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High-resolution ammonite, belemnite and stable isotope record from the most complete Upper Jurassic section of the Bakony Mts (Transdanubian Range, Hungary)

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Abstract: This research focuses on the cephalopod fauna and biostratigraphy of the latest Jurassic succession of the Lókút Hill (Bakony Mts, Transdanubia, Hungary). Fossils were collected bed-by-bed from Ammonitico Rosso facies and from the subsequent Biancone type rock. The poorly preserved cephalopods from the lowermost part of the profile, immediately above the radiolarite, may represent a part of the Oxfordian stage. The rich Kimmeridgian ammonite fauna is published for the first time while the formerly illustrated Tithonian fauna is revised. All the successive Kimmeridgian and Early Tithonian Mediterranean ammonite zones can be traced. The highest documented ammonite zone is the Late Tithonian Microcanthum Zone. The beds above yielded no cephalopods. Particular attention was paid to the belemnite fauna of over 120 specimens collected under strict ammonite control. Among the belemnite faunas an Early Tithonian, an early middle Tithonian, a late middle Tithonian, and a latest Tithonian assemblage can be distinguished. Thereby, an association is distinguished in the middle Late Kimmeridgian and one that characterizes the Oxfordian-Kimmeridgian boundary beds. The main difference from previously published belemnite data appears to be that the Hungarian assemblages are impoverished with respect to contemporary faunas from Italy and Spain (Mediterranean Province). An isotopic analysis of the belemnites show that the carbon-isotope data are consistent with carbon-isotope stratigraphies of the Western Tethys and show a decrease in values towards the Jurassic-Cretaceous boundary.

Key words: Late Jurassic, Hungary, Bakony Mts, biostratigraphy, Ammonitico Rosso, ammonites, belemnites, stable isotopes.

Introduction

Pelagic Jurassic to Cretaceous sediments are exposed close to the village of Lókút, Bakony Mts, Hungary. These rocks are rich in invertebrate macrofossils which were originally collected by a team from the Geological Institute of Hungary, in the early 1960s. The collection work was supervised by the late Prof. József Fülöp. Among the macrofossils of the Lókút profile belemnites were collected, but have remained unstudied until now. A biostratigraphical framework is provided for the Tithonian by ammonites (Vigh 1984) which is revised and updated in this paper. More recently Grabowski et al. (2010) provided a stratigraphical scheme based on magneto- and calpionellid-stratigraphy.

The aim of this study is: (a) to provide an accurate and updated biostratigraphy for the ammonite rich Upper Jurassic (?Oxfordian–Tithonian) part of the Lókút section, (b) to document the diverse belemnite fauna, as no belemnites were previously described from this stratigraphic interval from Hungary, and (c) to perform oxygen and carbon isotope analyses on belemnite calcite to compare with the biostratigraphical data and with previously published isotope curves. Belemnites were studied and described by Nico M.M. Janssen, István Főzy summarized ammonite biostratigraphy, while isotope analyses and interpretations were undertaken by Gregory D. Price.

Geological setting

The studied section is situated in the south-western part of the central Bakony Mts, about 600 meters from the village of Lókút, on the south-western edge of the Lókút Hill (Fig. 1). The outcrop is in the Transdanubian Range, representing a part of the Bakony Unit in the Austroalpine part of the AlCAPA (Alpine-Carpathian-Pannonian) composite terrain (Csontos & Vörös 2004). Lókút Hill is an exceptional place, where 7 of the 11 Jurassic stages are represented by means of macrofossils (mainly ammonites). The succession of the Lókút Hill is the most complete and thickest Jurassic succession of Transdanubia, deposited in a deep, pelagic environment, within a “horst and graben” context (Galácz & Vörös 1972). The Hettangian-Bajocian rocks are exposed in a long artificial trench and in a pit on the southern part of the hill (Galácz 1975; Géczy 1976). The Upper Jurassic succession, which is in the focus of our study, is exposed in a shallow, 20 meter long artificial trench on the southern slope of the Lókút Hill. The geographical coordinates for the section are

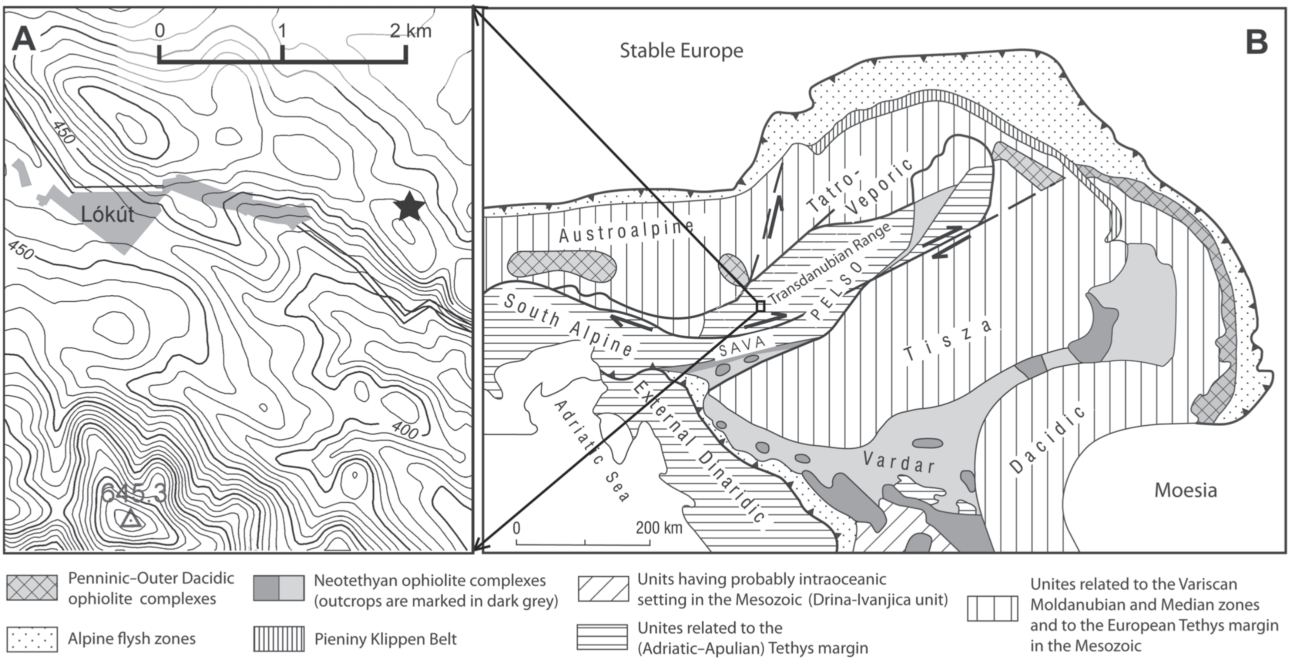

Fig. 1. The geographic (**A**) and tectonic position of the Lókút section (**B**). The location of the studied profile is marked by an asterisk. Map 'B' is modified Haas et al. (2006) showing the structural units of the pre-Cenozoic basement of the Pannonian Basin and the surrounding mountain ranges.

47°12′17″N, 17°52′56″E. Strata dip to north with mean orientation 360°/20°.

In the lowermost part of the section the cherty Lókút Radiolarite Formation crops out. This is succeeded by 0.1 m of light red-brown clay, followed by a light red-brown cherty limestone. The following few meters consist of red and yellowish, thick-bedded nodular limestone (the Pálihálás Limestone Formation), which passes continuously into light grey coloured, less nodular ammonite rich facies (the Szentivánhegy Limestone Formation). The uppermost part of the profile is formed by the white, thin-bedded, Biancone type limestone (of the Mogyorósdomb Limestone Formation), which continuously develops from the underlying formation. No sharp boundaries between the three carbonate formations are apparent. A brief description of the above-mentioned lithostratigraphical units are given in Császár (1997).

Stratigraphy

The cephalopods were gathered in 1962–1964. Because the original field notes are lost, the only available information on the sampling are the bed numbers written on the labels for each fossil and the thickness data of the beds in Vigh (1984). Vigh published the Tithonian ammonites of the section and also noted the presence of the Kimmeridgian strata. No details of the Kimmeridgian were, however, provided by Vigh (1984). Although it is not known exactly where the Bed 1 was placed in the section by Vigh (1984) as no obvious marker bed exists to anchor the succession, we were able to reconstruct the bed numbering after re-examination of the succession and comparing thickness, lithology and fossil content. Furthermore, we have recently resampled a number of horizons of the section to gather further ammonite data.

Grabowski et al. (2010), recently published magneto- and biostratigraphical schemes of the upper part of the section. They were able to recognize magnetochrons M21r through to 18r spanning the Jurassic-Cretaceous boundary. They also undertook calpionellid studies and on this basis they assigned the uppermost 4.5 meters of the section to the Berriasian. Consequently the studied part of the Lókút profile represents a succession spanning the ?Late Oxfordian–Kimmeridgian to earliest Berriasian.

Cephalopod fauna

Ammonites were preserved as only internal moulds throughout the section. As the fauna consists of solely Mediterranean (Tethyan) elements, the zonation scheme of Enay & Geyssant (1975) and Olóriz (1978) was used. Vigh (1984) described only the Tithonian part of the ammonite succession. In this paper we not only re-evaluate his data, but we also give details on the possible Late Oxfordian and on the Kimmeridgian fauna as well. The stratigraphic distribution of the most characteristic ammonites is given in Table 1.

The belemnite material studied is of varying quality. Many belemnites appear to be incomplete or fragmentary, probably as a result of the rigidity of the host rocks. In the reddish coloured ?Oxfordian–Kimmeridgian part (Beds 68 to 77) belemnites appear to be partially corroded. The stratigraphic distribution of the belemnites is given in Table 2.

The Tithonian cephalopods from the Lókút section are deposited in the Museum of the Hungarian Geological Insti-

Table 1: Distribution of the diagnostic Late Jurassic ammonites in the Lókút section. Phylloceratids and lytoceratids are not indicated. *Haploceras elimatum* and related microconch forms (*H. carachtheis* and associated species), although common throughout the Tithonian, are also not shown. (Haplocer. — Haploceratidae; H. — Himalayitidae.)

Stage	Substage	Ammonite Zone	Bed number
TITHONIAN	Upper Tithonian	Microcanthum + ?	7–24
TITHONIAN	Upper Tithonian	Po.	25–26
TITHONIAN	Lower Tithonian	Fallauxi	27–44
TITHONIAN	Lower Tithonian	Semiforme	45–53
TITHONIAN	Lower Tithonian	Darwini	54–57
TITHONIAN	Lower Tithonian	Hybon.	58–61
KIMMERIDGIAN	Upper Kimmeridgian	Beckeri	62–68
KIMMERIDGIAN	Upper Kimmeridgian	C.	69
KIMMERIDGIAN	Upper Kimmeridgian	Comps.	70–72
KIMMERIDGIAN	L. Kim.	D	73
KIMMERIDGIAN	L. Kim.	S	74
KIMMERIDGIAN	L. Kim.	P	75
OXF.			76–77

Family	Species	Range (beds)	Specimens per bed
Haplocer.	*Haploceras verruciferum* (Zittel, 1869)	53	53: 2
Haplocer.	*Haploceras cassiferum* Főzy, 1988	57	57: 2
Haplocer.	*Pseudolissoceras olorizi* Főzy, 1989	54	54: 1
Oppeliidae	*Streblites* cf. *tenuilobatus* (Oppel, 1863)	73	73: 1
Oppeliidae	*Neochetoceras* sp.	26–48	26: 1; 44: 2; 45: 1; 48: 1
Oppeliidae	*Taramelliceras* sp.	59–75	59: 2; 62: 1; 63: 1; 68: 3; 69: 5; 70: 6; 71: 2; 72: 2; 73: 3; 74: 2; 75: 2
Oppeliidae	*Taramelliceras strombecki* (Oppel, 1873)	73–74	73: 2; 74: 1
Oppeliidae	*Taramelliceras trachinotum* (Oppel, 1863)	69–70	69: 1; 70: 1
Oppeliidae	*Taramelliceras compsum* (Oppel, 1863)	68–70	68: 9; 69: 4; 70: 2
Oppeliidae	*Hemihaploceras nobile* (Neumayr, 1873)	68	68: 1
Oppeliidae	*Hemihaploceras schwageri* (Neumayr, 1873)	68	68: 1
Simoceratidae	*Nebrodites teres* (Neumayr, 1871)	73	73: 2
Simoceratidae	*Nebrodites* cf. *cafisii* (Gemmellaro, 1876)	72	72: 1
Simoceratidae	*Nebrodites agrigentus* (Gemmellaro, 1876)	72	72: 1
Simoceratidae	*Nebrodites* cf. *heimi* (Favre, 1877)	70	70: 1
Simoceratidae	*Nebrodites cavouri* (Gemmellaro, 1872)	69	69: 1
Simoceratidae	*Nebrodites* spp.	70–75	70: 3; 71: 3; 72: 7; 73: 8; 75: 19
Simoceratidae	*Lessiniceras martirei* Sarti, 1993	73	73: 1
Simoceratidae	*Trenerites* cf. *enayi* Sarti, 1993	71–75	71: 1; 75: 1
Simoceratidae	*Trenerites* cf. *evolutus* (Gemmellaro, 1876)	73–75	73: 1; 75: 2
Simoceratidae	*Presimoceras* sp.	73	73: 1
Simoceratidae	*Virgatosimoceras* cf. *albertinum* (Catullo, 1855)	61	61: 1
Simoceratidae	*Virgatosimoceras dunaii* Scherzinger et al, 2010	47	47: 1
Simoceratidae	*Virgatosimoceras* sp.	56	56: 1
Simoceratidae	*Volanoceras aesinense* (Meneghini, 1885)	53	53: 2
Simoceratidae	*Volanoceras peramatiforme* (Schauroth, 1865)	26	26: 1
Simoceratidae	*Simolytoceras volanensoides* (Vigh, 1984)	43–44	43: 1; 44: 1
Simoceratidae	*Simolytoceras* sp.	24	24: 1
Simoceratidae	*Simoceras* aff. *admirandum* Zittel, 1868	43–44	43: 2; 44: 4
Simoceratidae	*Simoceras admirandum* Zittel, 1868	36–37	36: 1; 37: 1
Simoceratidae	*Simoceras strictum* (Catullo, 1846)	29	29: 1
Simoceratidae	*Simospiticeras lojense* Olóriz et Tavera, 1977	10	10: 1
Aspidoceratidae	*Euaspidoceras* sp.	75	75: 4
Aspidoceratidae	*Orthaspidoceras* sp.	54	54: 1
Aspidoceratidae	*Physodoceras wolfi* (Neumayr, 1873)	75	75: 1
Aspidoceratidae	*Physodoceras altenense* (d'Orbigny, 1847)	75	75: 2
Aspidoceratidae	*Physodoceras avellanum* (Zittel, 1869)	60–69	60: 2; 62: 1; 69: 1
Aspidoceratidae	*Physodoceras neoburgense* (Oppel, 1863)	44–61	44: 1; 55: 2; 61: 1
Aspidoceratidae	*Physodoceras* sp.	68–75	68: 1; 70: 2; 73: 1; 75: 8
Aspidoceratidae	*Aspidoceras rogoznicense* Zeuschner, 1868	30–59	30: 1; 32: 1; 59: 1
Aspidoceratidae	*Aspidoceras rafaeli* (Oppel, 1863)	62	62: 1
Aspidoceratidae	*Aspidoceras* spp.	65–75	65: 1; 68: 2; 69: 5; 70: 15; 71: 6; 72: 10; 73: 8; 74: 2; 75: 8
Aspidoceratidae	*Pseudohimalayites kondai* Vigh, 1984	46	46: 1
Aspidoceratidae	*Pseudowaagenia acanthomphala* (Zittel, 1870)	65–68	65: 1; 68: 2
Aspidoceratidae	*Pseudowaagenia* sp.	68	68: 2
Aspidoceratidae	*Hybonoticeras* cf. *knopi* (Neumayer, 1873)	68	68: 1
Aspidoceratidae	*Hybonoticeras pressulum* (Neumayr, 1871)	68	68: 3
Aspidoceratidae	*Hybonoticeras* cf. *hybonotum* (Oppel, 1863)	59–61	59: 1; 61: 1
Aspidoceratidae	*Hybonoticeras* sp.	68–69	68: 4; 69: 1
Perisphinctidae	*Katroliceras* sp.	75	75: 1
Perisphinctidae	*Progeronia* spp.	73–74	73: 2; 74: 1
Perisphinctidae	*Trapanasites adelus* (Gemmellaro, 1872)	68–69	68: 8; 69: 2
Perisphinctidae	*Pseudosimoceras stenonis* (Gemmellaro, 1876)	74	74: 1
Perisphinctidae	*Subdichotomoceras pseudocolobrinus* (Kilian, 1889)	53–55	53: 1; 55: 1
Perisphinctidae	*Ataxioceras* sp.	57–61	57: 1; 59: 1; 61: 1
Perisphinctidae	*Parapallasiceras* sp.	55	55: 1
Perisphinctidae	*Discosphinctoides rhodaniforme* Olóriz, 1978	46–53	46: 1; 53: 1
Perisphinctidae	*Discosphinctoides* sp.	47	47: 5
Perisphinctidae	*"Pseudodiscosphinctes" chalmasi* (Kilian, 1889)	40	40: 1
Perisphinctidae	*Subplanitoides* sp.	29–46	29: 1; 44: 4; 46: 2
Perisphinctidae	*Lemencia* cf. *pergrata* (Schneid, 1914)	38	38: 1
Perisphinctidae	*Lemencia* sp.	29	29: 2
Perisphinctidae	*Oloriziceras* sp.	25–29	25: 1; 29: 1
Perisphinctidae	*Paraulacosphinctes* sp.	20	20: 1
Perisphinctidae	*Moravisphinctes moravicus* (Oppel, 1865)	17	17: 2
H.	*Micracanthoceras* spp.	10–24	10: 1; 11: 1; 24: 1

Table 2: Distribution of the Late Jurassic belemnites from Lókút section.

				Mesohibolitidae									Duvaliidae											Success.	
Stage	**Substage**	**Ammonite Zone**	**Bed number**	*Belemnites* indet.	*Hibolithes* sp. (indet.)	*Hibolithes semisulcatus* (Münster, 1830)	*Acutibelus* sp.	*Hibolithes* sp. (juv.) or *Subulibelus*?	*Subulibelus problematicus*? Riegraf, 1981	*Hibolithes conradi* Kilian, 1889	*Hibolithes* cf. *fellabrunnensis*? (Vetters, 1905)	*Hibolithes* or *Conobelus*	*Conobelus*? sp.	*Conobelus* cf. *massimoi*? (Mariotti, 2002)	*Conobelus strangulatus* (Oppel, 1865)	"*Pseudobelus*" *zeuschneri* (Oppel, 1865)	"*Pseudobelus*" ex gr. *zeuschneri* (Oppel, 1865)	"*Duvalia*" cf. *abeli* (Vetters, 1905)	"*Duvalia*" *ensifer* (Oppel, 1865)	*Duvalia* cf. *esba* (Gregorio, 1885) juv.	"*Duvalia*" *tithonia* (Oppel, 1865) juv/imm.	*Produvalia*? sp.1	*Produvalia* cf. *nicosiai*? (Mariotti, 2002)	Successive Belemnite Assemblages	Name of Belemnite Assemblages
TITHONIAN	Upper Tithonian	Microcanthum + ?	7																						
			8																						
			9																						
			10																						
			11																						
			12																						
			13																						
			14																						
			15																						
			16							1														Assemblage 6	TiBA-IV
			17																						
			18							1											1				
			19																						
			20																						
			21							1							1								
			22							1															
			23		2																				
			24		1					2															
	Lower Tithonian	Po.	25			4											2							Assemblage 5	TiBA-III
			26																						
		Fallauxi	27																						
			28																						
			29																						
			30			1																			
			31																						
			32		2						1						1			1					
			33																					??	??
			34																						
			35			2																			
			36																						
			37																						
			38																						
			39																						
			40			1																			
			41												1									Assemblage 4	TiBA-II
			42			2									2										
			43									2													
			44			8									4				1						
		Semiforme	45		2	3									3				2						
			46			1									2			1	2						
			47		1																			??	??
			48																						
			49																						
			50																						
			51																						
			52																						
			53																						
		Darwini	54																						
			55			1										1								Assemblage 3	TiBA-I
			56		1											1									
			57		2											1									
		Hybon.	58			5										1									
			59																						
			60																						
			61													2									
KIMMERIDGIAN	Upper Kimmeridgian	Beckeri	62		1																			??	??
			63																						
			64																						
			65																						
			66																						
			67																						
			68									1	1									1		Ass. 2	KiBA
		C.	69																						
		Comps.	70		3		?						1	1											
			71																					??	??
			72																						
	L. Kim.	D	73																						
		S	74	1	2																				
		P	75	3	6		1	2				3											1	Ass. 1	OxKiBA
OXF.			76	3	3	1		1	1																
			77	1	4	2			3														1		

tute, while the Kimmeridgian fossils were deposited to the collection of the Paleontological Department of the Hungarian Natural History Museum.

?*Oxfordian*

The lowermost two beds above the radiolarite (Beds 76, 77) yielded no ammonites only belemnites. It may indicate that these beds were deposited between the aragonite compensation depth and carbonate compensation depth. Some of these belemnites (*Subulibelus*) were previously described from the Oxfordian-Kimmeridgian levels of southwest Germany (Riegraf 1981). Others, like *Hibolithes semisulcatus*, are known to first occur in the latest Oxfordian (Riegraf 1981), probably after the *Epipeltoceras bimammatum* (Sub)Zone.

Since the Oxfordian is generally represented by the cherty formation of the Lókút Radiolarite, Oxfordian ammonites are rare in the Transdanubian Range. They are missing from other Bakony localities, and can be found only in the eastern part of the range, in the Gerecse Mts (Főzy & Meléndez 1997).

Kimmeridgian

Upwards in the sequence, from Bed 75, the following ca. 3 meters of reddish, clayey, ammonite rich marls are Kimmeridgian in age. All of the Kimmeridgian Mediterranean ammonite zones can be recognized. The stratigraphy is based on more then 200 ammonite specimens (Table 1), although many of them are preserved only as fragments. The lower part of the stage is rather condensed, hence the individual zones are represented by individual beds. Since the Kimmeridgian ammonite successions are poorly known all over the Mediterranean Province, and the usage of the ammonite zones is not obvious, the zonal boundaries in the Lókút section are also tentative. Among phylloceratids, *Sowerbyceras* is the most abundant, principally in the Lower Kimmeridgian beds. Oppeliids, especially taramelliceratids are diverse. *Taramelliceras strombecki* and *T. compsum*, index forms of the Strombecki and Compsum Zones are represented by some well preserved specimens. *Nebrodites* and related genera (*Lessiniceras*, *Trenerites*) are very common especially in the lower and middle part of the Kimmeridgian strata. The extremely evolutely coiled *Nebrodites cavouri* is represented by a single, but well preserved specimen. Aspidoceratids are also abundant but because their taxonomy is still problematic, their stratigraphic value is also rather limited. It seems that the flat sided, moderately evolute *Aspidoceras wolfi*, and the very globulose *Physodoceras avellanum* characterize the earliest Kimmeridgian interval. The common and moderately inflated, variably forms with a single or two rows of tubercles (*Orthasidoceras* and *Aspidoceras* s.str.) were not studied in detail. The evolute and flat shaped genera with or without ventral groove (*Hybonoticeras* and *Pseudowaagenia*) bloom in the uppermost Kimmeridgian Beckeri Zone. The zonal index was not found, but *H. pressulum*, which has a very similar range, is present. Among perisphinctids, the presence of the rarely recorded Early Kimmeridgian *Pseudosimoceras stenonis* and the abundance of the also poorly known *Trapanasites adelus* is noteworthy. Some of the important Kimmeridgian ammonites are illustrated in Figs. 2–4.

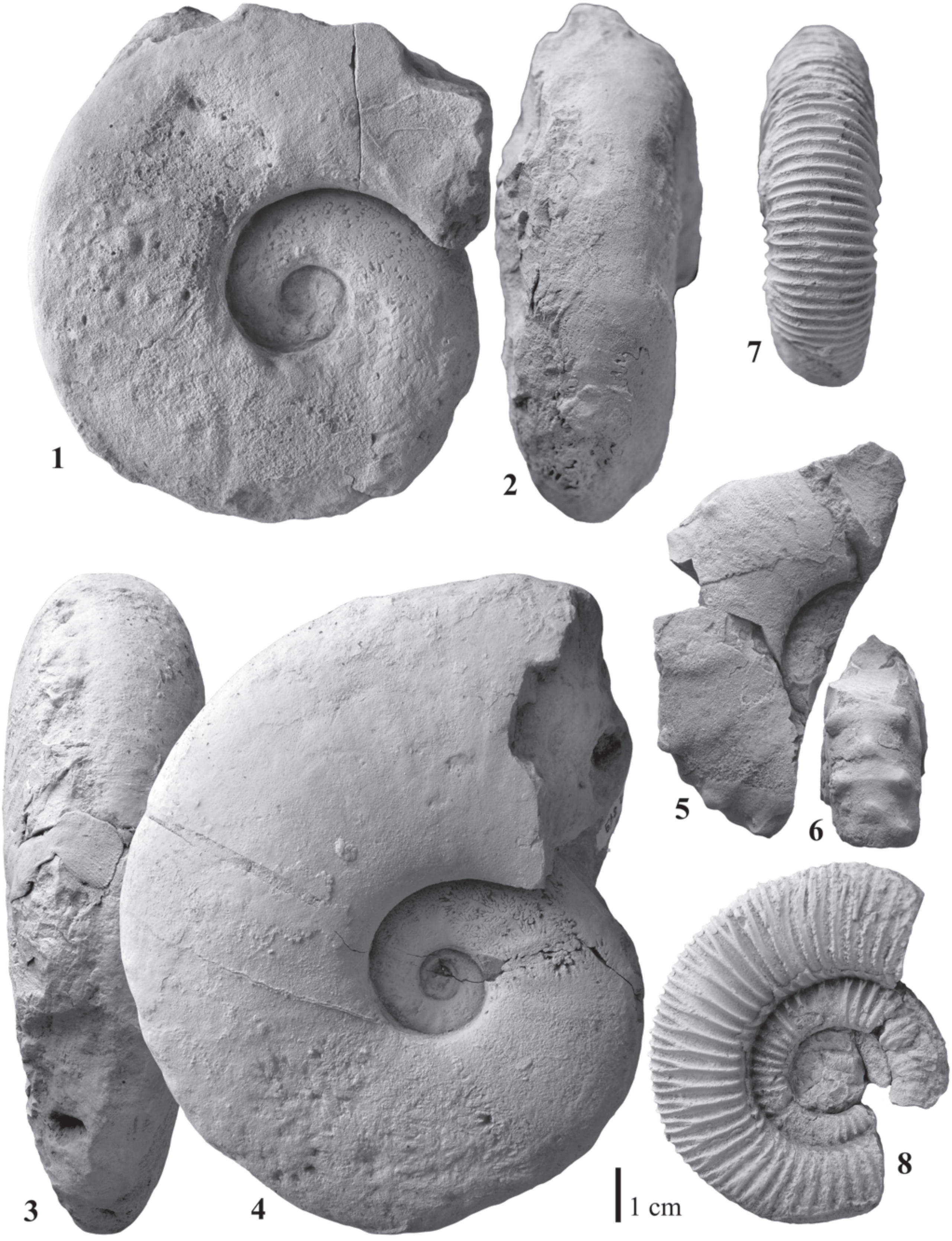

Fig. 2. Representative Kimmeridgian ammonites from the Lókút section. **1, 2** — *Physodoceras wolfi* (Neumayr, 1873) (Inventory number: M 92 852) Bed 75; **3, 4** — *Taramelliceras strombecki* (Oppel, 1858) (M 92 879) Bed 73; **5, 6** — *Hemihaploceras schwageri* (Neumayr, 1873) (M 82 931) Bed 68; **7, 8** — *Trapanesites adelus* (Gemmellaro, 1872) (M 92 886) Bed 68.

Fig. 3. Representative Kimmeridgian ammonites from the Lókút section. **1, 2** — *Taramelliceras compsum* (Oppel, 1863) (Inventory number: M 92 888) Bed 68; **3** — *Streblites* cf. *tenuilobatus* (Oppel, 1863) (M 92 1097) Bed 73; **4, 5** — *Pseudowaagenia acanthomphala* (Zittel, 1870) (M 92 1131) Bed 65; **6, 7** — *Trenerites* cf. *evolutus* (Gemmellaro, 1876) (M 92 958) Bed 73.

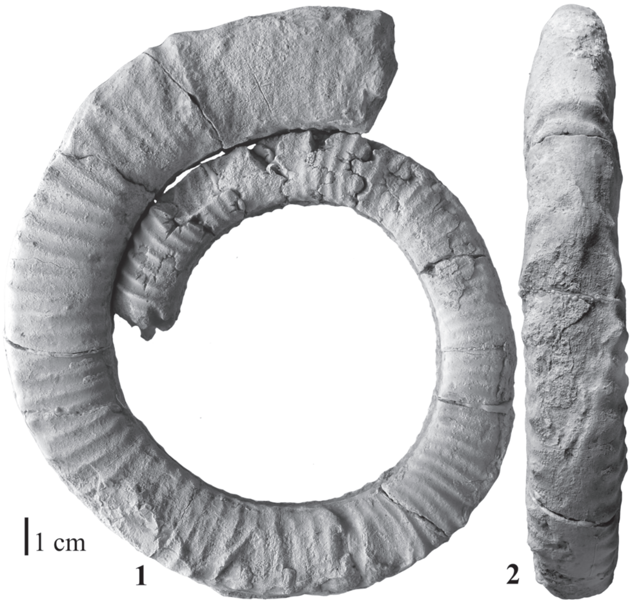

Fig. 4. A representative Kimmeridgian ammonite from the Lókút section. **1, 2** — *Nebrodites cavouri* (Gemmellaro, 1872) (M 92 1247) Bed 69.

Among the Kimmeridgian belemnites Mesohibolitidae are most abundant but overall belemnites are rather rare, apparently being restricted to the earliest Kimmeridgian and the middle part of the Late Kimmeridgian. The middle Late Kimmeridgian beds contain both Duvaliidae and Mesohibolitidae. As Late Kimmeridgian duvaliid belemnites are not known yet, the fauna is of particular interest. Unfortunately, the material is not well preserved and rather incomplete, hampering any certain specific determination. The earliest Kimmeridgian delivered a more abundant and diverse fauna. Here Mesohibolitidae (*Acutibelus*, *Hibolithes* and *Subulibelus*?) are clearly most abundant but some duvaliids do occur too (*Produvalia* aff. *nicosiai*).

Tithonian

The upper 61 beds of the red, nodular limestone, which become lighter coloured, nearly white up sequence, represent the Tithonian stage. All of the Early Tithonian ammonite zones were recognized, while the Late Tithonian is represented by the Microcathum Zone only. No younger cephalopods were found in Lókút.

Among phylloceratids, *Ptychophylloceras* (especially *P. ptychoicum*) is the most common. Lytoceratids, like the medium sized *Protetragonites* are also abundant, however bigger forms (*Lytoceras* and it's allies) are common too. With respect to the Ammonitina, the genus *Haploceras* (especially *H. elimatum* and associated forms) is very frequent. It makes up 23 % of the whole Tithonian fauna (Vigh 1984). The stratigraphy is based on more then 70 ammonite specimens, which are indicated on Table 1.

The lower part of the Tithonian succession contains some poorly preserved fragments of perisphinctids and aspidoceratids, including thickly ribbed *Hybonoticeras*, indicating the base of the lowermost Tithonian Hybonotum Zone (Beds 58–61). The presence of *Virgatosimoceras* cf. *albertinum* in Bed 61 is somewhat controversial. The specimen (figured by Scherzinger et al. 2010: fig. 5.2) is thought to be characteristic for the subsequent Darwini Zone (=Albertinum Zone in Olóriz 1978). This zone is represented by Beds 54–57, which also yielded a rather poor fauna, mainly of perisphinctids and aspidoceratids. The base of the zone was drawn by the appearance of *Haploceras cassiferum*. This ammonite, which is often regarded as a macroconch of *H. verruciferum*, (Cecca & Enay 1991), the characteristic ammonite of the subsequent ammonite zone (Semiforme/Verruciferum), is however often found, below the Semiforme Zone. The middle Tithonian Semiforme, Fallauxi and Ponti Zones were documented on the basis of diagnostic haploceratids, aspidoceratids, and simoceratids. The base of the Semiforme Zone (Beds 45–53) is marked by the simultaneous appearance of *H. verruciferum* and *Volanoceras aesinense*. The zonal index was found only in debris. Densely ribbed *Discosphinctoides rhodaniforme*, *Pseudohimalayites* and *Virgatosimoceras* are also present and characteristic. The latter is represented by a recently described species (*V. dunaii*) which fills the gap between the earlier known older and younger chronospecies (Scherzinger et al. 2010). The subsequent Fallauxi Zone (Beds 27–44) contains a diverse simoceratid fauna which clearly indicate the presence of the upper part of the zone (Biruncinatum/Admirandum Subzone). *Simoceras admirandum* and allied forms are relatively frequent, while typical *Simoceras biruncinatum* was not found in Vigh's collection. It was gathered only during our recent collecting work. The lower part (Richteri Subzone) cannot be documented by means of ammonites. Fragments of the large sized simoceratid (*Volanoceras perarmatiforme*) already mark the Ponti Zone (Beds 24, 25). Beds above yielded a moderately diverse fauna, including rare *Simospiticeras* and some specimens of *Moravisphinctes* and *Paraulacosphinctes*. Some of the stratigraphically important Tithonian ammonites are illustrated on Figs. 5, 6.

On the basis of the distribution of the belemnites the Tithonian sediments can be divided into four belemnite assemblages. The base of the Tithonian is characterized by "*Pseudobelus*" *zeuschneri* while *Hibolithes semisulcatus* is common. This low relative diversity assemblage is called TiBA-I and encompasses the Beds 55 to 61. According to the accompanying ammonites this assemblage corresponds to the *Hybonoticeras hybonotum* and the *Semiformiceras darwini* Zones. The next belemnite assemblage (TiBA-II; Beds 41 to 46) yields *Duvalia ensifer* and *Conobelus strangulatus*. It is found in the top of the *Semiformiceras semiforme* Zone and the base of the *Semiformiceras fallauxi* Zone. *Duvalia* cf. *abeli* and common *H. semisulcatus* further characterize this assemblage. "*Pseudobelus*" ex gr. *zeuschneri* and *Hibolithes conradi* occur in the latest *Semiformiceras fallauxi* Zone (*Simoceras admirandum* Subzone) to *Micracanthoceras microcanthum* Zone. This part encompasses the Beds 16 to 32 and can be divided into two successive belemnite assemblages (TiBA-III and IV; Table 2). TiBA-III furthermore yields *Hibolithes* cf. *fellabrunnensis*, *Duvalia* cf. *esba*? and the last *Hibolithes semisulcatus*. TiBA-IV yields *Hibolithes conradi*, "*Duvalia*" *tithonia* and the last "*Pb.*" ex gr. *zeuschneri*.

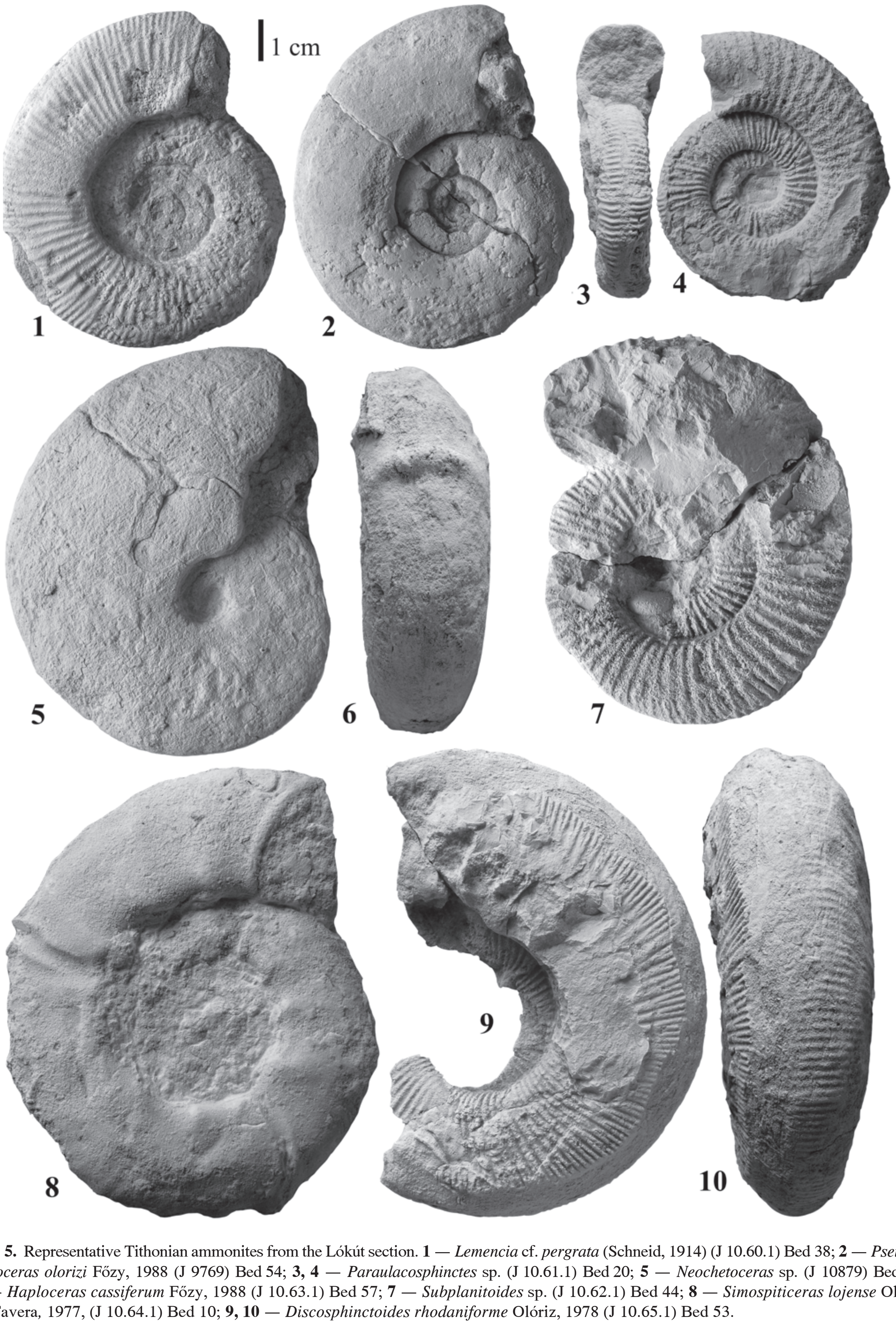

Fig. 5. Representative Tithonian ammonites from the Lókút section. **1** — *Lemencia* cf. *pergrata* (Schneid, 1914) (J 10.60.1) Bed 38; **2** — *Pseudolissoceras olorizi* Főzy, 1988 (J 9769) Bed 54; **3, 4** — *Paraulacosphinctes* sp. (J 10.61.1) Bed 20; **5** — *Neochetoceras* sp. (J 10879) Bed 43. **6** — *Haploceras cassiferum* Főzy, 1988 (J 10.63.1) Bed 57; **7** — *Subplanitoides* sp. (J 10.62.1) Bed 44; **8** — *Simospiticeras lojense* Olóriz & Tavera, 1977, (J 10.64.1) Bed 10; **9, 10** — *Discosphinctoides rhodaniforme* Olóriz, 1978 (J 10.65.1) Bed 53.

Fig. 6. Representative Tithonian ammonites from the Lókút section. **1, 2** — *Semiformiceras semiforme* (Oppel, 1865) (Inventory no: J 10.54.1) from loose; **3** — *Volanoceras perarmatiforme* (Schrauroth, 1865) (J 10.55.1) Bed 26; **4** — *Volanoceras aesinense* (Meneghini, 1885) (J 9778) Bed 53; **5** — *Simolytoceras* sp. (J 10.56.1) Bed 24; **6, 7** — *Orthaspidoceras* sp. (J 10.57.1) Bed 54; **8, 9** — *Physodoceras neoburgense* (Oppel, 1863) (J 10.58.1) Bed 55; **10, 11** — *Hybonoticeras hybonotum* (Oppel, 1863) (J 10.59.1) Bed 59.

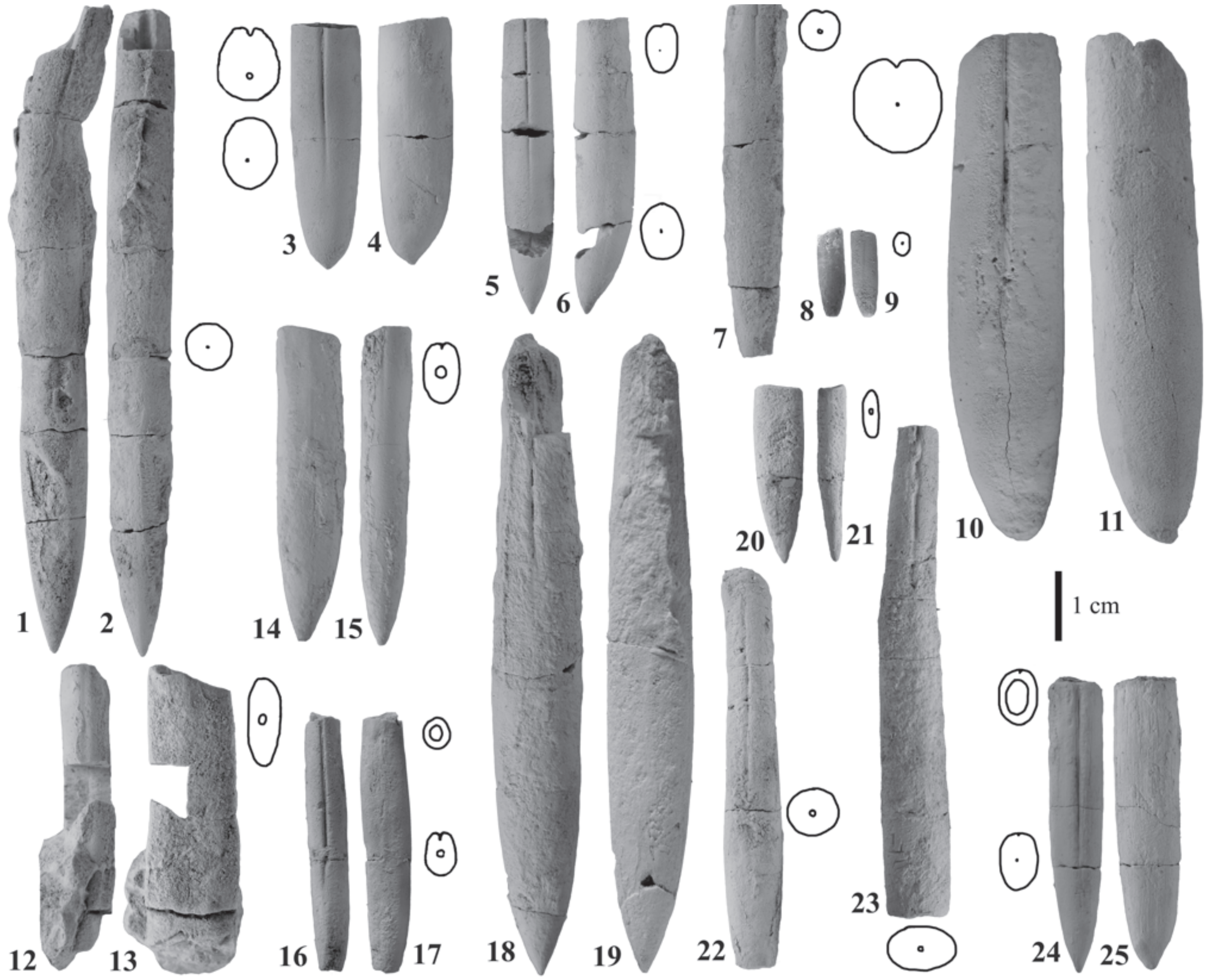

Fig. 7. Representative Tithonian belemnites from the Lókút section. **1, 2** — *Hibolithes* ex gr. *semisulcatus* (Münster, 1830) (Inventory no: J 10.1.1) Bed 46; **3, 4** — *Conobelus strangulatus* (Oppel, 1865) (J 10.2.1) Bed 41; **5, 6** — "*Pseudobelus*" ex gr. *zeuschneri* (Oppel, 1865) (J 10.3.1) Bed 32; **7** — *Hibolithes* cf. *fellabrunnensis* (Vetters, 1905) (J 10.4.1) Bed 32; **8, 9** — "*Pseudobelus*" *zeuschneri* (Oppel, 1865) juv. (J 10.5.1) Bed 61; **10, 11** — *Hibolithes conradi* Kilian, 1889 (J 10.6.1) Bed 24; **12, 13** — *Duvalia* cf. *abeli* (Vetters, 1905) (J 10.7.1) Bed 46; **14, 15** — *Duvalia ensifer* (Oppel, 1865) (J 10.8.1) Bed 45; **16, 17** — "*Pseudobelus*" *zeuschneri* (Oppel, 1865) (J 10.5.2) Bed 61; **18, 19** — *Hibolithes semisulcatus* (Münster, 1830) (J 10.9.1) Bed 25; **20, 21** — *Duvalia* cf. *esba* (de Gregorio, 1885) (J 10.10.1) Bed 32; **22** — *Hibolithes* ex gr. *semisulcatus* (Münster, 1830) (J 10.11.1) Bed 45; **23** — *Hibolithes* ex gr. *semisulcatus* (Münster, 1830) (J 12.12.1) Bed 58; **24, 25** — "*Pseudobelus*" *zeuschneri* (Oppel, 1865) (J 10.13.1) Bed 58.

Three of the four assemblages are separated by beds that apparently contain virtually no belemnites, the Beds 47 to 54 and the Beds 33 to 40. So do the Beds 62 to 67 that separate the first Tithonian assemblage from the very condensed beds that contain ?Oxfordian–Kimmeridgian cephalopods. Some of the Tithonian belemnites from Lókút are illustrated in Fig. 7.

Stable isotopes

Methodology

Stable isotopes were determined on a VG Instruments Optima Isotope Ratio Mass Spectrometer with a Multiprep Automated Carbonate System (at the University of Plymouth) using 200 to 300 micrograms of carbonate. Isotopic results were calibrated against NBS-19. Reproducibility for both $\delta^{18}O$ and $\delta^{13}C$ was better than ±0.1 ‰, based upon multiple sample analysis. All belemnite samples were analysed additionally for trace element contents to evaluate diagenetic alteration. Thin section analysis in conjunction with trace element analysis was used to determine the state of preservation of each of the fossil types examined. Prior to chemical and isotopic analysis, areas of each belemnite deemed most susceptible to diagenetic alteration, principally the exterior of each shell were removed. The remains were fragmented, washed in ultra pure water and dried in a clean environment. Fragments were subsequently picked under a binocular microscope to secure those judged to be best

Table 3: Isotopic and elemental compositions of belemnite rostra from Lókút.

Belemnite species	Bed number	δ13C (PDB)	δ18O (PDB)	Ca (ppm)	Fe (ppm)	Mg (ppm)	Mn (ppm)	Sr (ppm)
Hibolithes cf. *conradi**	Bed 16	0.9	1.4	371684	100	1890	64	240
Duvalia tithonia	Bed 18	–1.7	–1.5	355032	60	2026	29	1049
H. cf. *conradi*	Bed 18	–1.8	–0.9	359047	109	2317	20	972
Pseudobelus ex.gr. *zeuschneri*	Bed 21	–1.0	–0.2	350100	17	1799	5	895
Belemnites sp.*	Bed 21	–0.3	–1.8	391288	68	1384	33	234
H. cf. *conradi**	Bed 22	1.4	–0.4	356897	23	1615	26	270
Hibolithes sp.*	Bed 23	0.6	–1.2	385583	195	1963	179	208
H. cf. *conradi*	Bed 24	–1.6	–1.3	351484	26	2567	11	1055
Hibolithes sp. *	Bed 24	1.2	–2.6	361603	67	1993	140	525
Pseudobelus ex.gr. *zeuschneri*	Bed 25	–2.3	–2.9	353975	44	2151	24	898
H. cf. *semisulcatus**	Bed 25	–1.9	–2.2	349514	23	2231	104	794
H. cf. *semisulcatus**	Bed 30	–0.8	0.4	359052	53	2758	125	1002
Pseudobelus ex.gr. *zeuschneri*	Bed 32	–1.2	–0.9	351008	18	1860	10	955
Hibolithes sp.	Bed 32	–0.8	–1.1	362398	29	2431	9	995
H. cf. *fellabrunnesis*	Bed 32	–0.6	–1.3	362530	32	2503	26	864
Duvalia cf. *ensifer**	Bed 32	0.4	0.4	388057	87	1939	591	470
H. cf. *semisulcatus*	Bed 35	–1.4	–1.6	361858	22	2525	18	1119
*Hibolithes semisulcatus**	Bed 40	–1.2	–2.4	361213	72	1601	368	484
Conobelus cf. *strangulatus**	Bed 42	–1.0	–1.4	348063	293	1936	435	482
H. cf. *semisulcatus**	Bed 42	0.8	–1.2	349304	73	1933	69	536
Hibolithes sp.	Bed 43	–1.8	–2.2	365793	41	1861	20	1020
Duvalia cf. *ensifer*	Bed 44	–0.2	–0.1	358767	93	2004	14	908
Conobelus cf. *strangulatus**	Bed 44	–0.8	–1.7	344693	121	1937	111	860
Hibolithes cf. *semisulcatus**	Bed 44	–0.4	–1.1	328534	136	2240	248	801
*Duvalia ensifer**	Bed 45	–3.2	–2.1	365216	82	1365	115	334
Conobelus cf. *strangulatus**	Bed 45	0.0	–1.0	358167	61	2255	734	690
*Duvalia ensifer**	Bed 45	1.3	–0.8	363919	493	2585	134	442
Hibolithes sp. *	Bed 45	–0.8	–0.9	355709	19	2253	99	939
*Hibolithes semisulcatus**	Bed 45	1.3	–0.7	331695	152	2015	55	680
Hibolithes semisulcatus	Bed 46	–0.7	–1.1	339289	14	2286	11	771
Conobelus cf. *strangulatus*	Bed 46	–1.5	–1.2	351746	31	2166	19	1016
H. cf. *semisulcatus*	Bed 46	–0.9	–1.2	329436	34	2030	42	955
Conobelus cf. *strangulatus**	Bed 46	–1.5	–0.1	343629	61	1792	68	996
Duvalia cf. *abeli**	Bed 46	1.9	–1.2	347496	318	2163	118	215
Duvalia cf. *ensifer**	Bed 46	–1.2	–0.4	362948	24	1738	84	981
Duvalia cf. *ensifer**	Bed 46	–0.5	0.3	361830	24	2171	84	1029
Hibolithes sp.*	Bed 47	–0.1	–1.3	356315	195	1834	869	458
Pseudobelus cf. *zeuschneri*	Bed 55	0.4	–1.2	356031	93	1827	8	989
H. cf. *semisulcatus**	Bed 55	0.3	–1.6	363467	55	2851	68	1097
Hibolithes sp.	Bed 56	1.8	–1.4	381341	17	2627	36	932
Hibolithes sp.*	Bed 57	0.3	–0.5	346926	128	1927	684	713
Pseudobelus cf. *zeuschneri*	Bed 58	0.5	1.1	368994	76	1810	52	856
Hibolithes semisulcatus	Bed 58	1.4	–0.6	339196	80	1804	31	436
*Hibolithes semisulcatus**	Bed 58	–0.4	–1.4	377196	69	2788	82	1131
*Pseudobelus zeuschneri**	Bed 61	–0.7	–1.8	347528	63	1960	105	1067
Hibolithes sp. *	Bed 62	–0.1	–0.4	368284	75	2635	93	1077
Belemnites sp.	Bed 76	–0.3	0.5	365134	8	2328	8	855
Belemnites sp.	Bed 76	–0.6	0.2	369019	64	1626	8	918
Belemnites sp.	Bed 77	–0.5	0.3	370522	7	1500	6	901

* Deemed diagenetically altered

preserved, which were then analysed for oxygen and carbon isotopes. Subsamples for chemical analysis weighing 5–10 mg were dissolved in nitric acid and analysed using a Varian 725-ES Inductively Coupled Plasma spectrometer. According to analysis of duplicate samples, reproducibility was better than ±4 % of the measured concentration of each element.

Fossil preservation

The belemnites were not only fragmentary and frequently displayed solution marks, as noted above, they were also often 'chalky' in appearance. After the death of an organism, microbial agents may attack the shells, digesting the organic matrix that surrounds the calcium carbonate crystallites (Glover & Kidwell 1993; Brand 1994). The disassociation of these crystallites due to the loss of the organic matrix holding them together has an effect similar to chemical dissolution and causes pitting of the surface, chalkiness, and loss of colour and/or lustre (Glover & Kidwell 1993; Brand 1994). A chalky appearance alone is however, not a reliable criterion for defining the degree of diagenetic alteration. Diagenetic alteration was also apparent using standard thin section analysis. Many rostra examined (Fig. 8b–e) displayed a mottled texture and possible cloudy opaque dissolution residues. Mottling and cloudiness was often concentrated around the apical line as well the margins of the rostra. Within those samples showing a better state of preservation (Fig. 8a,f) the calcite is generally clear and primary growth lines are apparent. Those rostra appearing cloudy in hand specimen were also those that displayed the mottling and cloudiness seen in thin section.

Our trace elemental analysis is consistent with these petrographic observations in that they reveal the poor state of preservation of many of the belemnite rostra. Fe concentrations range from 15–493 ppm, Mn concentrations from 5–869 ppm, Mg concentrations from 1341–2851 ppm and Sr concentrations from 186–1131 ppm in all 49 belemnite rostra analysed (Table 3). Well-preserved belemnites typically show low concentrations of Mn (<50 ppm) and Fe (<200 ppm) and higher concentrations of Sr (ca. 600–1600 ppm) (e.g. Nunn et al. 2009; Price et al. 2009). Fe and Mn concentrations are typically higher in diagenetically altered calcite, as Fe^{2+} and Mn^{2+} are more soluble under reducing conditions and thus available for replacing Ca^{2+} in the calcite lattice (Brand & Veizer 1980; Veizer 1983). Under such conditions there may also be a loss of 'marine' Mg and Sr (Veizer 1983). Hence many belemnites were excluded on the basis of relatively high concentrations of Mn and Fe or reduced concentrations of Sr and Mg potentially reflecting dissolution as indicated by the chalky nature of many of the belemnites.

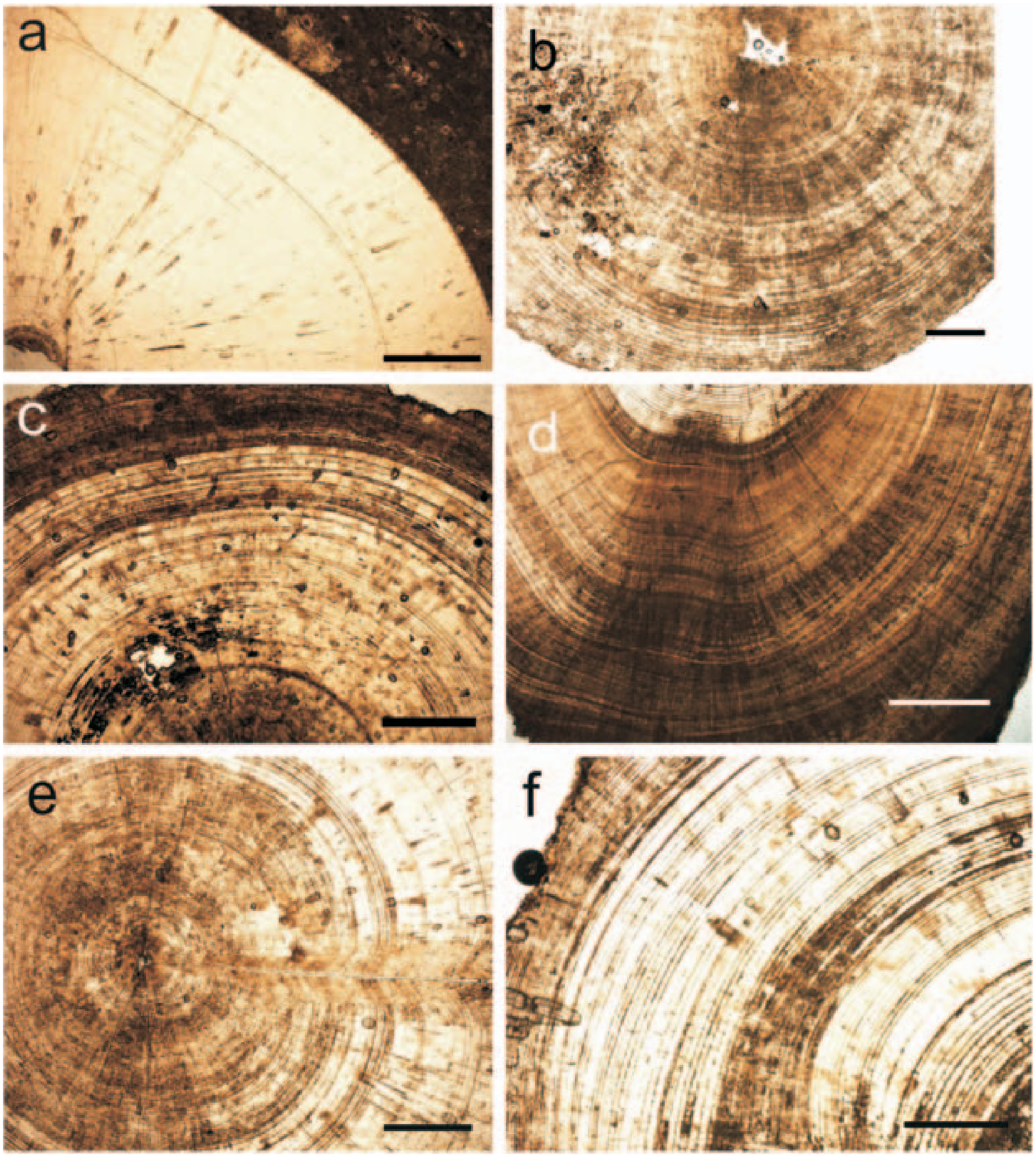

Fig. 8. Photomicrographs of belemnite rostra. **a** — Sample *Belemnites* sp., Bed 77 displaying clear and translucent growth lines. Scale bar is 1 mm. **b** — Sample *Hibolithes semisulcatus*, Bed 58 showing a mottled texture particularly concentrated around the apical line. Scale bar is 1 mm. **c** — Sample *Hibolithes* sp., Bed 57 showing mottling and opaque cloudy texture particularly around the margin of the rostrum. Scale bar is 1 mm. **d** — Sample *Duvalia* cf. *abeli,* Bed 46 shows a dense mottling and opaque cloudy texture. Scale bar is 1 mm. **e** — Sample *Hibolithes* cf. *semisulcatus*, Bed 44 shows a mottled texture particularly concentrated around the apical line. Scale bar is 1 mm. **f** — *Duvalia tithonia*, Bed 18 shows generally clear calcite and primary growth lines with more opaque calcite around the margin of the rostrum. Scale bar is 0.5 mm.

Isotope results

Apart from the isotope data from the lowermost (?Oxfordian) beds, the carbon isotope values of the belemnite calcite through the Tithonian part of the section show a decline in values from 1.8 ‰ in the Darwini Zone to −1.7 ‰ (V-PDB) in the Microcanthum Zone. The belemnite oxygen isotopes show some variability ranging from −2.9 to −0.1 ‰ (V-PDB). Obvious stratigraphic trends are not evident. Likewise although a range of species were analysed (e.g. *Hibolithes* and *Duvalia*), because of the generally poor state of preservation only two *Duvalia* were deemed well-preserved. Hence potential ecological trends were not discernable from the isotope data. The oxygen isotope data from the ?Oxfordian samples show a narrow range (0.2–0.5 ‰ V-PDB). These data are a little more positive than our Tithonian data.

Discussion

Ammonites

The Upper Jurassic ammonite fauna of the Lókút section has a strong Mediterranean character, which is reflected by the presence of numerous exclusively Tethyan ammonite genera and species, as well as by the proportion of ammonite suborders. As a result of this phylloceratids and lytoceratids are very common throughout the section. For example, in the Tithonian part of the succession these groups comprise about 60 % of the whole fauna (Vigh 1984).

Data for the Oxfordian are very scarce in Lókút, therefore it cannot be discussed in detail. In contrast, the Kimmeridgian is well developed and can be compared with some of the well-documented Tethyan fauna, especially known from the Subbetics (Olóriz 1978), Southern Alps (Sarti 1984, 1993) and Sicily (Pavia & Cresta, Eds. 2002). The Kimmeridgian succession of the Lókút Hill — although still condensed, as always in the Rosso Ammonitico facies — is the thickest and most complete representation of the stage in Hungary, where all Kimmeridgian ammonite zones can be traced.

Because the Tithonian in Lókút also shows a strong Mediterranean affinity and its ammonite succession can be compared easily with those known from other Tethyan localities, the novel zonal scheme, introduced by Vigh (1984) was revised and replaced by a standard scheme. As in other localities of the Transdanubian Range the middle Tithonian is better represented than the lowermost part of the stage. The Semiforme and Fallauxi Zones contain more beds then those of the Hybonotum and Darwini Zones. The Ponti Zone is thin, but the base of the Upper Tithonian (Microcanthum Zone) is characterized by numerous beds and a relatively diverse and typical, but poorly known assemblage. This fauna contains some little known ammonites, including flat, discoidal perisphinctids with, or without a ventral groove (like *Paraulacosphintes* and *Oloriziceras*), and some himalayitids (*Microcanthoceras*) which are best known from the Subbetics (Tavera 1985).

Belemnites

The most recent information regarding Mediterranean Late Jurassic belemnites originates from Italian sections (Combémorel & Mariotti 1986a,b, 1990; Mariotti 1995, 2002a,b, 2003). However, knowledge about the bed-by-bed distribution of Tethyan belemnites is sparse (Mariotti 1995: p. 222–225). Combémorel & Mariotti (1986a) described belemnites from the Central Apennines. They dealt with belemnites from either the *S. semiforme* Zone or the *Volanoceras volanense* Zone, although later on Mariotti (1995) accepted a Volanense (= Ponti) age for the sediments. Cecca & Enay (1991) mentioned *Duvalia ensifer* from the *R. richteri* Subzone, from Tithonian sediments in the southeast of France. Combémorel & Mariotti (1986b) described *Duvalia tithonia* from the A2 Calpionellid Zone and discuss to some more extent stratigraphical details about this species.

Janssen (1997: text-fig. 2) described and mentioned some belemnites from the latest Jurassic and earliest Cretaceous from the southeast of Spain. However, especially the *Conobelus*-species most probably are erroneous and additional material (a.o. "*Pseudobelus*" *fischeri* Combémorel & Mariotti, 1990) still needs to be published. It appears, however, that many belemnites that occur in TiBA-III and IV disappear in the beds that straddle the Jurassic-Cretaceous boundary.

The latest Kimmeridgian to earliest Tithonian is characterized by belemnite faunas which are very low in diversity but are generally very abundant (Riegraf 1981; Combémorel 1997). Most numerous are *Hibolithes*, a group of belemnites which in general lack unambiguous traits. *Hibolithes* ex gr. *semisulcatus* are well known from the Kimmeridgian-Tithonian boundary sediments and occur abundantly in both the Submediterranean as in the Mediterranean Province, and occasionally even in the Boreal-Atlantic Realm.

Duvalia-like belemnites are known from the Tethyan Late Bathonian to Oxfordian, and probably the late Early Kimmeridgian (Mariotti 2002a,b). Recently Hikuroa (2004) and Challinor & Hikuroa (2007) published sedimentary successions from the Antarctic Peninsula which yielded Duvaliidae from sediments of comparable ages. For the moment, there appears to be a period (within the literature) from the Late Kimmeridgian to earliest Tithonian in which the Duvaliidae-do not occur. The "reappearance" of Duvaliidae (*Conobelus* and duvaliid belemnites related to *Duvalia* ex gr. *ensifer*) coincides approximately with the boundary between the Lower and middle Tithonian.

In comparing the Hungarian belemnite assemblages with assemblages from Italy (Combémorel & Mariotti 1986a; Mariotti 1995, 2002b, 2003), some discrepancies occur, moreover the Hungarian assemblages appear to be impoverished. TiBA-IV contains belemnites that are characteristic for the latest Jurassic. However, characteristic genera and species like *Conobelus* and "*Pb.*" *fischeri*, are absent. *Duvalia tithonia* is not know from older sediments than with calpionellids that characterize the A2 Calpionellid Zone. Apparently, our specimen occurs within the top of the Chitinoidella Calpionellid Zone (cf. Grabowski et al. 2010).

Moreover, the Hungarian material indicate that much more distinct assemblages emerge between the Early–middle Tithonian and the middle–Late Tithonian than previously indicated. The assemblage described by Combémorel & Mariotti (1986a) from the *V. volanense* Zone (Mariotti 1995) appears to be comparable to TiBA-II in the Lókút section (top *S. semiforme* and base *S. fallauxi* Zones) but the Hungarian assemblage is clearly less diverse. In the Lókút section TiBA-I encompasses almost the entire Early Tithonian (if distinguishing between the Lower and middle Tithonian). The characteristic belemnite ("*Pb.*" *zeuschneri*), would be the first indication that duvaliids occur in the earliest Tithonian, shortening the previously mentioned interval of "lacking duvaliids".

Duvaliids also occur in the Bed 68 (base *Hybonoticeras beckeri* Zone). Due to the rigidity of the host-rock only the transverse section can be studied, which shows an elongated subquadrangular laterally flattened cross-section, typical for duvaliid belemnites. Moreover, the Beds 68 and 70 yielded conobeloid belemnites, and in the Bed 70 one resembles *Conobelus massimoi* (Mariotti, 2002). The latter has been described from the *Crussoliceras divisum* Zone of northern Italy. In the Beds 75 and 77 (probably Oxfordian-Kimmeridgian boundary beds) duvaliids occur again.

Isotopes

Increasingly negative $\delta^{18}O$ values in carbonates can be related to higher temperatures in environmental settings where continental ice volume over time is relatively constant (and therefore $\delta^{18}O_{seawater}$ is relatively invariable) and evaporation or freshwater input are minor factors. Belemnites are also

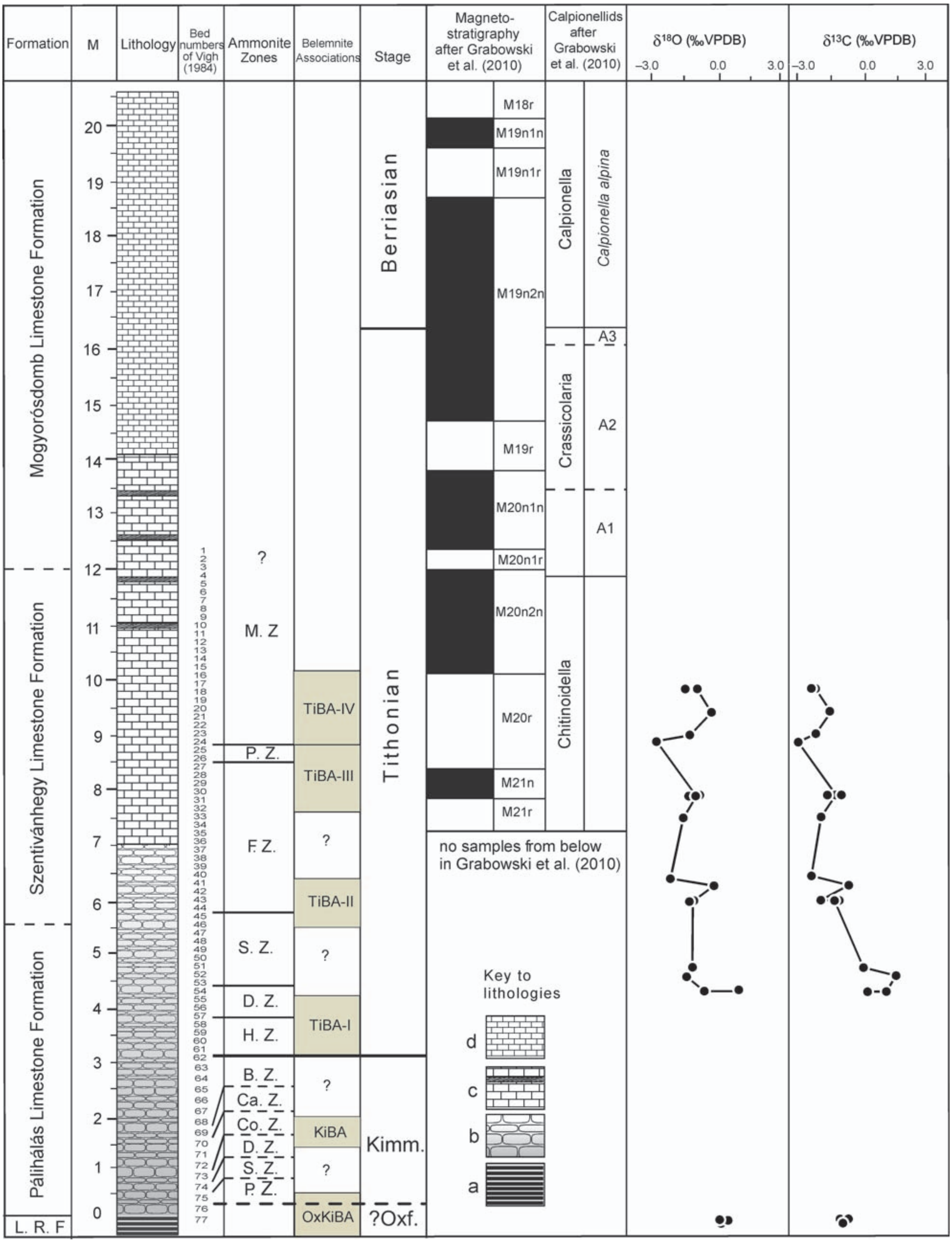

Fig. 9. Integrated stratigraphy of the Lókút section showing the correlation between biostratigraphic data and those based on magnetostratigraphy. The measured log is tentatively correlated with the bed numbers published by Vigh (1984). Correlation is based on known thickness of the Tithonian part of the section, observed lithological changes and re-sampling of the profile. Ammonite zones for the Kimmeridgian and Tithonian follow the standard zonation scheme by Enay & Geyssant (1975) and Olóriz (1978), respectively. Abbreviations: (**a**) radiolarite (Lókút Fm), (**b**) red nodular limestone (Pálihálás Fm), (**c**) light coloured, thin-bedded limestone, with cherty layers (Szentivánhegy Fm), (**d**) white, Biancone type limestone (Mogyorósdomb Fm). For the zonal names, from the oldest to the youngest: Platynota, Strombecki, Divisum, Compsum Cavouri, Beckeri, Hybonotum, Darwini, Semiforme, Fallauxi, Ponti, Microcathum Zones. Belemnite Assemblages are in accordance with the data published herein.

thought to have secreted their carbonate in isotopic equilibrium with ambient seawater (e.g. Lowenstam & Epstein 1954; Price & Mutterlose 2004). This assumption is supported by the fact that the $\delta^{18}O$ values of modern *Sepia* shells (an extant relative of belemnites) also appear close to equilibrium fractionation (Bettencourt & Guerra 1999). Hence assuming oxygen isotope equilibrium, relatively cool temperatures are seen in the Oxfordian and warmer conditions in the Tithonian. The $\delta^{18}O$ values of belemnites imply temperatures as low as 8 °C, if a $\delta_{seawater}$ value of –1.0 ‰ (SMOW), thought to be appropriate for assumed non-glacial periods (Shackleton & Kennett 1975) using the paleotemperature equation of Anderson & Arthur (1983) is used. According to the same assumptions the warmest paleotemperatures reach 22 °C consistent with the paleolatitude of the site. As the few Oxfordian samples were derived from just above the Lókút Radiolarite, cooler conditions may be indicative of a deeper depositional setting although warmer conditions in the Tithonian are consistent with data published from elsewhere (e.g. the Russian Platform, Riboulleau et al. 1998; Price & Rogov 2009).

The carbon isotope data show a decrease through the Tithonian part of the section that is consistent with carbon-isotope stratigraphies of the Western Tethys (e.g. Weissert & Channell 1989; Weissert & Mohr 1996) and also the Russian Platform (Price & Rogov 2009) which show a decrease in values towards the Jurassic-Cretaceous boundary. Weissert & Channell (1989) interpret this $\delta^{13}C$ decline as evidence of increasingly oligotrophic conditions in the Tethyan seaway. This pattern is therefore thought to reflect a global signal of carbon cycling in the Late Jurassic oceans. Further stable isotope data from the Lókút section are, however, required to substantiate linkages between global records.

Conclusions

Re-measuring and re-sampling the section of the Lókút Hill allowed us to allocate and anchor the cephalopod collection, gathered nearly 50 years ago.

Based on the rich and relatively well preserved, bed-by-bed collected ammonite fauna, the biostratigraphical subdivision of the lower, cephalopod bearing part of the Upper Jurassic–Lower Cretaceous section was precisely done. Above the lowermost (possibly Oxfordian) beds, a relatively complete succession of the Kimmeridgian Platynota, Strombecki, Divisum, Compsum, Cavouri and Beckeri Zones was recognized, which is followed by the Tithonian Hybonotum, Darwini, Semiforme, Fallauxi, Ponti and Microcanthum Zones.

The belemnite fauna — also collected under strict stratigraphic control, together with the ammonites — allowed us to recognize four belemnites assemblages (TiBA-I to TiBA-IV) for the Tithonian part. We distinguished one assemblage in the middle late Kimmeridgian and one for the ?Oxfordian-Kimmeridgian boundary beds. However, due to the low amount and quality of the material the latter two are only tentatively distinguished. The Tithonian assemblages can be compared with previously published belemnite assemblages but appear impoverished in relation to Mediterranean (Italy, Spain) assemblages. The rather species poor Kimmeridgian belemnite assemblage cannot be compared because belemnite stratigraphical and taxonomical details are missing from literature except for Mariotti (2002b, 2003). The latter author published a highly diverse assemblage from the *C. divisum* Zone of northern central Italy.

The ?Oxfordian-Kimmeridgian assemblage which appears rather diverse (mainly Mesohibolitidae) cannot be compared in detail to other areas yet, because detailed stratigraphical data are also missing. However, the general picture, repeated in literature showing an abundance of Mesohibolitidae in the Upper Oxfordian to Lower Tithonian sediments of the Mediterranean Tethys could actually be artificial due to lack in well investigated sections, as demonstrated by Mariotti (2002b, 2003). Moreover, we find indications that duvaliids occur throughout the interval we investigated.

Despite the poor preservation of many of the rostra our geochemical analyses of belemnite specimens from a stratigraphically well-constrained section yielded new data for reconstructions of paleoclimate and paleoecology. These data point to a cool (or deeper) ?Oxfordian and a warmer Tithonian. Our $\delta^{13}C$ data are consistent with other isotope stratigraphies and allude to the possibility of the Lókút section recording global events.

Systematic section

On a family level there appear to be no large differences between latest Jurassic and Early Cretaceous belemnites, only abundances fluctuate heavily. The belemnites described here can be divided into two families, namely the Mesohibolitidae and Duvaliidae. This division is based on the position of the siphon towards the alveolar groove, being opposite in Duvaliidae and situated on the same side in Mesohibolitidae. In addition the general morphology of the rostrum adds to this separation, in which Duvaliidae are generally laterally flattened, while Mesohibolitidae are rounded or dorso-ventrally flattened and spindle-shaped (hastate or (sub)fusiform). However, the alveolar area of some *Hibolithes* can be laterally compressed, as in *Hibolithes conradi*. Some suspected Duvaliidae also show the same outer morphology during their ontogenetical development, especially *Conobelus*. Thus generic attribution is not always definite, as the position of the siphon is often not known. Moreover, the stratigraphical record of the Duvaliidae is momentarily incomplete. There are gaps in our knowledge regarding the phylogenetic relation between Late Jurassic and Early Cretaceous genera, although morphological differences are often meagre. This is largely the result of the near absence of published stratigraphical data on belemnites from the Berriasian.

The main quandary is represented by the Tithonian belemnites attributed to the genus *Pseudobelus*. There is momentarily no firm ground to place them in the genus created by Blainville (1827) other than a morphological resemblance (pers. observ. Janssen). For the moment they appear to belong to a genus closely related to the Tithonian–earliest Cretaceous duvaliids, or representing a genus between *Produvalia* and *Duvalia*. These belemnites do show some characteristics of *Produvalia* or *Duvalia* and of *Pseudobelus*. Yet, lateral lines or incisions are often noted in other duvaliids too, and especially juvenile to immature specimens do tend to have the same morphology as compared to pseudobeloid belemnites. *Pseudobelus* s.s. are currently known to occur in uppermost Berriasian to lower Upper Hauterivian sediments only.

Family: **Mesohibolitidae** Nerodenko, 1983
Genus: *Acutibelus* Riegraf, 1981

Acutibelus sp.

?1877 *Belemnites semisulcatus* Münster — Favre, pl. I, fig. 3a–b

Material: One incomplete specimen from Bed 75 and one doubtful specimen from Bed 70.

Description: A very elongated specimen with rather faint alveolar groove. The juvenile or immature specimen from Bed 70 shows a very deep and very sharp alveolus.

Range: Early to earliest Late Kimmeridgian.

Occurrence: Late Early to earliest Late Kimmeridgian of southwest Germany (Riegraf 1981), Savoie (?Favre 1877) and Hungary.

Genus: *Hibolithes* Denys de Montfort, 1808

Hibolithes conradi Kilian, 1889
(Fig. 7.10,11)

1868 *Belemnites* cfr. *semisulcatus* Münster — Zittel, pl. I, fig. 8 (*fide* Kilian, 1889)
?1871 *Belemnites* cfr. *semisulcatus* Münster — Gemmellaro, p. 21, pl. III, figs. 2–3
1889 *Belemnites* (*Hibolites*) *Conradi* n. sp. Kilian, pp. 635, 690 (cf.), pl. XXVI, fig. 4
?1922 *Belemnites Conradi* Kilian — de Gregorio, p. 8, pl.I, fig. 12
pars 1990 *Hibolithes semisulcatus* (Münster): Combémorel & Mariotti, pl. II, fig. 9
pars 1997 *Hibolithes semisulcatus* (von Münster) — Janssen, pp. 12–13

Material: Six incomplete specimens from Beds 24 to 16.

Description: A robust rounded semihastate rostrum with pointed, centrally placed apex. The alveolar area is characterized by lateral compression. Alveolus shallow with well developed wide alveolar groove. The apical line is central.

Range: Latest Tithonian (*M. microcanthum* Zone) to Late (?)Berriasian (Zone unknown).

Occurrence: Hungary, Italy, Spain and (?)northern Alps.

Hibolithes cf. *fellabrunnensis* (Vetters, 1905)
(Fig. 7.7)

1905 *Belemnites Fellabrunnensis* Vetters, p. 245, text-fig. 1

Material: One incomplete rostrum from Bed 32 (the alveolar part is lacking).

Description: Elongated rounded to slightly dorso-ventrally compressed rostrum with a relative long alveolar groove, well on to the *rostrum sollidum*, and a shallow alveolus. The alveolar area is rounded (cf. Vetters 1905) but not preserved in our material.

Range: Late middle Tithonian (top *S. fallauxi*).

Occurrence: Hungary and northern Alps.

Hibolithes semisulcatus (Münster, 1830)
(Fig. 7.1,2,18,19,22,23)

1830 *Belemnites semisulcatus* Münster, pp. 6–7, pl. 1, figs. 1–8, 15
1862 *Belemnites diceratiana* Etallon, p. 69
1870 *Belemnites* cfr. *semisulcatus* Münster — Zittel, p. 30, pl. I (25), fig. 5
1886 *Belemnites diceratianus* Etallon — Loriol, pp. 37–38, pl. I, figs. 1–4
1986a *Hibolites semisulcatus* (Münster) — Combémorel & Mariotti, pp. 312–313, pl. 2, figs. 14–16 (cum syn.)
1986a *Hibolites* sp. — Combémorel & Mariotti, pp. 314, pl. 2, figs. 17–20
pars 1990 *Hibolithes semisulcatus* (Münster) — Combémorel & Mariotti, p. 213, pl. 2, figs. 5–8, 10
1995 *Hibolithes semisulcatus* (Münster) — Mariotti, p. 235, pl. III, figs. 3–4
1999 *Hibolithes semisulcatus* (Münster) — Schweigert, pp. 3–4, text-figs. 1, 3–4, pl. 1, figs. 1–4, pl. 2, figs. 1–6, pl. 3, figs. 1–2, pl. 4, figs. 1–7, pl. 7, fig. 3 (cum syn.)
2002b *Hibolithes semisulcatus* (Münster) — Mariotti, pp. 218–219, text-fig. 5.1–4
?2006 *Hibolithes* (*Hemihibolites*) ex gr. *semisulcatus* (Münster) — Ippolitov, pp. 57, 59, 60, text-figs. 3a–g (morph A), 3d–z (morph B)
2009 *Hibolithes* (gr.) *semisulcatus* (Münster) — Lukeneder, pl. 3, fig. G

Material: 31 near complete to fragmentary specimens from Beds 77 to 25.

Description: A slender rounded to dorso-ventrally compressed hastate rostrum with pointed to obtuse centrally placed apex. The alveolar area is characterized by a well-developed constriction towards the *rostrum sollidum*. Lateral compression of the alveolar area is not always apparent, or might be absent. The alveolus is shallow with a well developed fine but clear alveolar groove. The length of the groove various, but might run well onto the *rostrum sollidum*. The apical line is central.

Range: Latest Oxfordian to middle Tithonian.

Occurrence: Throughout the (sub-) Mediterranean Tethys. Occasional occurrences outside this Province are noted (Russian Platform; cf. Ippolitov 2006).

Genus: *Subulibelus* Riegraf, 1981

Subulibelus problematicus? Riegraf, 1981

1981 *Subulibelus problematicus* n. gen. et n. sp. Riegraf, pp. 99–100, text-fig. 231, pl. 7, fig. 69
1981 *Subulibelus* cf. *problematicus* n. gen. et n. sp. — Riegraf, pp. 101–102, text-fig. 232, pl. 7, fig. 70

Material: One near complete specimens from Bed 76 and three incomplete specimens from 75.

Description: Small to medium sized very elongated, very hastate specimens. In Bed 77 an incomplete specimen shows a very shallow alveolus. No alveolar groove visible or preserved.

Range: Latest Oxfordian (?) to earliest Kimmeridgian.

Occurrence: Latest Oxfordian (*Ringsteadia pseudocordata* Zone) and earliest Kimmeridgian (*S. platynota* Zone) of southwest Germany (Riegraf 1981) and eventually Hungary.

Subulibelus? sp. or juvenile *Hibolithes* sp.

Material: Two specimens from Bed 75 and one from Bed 76.

Description: Very small specimens (< 15 mm) which show a clear hastate sagital section. However, the potential elongated proximal part of the rostrum is not preserved.

Range: They occur in the ?Oxfordian-Kimmeridgian boundary beds.

Occurrence: *Subulibelus* is described from the latest Oxfordian and the Oxfordian-Kimmeridgian boundary beds of southwest Germany (Riegraf 1981).

Family: **Duvaliidae** Pavlow, 1914
Genus: *Conobelus* Stolley, 1919

Conobelus strangulatus (Oppel, 1865)
(Fig. 7.3,4)

1865 *Belemnites strangulatus* Oppel, p. 545
1868 *Belemnites strangulatus* Oppel — Zittel, pp. 35–36, pl. 1, figs. 6–7
1890 *Belemnites Orbignyi* Duval-Jouve — Toucas, pp.587–588, pl. XV, fig. 1
1890 *Belemnites Orbignyi* Duval-Jouve var. *suborbignyi* Toucas, p. 588, pl. XV, fig. 2
?1922 *Belemnites strangulatus* Oppel — de Gregorio, p. 8, pl. I, fig. 15
1942 *Conobelus strangulatus* Oppel — Mandev, pp. 51–52, pl. III, figs. 3–4
(sic)1986a *Rhopaloteuthis strangulatus* (Oppel) — Combémorel & Mariotti, pp. 307–308, pl. 1, figs. 12–15 (cum syn.)
(sic)1995 *Rhopaloteuthis strangulatus* (Oppel) — Mariotti, p. 233, pl. II, fig. 11
(sic)1997 *Rhopaloteuthis strangulatus* (Oppel) — Combémorel, pl. 28, fig. 13 [cast of HT]
non?1997 *Rhopaloteuthis strangulata* (Oppel) — Janssen, pp. 31–32, pl. 3, figs. 3–4 [?non], *nec* figs. 5–6 [= *Conobelus incertus* Weiss]

Material: Twelve complete to fragmentary specimens from Beds 46 to 41.

Description: Rounded to laterally flattened conobeloid rostrum with well developed alveolar area. The dorsal and ventral sides are near parallel, except for the apical part. The alveolus is shallow and a faint but clear alveolar groove runs well onto the *rostrum sollidum*. The apex is obtuse to mucronate (in gerontic specimens) and shifted to the dorsal side; this might not be clearly visible in (incomplete) immature to juvenile specimens. The apical line is shifted to the ventral side.

Range: Middle Tithonian to (?) earliest Berriasian (top *S. semiforme*–(?)early *B. jacobi* Zones).

Occurrence: Mediterranean Tethys.

Conobelus cf. *massimoi*? (Mariotti, 2002)

?1873 Belemnites Beneckei nov. sp. Neumayr, p. 156 (16), pl. XXXI, fig. 1

Material: One incomplete, weathered specimen (Bed 70).

Description: Stout, slightly hastate, medium to small sized rostra with rounded cross-sections, a deep alveolar cavity (almost halfway the rostrum). The alveolar groove could not be seen. See Mariotti (2002b) for more specific details.

Remarks: The specimen resembles the species described by Mariotti (2002b). However, as the ontogeny is not known the immature specimens from the same bed, and from Bed 68, are gathered as *Conobelus*? sp.

Range: Middle Late Kimmeridgian.

Occurrence: Latest Early Kimmeridgian (*Crussoliceras divisum* Zone) of northern Italy, and possibly the uppermost *T. compsum* to basal *H. beckeri* Zones of Hungary.

Genus: *Duvalia* Bayle, 1878

Duvalia cf. *abeli* (Vetters, 1905)
(Fig. 7.12,13)

?1894 *Duvalia ensifer* (Oppel) — Retowski, pp. 218–219, pl. XIV, fig. 1
1905 *Belemnites Abeli* Vetters, pp. 246–247, text-fig. 3
1986a *Duvalia aesinensis* nov. sp. — Combémorel & Mariotti, pp. 304–305, pl. 1, fig. 4
1995 *Duvalia aesinensis* Combémorel & Mariotti — Mariotti, pp. 230–231, pl. II, fig. 4

Material: One incomplete specimen from Bed 46.

Description: The rostrum is characterized by an extremely laterally flattened *rostrum sollidum* with an angular cross-section and with an expanded alveolar area (not preserved in our specimen). The alveolar opening is more or less quadrangular, with a shallow alveolus and a short alveolar groove (cf. Vetters 1905).

Range: Middle Tithonian (top *S. semiforme*–(?)*M. ponti* Zones).

Occurrence: Crimea(?), Hungary, Italy and northern Klippenbelt of Calcareous Alps.

Duvalia ensifer (Oppel, 1865)
(Fig. 7.14,15)

1865 *Belemnites ensifer* Oppel, p. 545
1868 *Belemnites ensifer* Oppel — Zittel, p. 36, pl. 1, figs. 9 ["Normalform"], 10
?1868 *Belemnites ensifer* Oppel var. Zittel, pl. 1, fig. 11 [=?*Duvalia esba*]
?1875 *Belemnites ensifer* Oppel — Pillet & de Fromentel, pp. 14, 65, pl. VIII, figs. 1–3 [= ?*Duvalia esba*]
non1889 *Belemnites ensifer* Oppel — Sokolov, pp. 131–132, pl. II, fig. 8a–c [= *Duvalia* gr. *lata*]
non1894 *Belemnites ensifer* Oppel — Retowski, pp. 218–219, pl. XIV, fig. 1[= ?*Duvalia abeli*]
?1897 *Belemnites ensifer* Oppel — Roman, p. 279, pl. I, fig. 1 [= ?*Conobelus*]
?1904 *Belemnites ensifer* Oppel — Schiller, p. 27 (133), text-fig. 3 [= ?*Conobelus*]
non1922 *Belemnites ensifer* Oppel — de Gregorio, p. 8, pl. I, figs. 20 [= ?*Conobelus* sp. indet.], 21 [= ?"*Pb.*" gr. *zeuschneri*]
1935 *Belemnites ensifer* Oppel — Beregov, pp. 68 (19), 106 (56), 110 (60), pl. I, fig. 10
1986a *Duvalia ensifer* (Oppel) — Combémorel & Mariotti, pp. 303–304, pl. 1, figs. 1–3
1990 *Duvalia ensifer* (Oppel) — Combémorel & Mariotti, pp. 210–211, pl. 1, figs. 4–5

Material: Five incomplete specimens from Beds 46 to 44.

Description: Typical duvaloid rostrum with (strong) lateral compressed rostrum with elongated rounded cross-sections and a dorsally orientated apex. The alveolus is moderately deep and an alveolar groove is well developed, generally running well on to the *rostrum sollidum*. Lateral lines (two parallel lines) may be visible on well-preserved specimens. Juvenile to immature specimens do not show the same outer-morphology as mature specimens.

Range: Middle Tithonian (topmost *S. semiforme*-base *S. fallauxi* Zones).

Occurrence: Mediterranean Tethys.

Duvalia cf. *esba* (de Gregorio, 1885)
(Fig. 7.20,21)

?1868 *Belemnites ensifer* Oppel var. Zittel, pl. I(25), fig. 11
?1875 *Belemnites ensifer* Oppel — Pillet & de Fromentel, pp. 14, 65, pl. VIII, figs. 1–3
1885 *Belemnites esbus* de Gregorio, p. 242
1886 *Belemnites esbus* de Gregorio — de Gregorio, p. 4, pl. 1, figs. 12a–c
?1917 *Belemnites* (*Duvalia*) *latus* Blainville — Kilian & Révil, pl. XV, fig. 1
?1997 *Duvalia* sp. nov? spec. indet. Janssen, pp. 26–27, pl. 2, figs. 5–6

Material: One incomplete, juvenile specimen from Bed 32.

Description: Typical duvaliid latatoid rostrum with a laterally strongly compressed *rostrum sollidum* and a constricted alveolar area. The alveolar groove is short and the alveolus is shallow. This species most probably belongs to the group of belemnites around *ensifer*, but the overall shortage of material does not permit more than morphologically comparison with the specimen depicted by de Gregorio. It appears to be much more laterally compressed as compared to typical *ensifer*-species, with a more constricted alveolar area and consequently a much shallower alveolus.

Range: Late middle Tithonian–earliest Berriasian (top *S. fallauxi*-(?)base *B. jacobi* Zones).

Occurrence: Hungary, Italy, and possibly in Spain and the Swiss Alps.

Duvalia tithonia (Oppel, 1865)

1865 *Belemnites tithonius* Oppel, p. 545
1868 *Belemnites tithonius* Oppel — Zittel, p. 37, pl. I, figs. 12–13
1889 *Belemnites* (*Duvalia*) *Deeckei* n. sp. Kilian, p.636, pl. XXVI, fig. 5
1894 *Belemnites tithonius* Oppel — Retowski, pp. 221–222, pl. XIV, figs. 3–4
non1922 *Belemnites tithonius* Oppel — de Gregorio, p. 8, pl. I, fig. 11
1983 *Biplanidelus* [sic!; recte *Biplanibelus*] *tithonia* (Zittel) — Nerodenko, p. 42
(sic)1986b *Duvalia tithonica* (Oppel) emend. Zittel — Combémorel & Mariotti, pp. 36–39, text-fig. 2 (cum syn.)
(sic)1990 *Duvalia tithonica* (Oppel) — Combémorel & Mariotti, p. 211, pl. 1, fig. 6
(sic)1992 *Pseudoduvalia tithonica* (Oppel) — Barskov & Weiss, p. 74
(sic)1995 *Duvalia tithonica* (Oppel) em. Zittel — Mariotti, pp. 231–232, pl. II, figs. 5–6, pl. III, fig. 10
(sic)1996 *Duvalia tithonica* (Oppel) — Eliáš et al., pp. 263, 267, pl. IV, figs. 12–14

Material: One poorly preserved, incomplete juvenile to immature specimen from Bed 18.

Description: An atypical duvaliid rostrum characterized by dorsal and ventral hollows. These are barely visible on the dorsal side of this immature specimen. The *rostrum sollidum* is laterally flattened, and the alveolar area is characterized by a constriction. See Combémorel & Mariotti (1986b) for more details.

Range: Latest Tithonian–earliest Berriasian (Microcanthum–early Jacobi Zones).

Occurrence: Mediterranean Tethys.

Genus: *Produvalia* Riegraf, 1981

Produvalia (?) sp. 1

Material: One incomplete specimen (Bed 68) which shows the typical laterally flattened sub-rectangular duvaliid cross-section. The section shows rounded lateral sides. The ventral side is rounded to sub-angular while the dorsal outline is slightly flattened and a trace of a groove appears to be visible. The alveolar cavity, just visible in the specimen, is centrally placed.

Remarks: The cross-section does remind of *Produvalia*, more specific of the late Early to early Late Oxfordian *Produvalia neyrivensis* (Favre) hence the generic attribution.

Range: Late Kimmeridgian (earliest *H. beckeri* Zone).

Produvalia (?) aff. *nicosiai*? (Mariotti, 2002)

Material: Two incomplete specimens from the Beds 75 and 77 which show sub-rounded to sub-rectangular cross-sections. These sections are laterally compressed with near straight lateral sides. Lateral incisions are faint but visible. Both the ventral (slightly more inflated) as well as the dorsal side are rounded. The part from Bed 77 is best preserved (30 mm), and shows an almost straight dorsal side and a slightly curved ventral side, in lateral view. The ventral side narrows towards the alveolar area. A dorsal groove is not visible and no alveolar part is preserved. The alveolar line is centrally placed. In this specimen the cross-section near the alveolar region is visible. It shows a rounded outline with weak dorso-lateral depressions. Overall, the outline and lateral compression point to a duvaliid rostrum.

Remarks: The general form is similar to *Produvalia nicosiai* (Mariotti, 2002) but the anterior cross-section appears much more rounded and the dorsal side is less hastate.

Range: Latest Oxfordian(?) to earliest Kimmeridgian (*S. platynota* Zone).

Genus: *Pseudobelus* Auctorum non de Blainville, 1827
(= *Pseudobelus* s.l.; = ?genus novum)

"*Pseudobelus*" *zeuschneri* (Oppel, 1865)
(Fig. 7.8,9,16,17,24,25)

1865 *Belemnites Zeuschneri* Oppel, p. 545
1870 *Belemnites Zeuschneri* Oppel — Zittel, p. 28, pl. (I) 25, fig. 9
1889 *Belemnites Zeuschneri* Oppel — Sokolov, pp. 122–123, pl. III, fig. 5
pars?1922 *Belemnites Zeuschneri* Oppel sp. aff. — de Gregorio, p. 8, pl. I, figs. 14, 21
1986a *Pseudobelus zeuschneri* (Oppel) — Combémorel & Mariotti, pp. 310–311, pl. 2, figs. 1–6 (cum syn.)
1990 *Pseudobelus zeuschneri* (Oppel) — Combémorel & Mariotti, p. 212, pl. 1, figs. 11–14

1995 *Pseudobelus zeuschneri* (Oppel) — Mariotti, p. 234, pl. II, fig. 10, pl. III, fig. 9 (cum syn.)

Material: Six incomplete to fragmentary specimens from Beds 61 to 55.

Description: Medium sized elongated duvaliid belemnites with vague lateral impressions, especially in the apical area. The alveolus is relative deep and the alveolar groove runs well on to the *rostrum sollidum*. The apex is shifted to the dorsal side. Lateral sides are near parallel.

Remarks: The lateral depressions which characterize *Pseudobelus* s.s. appear to be different from the Tithonian–earliest Berriasian *Pseudobelus* s.l. but are clearly comparable to morphological features as can be observed on some *Produvalia* and *Duvalia*. Combémorel & Mariotti (1986a: p. 310) indicate that the original as depicted by Zittel (1870) is not complete (anymore; lacking the alveolar part). Despite that they do not mention it, in my opinion, the depth of the lateral incisions is exaggerated.

Range: Late Early Tithonian to earliest Late Tithonian (probably Semiforme–Ponti Zones).

Range: Early Tithonian (*H. hybonotum*–*S. darwini* Zones), probably also in younger sediments.

Occurrence: Mediterranean Tethys.

"*Pseudobelus*" ex gr. *zeuschneri* (Oppel, 1865)
(Fig. 7.5,6)

Material: Four incomplete to fragmentary specimens from Beds 32 to 21.

Description: Comparable to *zeuschneri* but with a well-developed constriction between the alveolar area and the *rostrum sollidum*. In the Hungarian material the alveolar areas are not preserved. Given the strong constriction, the alveolus is most probably very shallow. Lateral lines are very vague. The apex is pointed to mucronate, and shifted towards the dorsal side. In general, these belemnites give the impression of immature *Duvalia*.

Range: Latest middle Tithonian–early Late Tithonian (top *S. fallauxi*–base of *M. microcanthum* Zones).

Occurrence: Hungary.

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