16	23	36	24	66	35
201P/RJ9	50	21	?15	–	42	30	?71	–
ZNG PAN B-I-74/RJ20	38	16	12	14	42	31	75	36

Description: Small-sized, evolute specimens, with subquadrate whorl section and broad tricarinate-bisulcate venter. Umbilical margin is rounded. Umbilical wall inclined, almost vertical. Umbilicus is wide (201P/RJ6) and moderately wide (only in 201P/RJ8 specimen; in 201P/RJ9 umbilicus is covered). Dorsal area smooth and not very conspicuous. Spiral groove on the side of the whorl not present. Robust ornamentation, similar to that of *Hildoceras bifrons* is represented by moderately dense, strongly backward arcuate ribs on the outer two-thirds of the whorl.

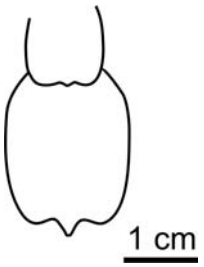


Fig. 6. Whorl sections of *Hildoceras sublevisoni* Fucini, 1919; specimen 201P/RJ6

Remarks: The ammonites described here as species *Hildoceras sublevisoni* Fucini,1919 are also similar to the species *Hildoceras bifrons* (Bruguière) but differ from it in the lack of spiral groove on the whorl side. Our specimens indicate also similarity to the species *Hildoceras lusitanicum* Meister but differ by more reduced dorsal smooth area.

Occurrence: The specimens were found at the Huciański Klin section in the adits no. 7 and no. 4 (specimens 201P/RJ6 and 201P/RJ8, adit no. 7, position in the section see Fig. 2; specimen 201P/RJ9, adit no. 4, collected in debris). Specimens ZNG PAN B-I-74/RJ11, ZNG PAN B-I-74/RJ12 and ZNG PAN B-I-74/RJ20 were collected at the Czerwona Skałka section, Krížna unit, Western Tatra Mountains. The species *Hildoceras sublevisoni* Fucini is known from the Lower Toarcian (*Sublevisoni* Subzone of the *Bifrons* Zone; Goy & Martinez, 1990; Elmi *et al.*, 1997).

Cephalopod fauna state of preservation

Macrofauna of the Adnet type deposits at the Huciański Klin section occurs in two well defined levels. Ammonites are accompanied by other nektonic fauna remains, such as nautiloids, belemnites and fish teeth (Gradziński *et al.*, 2004). The lower cephalopod-bearing level occurs in the middle part of the section built of partly nodular red limestones alternated with marlstones (Fig. 2). Ammonites and nauti- loids occur as complete calcareous concretionary internal moulds of light-red colour with visible suture line; however, they were fragmented while have been collected. Their state of preservation is poor or moderately good, despite the fact that no signs of reworking, abrasion or roundness have been observed. Macrofauna is horizontally oriented, mainly with no evidence of compaction. Internal sediment of moulds is different in texture from the sedimentary matrix. Moulds are composed of mudstones with rare fragments of *Bositra* shells and echinoderms, whereas matrix is

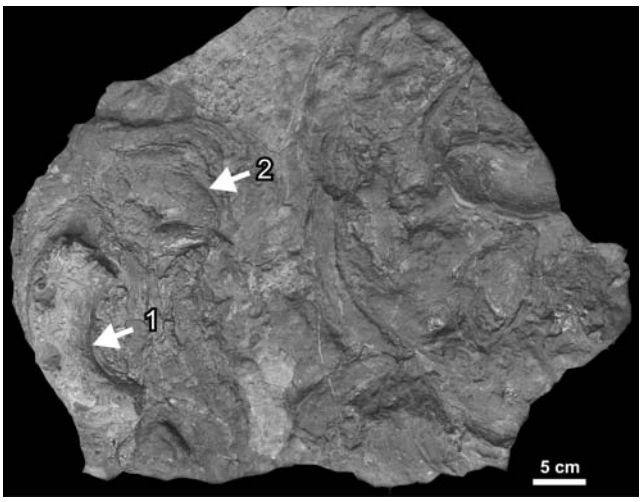


Fig. 7. *Lytoceras* sp. moulds (1) and shells (2) partly covered with stromatolites. Huciański Klin section

represented by *Bositra* packstones. The boundary between moulds and matrix is sharp.

The upper cephalopod-bearing level occurs in the uppermost part of the Adnet type deposit section. This level has the character of condensed bed. Its surface is accentuated by accumulation of ferruginous microbial-foraminiferal macrooncoids and fragmented internal moulds of ammonites, locally covered by stromatolites or thin Fe crusts. It was noticed that ammonite fragments often formed nuclei of macrooncoids (cf. Zejszner, 1852). Ammonite fauna from this level is far less diverse than from the lower level, because it is represented almost exclusively by *Lytoceras* sp. Internal moulds of phragmocones are dominant fossils. The state of preservation of ammonites is relatively poor. Accumulated elements are usually fragmented, but bear no signs of rounding. Some of specimens have preserved calcified shells, especially those encrusted by microbial stromatolite (Fig. 7). Internal sediment filling moulds differs slightly from host deposits. It is composed of wackestones with abundant juvenile ammonites, rare *Bositra* shells and fragmented echinoderm spines, while wackestone type host deposit contains echinoderms and bivalve shell fragments, juvenile ammonites and foraminifers.

DISCUSSION

Taphonomy

A few metres thick Adnet type deposits of the Krížna unit in the Western Tatra Mountains include moderately diverse cephalopod fauna. Preservation of specimens from the lower cephalopod-bearing level as concretionary internal moulds filled with mudstone enclosed by *Bositra* packstones proves early lithification processes (Fig. 2). Internal moulds bearing no signs of rounding or abrasion indicate that they were not influenced by reworking. Only host sediment was affected by winnowing. This process is also evidenced by accumulation of *Bositra* shells in the host deposit (*cf.* Jach, 2007). Probably larger specimens such as ammonites were not influenced by weak currents while lying on the seafloor. This level does not show clearly visible features of condensation; however, *Bositra* packstone type sediment is indicative of low rate of sedimentation and a low-energy setting (Jach, 2007).

The upper cephalopod-bearing level, which has the character of condensed bed, contains mainly *Lytoceras* sp. Generally, ammonite fauna of this level shows a very high proportion of incomplete phragmocones (Fig. 7). Fragmentation of the shells evidences their reworking. This process was probably related to resedimentation (*i.e*., displacement on the sea bottom before their burial) than reelaboration (*i.e.*, exhumation and displacement before their final burial; terminology after Fernández-López, 2007). Ammonite fragments show no traces of roundness, which evidences that turbulence near water/sediment surface was relatively low (*cf.* Fernández-López, 2007). Aragonitic shells of some specimens were not dissolved exclusively in the case of that encrustated by a stromatolite (*cf.* Jenkyns, 1971; Pallini *et al.*, 2003–2004).

Adnet type deposits of the Krížna unit are interpreted as laid down in pelagic conditions during gradual deepening of the basin. This is proved by vertical trends described within the section (Gradziński *et al.*, 2004). As deposits of the upper part of the section, with discontinuity surfaces with ammonites and macrooncoids, developed in the elevated parts of the basin, probably in a perched subbasin, therefore ammonites of this level must have been resedimented only *in situ* (cf. Pallini *et al.*, 2003–2004). They were broken and reworked during long-lasting sedimentary break. Uncompacted ammonite shells testify early lithification of their internal sediment, whereas low sedimentation rate is proved by ferruginous macrooncoids and stromatolites, Fe crusts, fine-grained sediment removal and macrofauna concentration.

Remarks on stratigraphy

The fauna in question occurs in two levels, but only lower one has stratigraphic importance. Nevertheless, scarcity of biostratigraphic data within Jurassic deposits of the Krížna unit causes that new data are of special importance. However, the lack of stratigraphically diagnostic fossils hindered precise age determination of under- and overlying deposits; *Bositra* limestones are ascribed to the Aalenian–Lower Bathonian since they are covered by Upper Bathonian–Lower Kimmeridgian radiolarites (Polák *et al.*, 1998; Jach, 2007).

The described ammonite assemblage of the Adnet type deposits includes species belonging to the families: Phyloceratidae, Lytoceratidae, Hildoceratidae and Dactylioceratidae. Some of the described specimens from the Adnet type deposits have not been yet reported from the Krížna sequence, for example *Cleviceras elegans* (Sowerby). Recorded ammonite association from lower cephalopod-bearing level shows abundant specimens corresponding to the upper Lower Toarcian *Serpentinum* Zone and lower Middle Toarcian *Bifrons* Zones. The *Serpentinum* Zone may be recognised by occurrence of *Harpoceras serpentinum* (Schlo-

theim), *Phylloceras* ex gr. *heterophyllum* (Sowerby), *Cleviceras elegans* (Sowerby), *Harpoceras falciferum* (Sowerby) and *Nodicoeloceras* cf. *crassoides* Simpson (see also Myczyński & Lefeld, 2003; *cf.* Elmi *et al.*, 1997). Middle Toarcian *Sublevisoni* Subzone of the *Bifrons* Zone is characterized by the occurrence of *Hildoceras sublevisoni* Fucini and *Harpoceras falciferum* (Sowerby). The *Bifrons* Subzone (*Lusitanicum*, *Apertum* and *Bifrons* horizons) is recognized on the basis of *Phylloceras* ex gr. *heterophyllum* (Sowerby), *Phymatoceras* cf. *robustum* Hyatt, *Lytoceras* cf. *cornucopiae* (Young et Bird) and *Hildoceras bifrons* (Bruguière) (see also Zejszner, 1952; Sokołowski, 1925; Myczyński & Lefeld, 2003). Other age indicators described by previous authors are *Harpoceras serpentinum* (Schlotheim) and *Hildoceras bifrons* (Bruguière) (Zejszner, 1852; Myczyński & Lefeld, 2003).

The Adnet type deposits in the whole Krížna Basin have strongly diachronic lower boundary (Mišík & Rakús, 1964). The record of beginning of their sedimentation is noticed from Lotharingian, based on the occurrence of *Asteroceras obtusum* (Sowerby), *Echioceras raricostatum* (Zieten), *Oxynticeras oxynotum* (Quenstedt), to the Middle Toarcian based on *Hildoceras bifrons* (Bruguière) as it was evidenced in the papers by Rakús (1964) and Mišík and Rakús (1964). The *Hildoceras sublevisoni* Fucini from the Adnet type deposits in the Huciański Klin section derive from the middle part of the section, that is from the lower cephalopod-bearing level, and it corresponds in age to the Middle Toarcian *Sublevisoni* Subzone of the *Bifrons* Zone. However, Lower Toarcian *Serpentinum* Zone could be recognized on the basis of ammonites derived form debris. Therefore the lower age range may be estimated as Lower Toarcian *Serpentinum* Zone.

Dumortieria cf. *levesquei* (Orbigny) and *Catulloceras* aff. *dumortieri* (Thiollière), which indicate Late Toarcian, evidenced the youngest Adnet type deposits known from the Krížna unit (Rakús, 1964; Bujnovský & Polák, 1979). Similarly, Late Toarcian age of these deposits in the Western Tatra Mountains was proved by the occurrence of *Catulloceras* cf. *dumortieri* from the Czerwona Skałka section (Myczyński & Lefeld, 2003). However, the location of this ammonite in the section is not known. These data make it possible to estimate the upper age range of the Adnet type deposits as Late Toarcian (*Levesquei* Subzone of the *Pseudoradiosa* Zone; Elmi *et al.*, 1997). However, one cannot exclude their younger age, since the stratigraphically important fauna is not known from the uppermost part of these deposits. This part comprises discontinuity surfaces, pointing to its origin in the condition of low sedimentation rate. Moreover, overlying *Bositra* limestones, do not contain diagnostic fauna fossils either.

The Toarcian was a period when long lasting provincionalism between the North-Western Europe and Mediterranean Domains really existed. The only exceptions were the Middle Toarcian *Bifrons* Zone and Upper Toarcian *Aalensis* Zone periods. The Middle Toarcian *Bifrons* Zone is a moment of unification of ammonite assemblages in the North-Western Europe and Mediterranean Domains (Elmi *et al.*, 1997). The Krížna Basin was an integrate part of the Tethys Ocean which was connected with the epicontinental sea of the North-Western Europe. Fluctuation of these connections during Toarcian caused that the influence of North-Western Europe ammonite taxa is observed in Late Toarcian sediments in the Krížna Basin (Rakús, 1964). In spite of the fact that Middle Toarcian *Bifrons* Zone is a period of ammonite fauna unification within the North-Western Europe and Mediterranean Domains, the studied ammonite fauna represents taxonomic composition typical of the Mediterranean Province (*cf.* Géczy & Szente, 2006 and references cited herein).

CONCLUSIONS

Two cephalopod-bearing levels were recognized within the Adnet type red deposits of the Krížna unit in the Western Tatra Mountains. The *Serpentinum* Zone of the Early Toarcian were identified only on the basis of ammonite assemblage collected from the debris. The Middle Toarcian *Sublevisoni* and *Bifrons* Subzones of *Bifrons* Zone were recognized on the basis of ammonites derived from the lower cephalopod-bearing level in the Huciański Klin sections. The upper age range of Adnet type deposits represents the Late Toarcian (probably *Levesquei* Subzone of the *Pseudoradiosa* Zone) due to occurrence of characteristic taxa mentioned by previous authors. Therefore, the Adnet type deposits of the Krížna unit in the Western Tatra Mountains represents *Serpentinum* Zone of the Early Toarcian – *Pseudoradiosa* Zone of the Late Toarcian.

Ammonites and nautiloids are preserved as internal moulds or resedimented internal moulds rarely with relicts of shells. The latter are related to low sedimentation rate due to deposition at the elevated parts of the Krížna Basin. The determined ammonite assemblage is closely related to fauna of the Mediterranean Domain.

Acknowledgement

Thanks are due to Cyprian Kulicki from the Institute of Palaeobiology of the Polish Academy of Sciences for making photographs of ammonites used as illustrations in this paper. We are also grateful to the authority of the Tatra National Park for giving the permission for the field work. The authors thank for providing the access to the ammonite collections of the Geological Museum of the Institute of Geological Sciences, Polish Academy of Sciences in Kraków. The paper has benefited from valuable comments and constructive criticism by the reviewers Prof. Andrzej Wierzbowski and Dr. Jan Schlögl.

REFERENCES

Arkell, W. J., 1950. A classification of the Jurassic ammonites. *Journal of Palaeontology*, 24: 354–364.

Arkell, W. J., Kümmel, B. & Wright, C. W., 1957. Mesozoic Ammonoidea. In: Moore, R. C. (ed.), *Treatise on Invertebrate Paleontology, Part L. Mollusca (4), Cephalopoda, Ammonoidea.* Geological Society of America and University of Kansas Press, Lawrence, pp. 29–402.

Bac, M., 1971. Tektonika jednostki Bobrowca w Tatrach Zachodnich. *Acta Geologica Polonica*, 21: 279–315.

Bac-Moszaszwili, M., Burchart, J., Głazek, J., Iwanow, A., Jaroszewski, W., Kotański, Z., Lefeld, J., Mastella, L., Ozimkowski, W., Roniewicz, P., Skupiński, A. & Westwalewicz-Mogilska, E., 1979. *Geological map of the Polish Tatra Mountains 1:30000.* Wydawnictwa Geologiczne. Warszawa.

Böhm, F., Ebli, O., Krystyn, L., Lobitzer, H., Rakús, M. & Siblík, M., 1999. Fauna, stratigraphy and depositional environment of the Hettangian-Sinemurian (Early Jurassic) of Adnet (Salzburg, Austria). *Abhandlungen der Geologischen Bundesanstalt*, 56: 143–271.

Bujnovský, A. & Polák, M., 1979. Korelácia mezozoických litostratigrafických jednotiek Malej Fatry, Veľkej Fatry a sz. časti Nízkých Tatier. *Geologicke práce, Správy*, 72: 77–96.

Elmi, S., Rulleau, L., Gabilly, J. & Mouterde, R., 1997. 4 – Toarcien, In: Cariou, E. & Hantzpergue, P. (eds), *Biostratigraphie du Jurassique Ouest-Européen et Méditerranéen: Zonations paralleles et distribution des invertébrés et microfossiles*. Bulletin du Centre de Recherches Elf Exploration Production, Mémoire, 17: 25–36.

Fernández-López, S., 2007. Ammonoid taphonomy, palaeoenvironments and sequence stratigraphy at the Bajocian/Bathonian boundary on the Bas Auran area (Subalpine Basin, south-eastern France). *Lethaia*, 40: 377–391.

Gabilly, J., 1975. Ëvolution et systématique des Phymatoceratinae et des Grammoceratinae (Hildocerataceae, Ammonitia) de la region de Thouars, stratotype du Toarcien. *Mémoires de la Société Géologique de France*, *Nouvelle Série*, 54: 1–196.

Géczy, B., 1966. Ammonoides jurassiques de Csernye, Montagne Bakony, Hongrie. Part I (Hammatoceratidae). *Geologia Hungarica, Series Palaeontologica*, 34: 1–275.

Géczy, B., 1967. Ammonoides jurassiques de Csernye, Montagne Bakony, Hongrie. Part II (excl. Hammatoceratidae). *Geologia Hungarica, Series Palaeontologica*, 35: 1–413.

Géczy, B. & Szente, I., 2006. Middle Toarcian Ammonitina from the Gerecse Mts, Hungary. *Acta Geologica Hungarica*, 49: 223–252.

Goy, A. & Martinez, G., 1990. Biozonación del Toarciense en el area de la Almunia de Doña Godina-Ricla (Sector Central de la Cordillera Ibérica). *Cuadernos de Geologia Ibérica*, 14: 11–53.

Gradziński, M., Tyszka, J., Uchman, A. & Jach R., 2004. Large microbial-foraminiferal oncoids from condensed Lower – Middle Jurassic deposits: A case study from the Tatra Mountains, Poland. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 213: 133–151.

Guex, J., 1972. Répartition biostratigraphique des ammonitesdu Toarcien moyen de la bordure sud des Causses (France) et révisiondes ammonites déscrites et figurées par Monestier (1931). *Ecloge Geologicae Helvetiae*, 65: 611–645.

Howarth, M. K., 1992. The Ammonite family Hildoceratidae in the Lower Jurassic of Britain. *Monograph of the Palaeontographical Society, part 2*, 146: 107–200.

Jach, R., 2002. Traces of historical exploitation of manganiferous ores in the Western Tatra Mountains. (In Polish, English summary). *Przegląd Geologiczny*, 50: 1159–1164.

Jach, R., 2005. Storm-dominated deposition of the Lower Jurassic crinoidal limestone in the Krížna unit, Western Tatra Mountains, Poland. *Facies*, 50: 561–572.

Jach, R. & Dudek, T., 2005. Origin of a Toarcian manganese carbonate/silicate deposits from the Krížna Unit, Tatra Mountains, Poland. *Chemical Geology*, 224: 136–152.

Jach, R., 2007. *Bositra* limestones – a step towards radiolarites: case study from the Tatra Mountains. *Annales Societatis Geologorum Poloniae*, 77: 161–170.

Jenkyns, H., 1971. The genesis of condensed sequences in the Tethyan Jurassic. *Lethaia*, 4: 327–352.

Krajewski, K. P., Lefeld, J. & Łącka, B., 2001. Early diagenetic processes in the formation of carbonate-hosted Mn ore deposit (Lower Jurassic, Tatra Mountains) as indicated from its carbon isotopic record. *Bulletin of the Polish Academy of Sciences, Earth Sciences*, 49: 13–29.

Kümmel, B., 1956. Post-Triassic Nautiloid genera. *Bulletin of the Museum of Comparative Zoology at Harvard College,* Cambridge, 114: 319–494.

Lefeld, J., Gaździcki, A., Iwanow, A., Krajewski, K. & Wójcik, K., 1985. Jurassic and Cretaceous litostratigraphic units in the Tatra Mountains. *Studia Geologica Polonica*, 84: 7–93.

Martire, L., 1996. Stratigraphy, facies and synsedimentary tectonics in the Jurassic Rosso Ammonitico Veronese (Altopiano di Asiago, NE Italy). *Facies*, 35: 209–236.

Mišík, M. & Rakús, M., 1964. Bemerkungen zu räumlichen Beziehungen des Lias und zur Paläogeographie des Mesozoikum in der Grossen Fatra. *Sborník Geologických Vied, Západne Karpaty*, 1: 157–199.

Myczyński, R. & Lefeld, J., 2003. Toarcian ammonites (Adneth facies) from the Subtatric Succession of the Tatra Mts (Western Tatra Carpathians). *Studia Geologica Polonica*, 121: 51–79.

Neige, P. & Rouget, I., 2002. Les ammonites du Toarcien de Chantonnay (Vendée, France) analyse paléontologique, biostratigraphie et reflexion sur les Hildoceratinae. *Geodiversitas*, 24: 765–784.

Neumayer, M., 1871. Jura studien, 3. Die Phylloceraten des Dogger und Malm. *Jahrbuch der Kaiserlich-Königlichen Geologischen Reichsanstalt*, Wien, 21: 297–378.

Pallini, G., Elmi, S. & Gasparri, F., 2003–2004. Late Toarcian – Late Aalenian ammonites assemblage from Mt. Magaggiaro (Western Sicily, Italy). *Geologica Romana*, 37: 1–66.

Pelosio, G., 1968. Ammoniti del Lias superiore (Toarciano) dell'Alpe Turati (Erba, Como). Part IV: generi Hildoceras, Phymatoceras, Paroniceras e Frechiella. Conclusioni generali. *Memorie della Societá Italiana di Science Naturali e del Museo Civico di Storia Naturale di Milano*, 17: 143–204.

Pinna, G., 1968. Ammoniti del Lias superiore (Toarciano) dell'Alpe Turati (Ebra, Como). Part III: famiglie Lytoceratidae, Nannolytoceratidae, Hammatoceratidae (excl. Phymatoceratidae), Hildoceratidae (excl. Hildoceratinae e Bouleiceratinae). *Memorie della Societa italiana di Scienze naturali e del Museo Civico di Storia naturale di Milano*, Milano, 17: 1–69.

Polák, M., Ondrejičková, A. & Wieczorek, J., 1998. Lithostratigraphy of the Ždiar Formation of the Krížna nappe. *Slovak Geological Magazine*, 4: 35–52.

Quensted, F. A., 1885. *Die Ammoniten des Schwäbischen Jura. I, Der Schwarze Jura (Lias)*. pp. 241–440.

Rakús, M., 1964. Paläontologische Studien im Lias der Grossen Fatra und des westlichen Teils der Niederen Tatra. *Sborník Geologickych Vied, Zapadné Karpaty*, 1: 93–199.

Rulleau, L., 1998. Évolution et systématique des Phylloceratidae et des Lytoceratidae du Toarcien et du Dogger inférieur de la région Lyonnaise. *Documents des Laboratoires de Géologie Lyon*, 149: 1–167.

Schlegelmilch, R., 1976. *Die Ammoniten des süddeutschen Lias*. Fischer Verlag, Stuttgart, 212 pp.

Siemiradzki, J., 1923. *Fauna utworów liasowych i jurajskich Tatr i Podhala*. Towarzystwo Naukowe, Lwów, 52 pp.

Sokołowski, S., 1925. Beobachtungen über das Alter und die Entwicklung des subtatrischen Lias im Tatragebirge. (In Polish, German summary). *Rocznik Polskiego Towarzystwa*

Geologicznego, 2: 78–84.

Sowerby, J., 1815. *The Mineral conchology of Great Britain*. Taylor, London, 2: 1–28.

Sowerby, J., 1819. *The Mineral conchology of Great Britain*. Taylor, London, 3: 1–186.

Sowerby, J., 1820. *The Mineral conchology of Great Britain*. Taylor, London, 3: 254–271.

Tucker, M. E. & Wright, V. P., 1990. *Carbonate Sedimentology*. Blackwell, Oxford, 482 pp.

Uhlig, V., 1897. Die Geologie des Tatragebirges. I. Einleitung und stratigraphischer Teil. *Denkschrifte der Akademie Wissenschaftliche in Wien, Matematische-Naturwissentschaftliche Klasse*, 64: 643–684.

Wieczorek, J., 1983. Uwagi o facji "ammonitico rosso". (In Polish, English summary). *Przegląd Geologiczny*, 31: 247–252.

Zanzzuchi, G., 1963. Le Ammoniti del Lias superiore (Toarciano) di Entratico in val Cavallina (Bergamasco orientale*). Memorie della Societá Italiana di Science Naturali e del Museo Civico di Storia Naturale di Milano*, 13: 101–146.

Zejszner, L., 1852. Monograficzny opis wapienia liasowego w Tatrach i przyległych pasmach karpackich. (In Polish). *Rocznik Towarzystwa Nauk, Oddział Nauk Przyrodniczych i Lekarskich*, 6: 157–343.