



Integrated isotope and biostratigraphy of a Lower Cretaceous section from the Bakony Mountains (Transdanubian Range, Hungary): A new Tethyan record of the Weissert event

István Fózy^{a,*}, Nico M.M. Janssen^b, Gregory D. Price^c, József Knauer^d, József Pálffy^{a,e}

^a Department of Paleontology and Geology, Hungarian Natural History Museum, POB 137, Budapest H-1431, Hungary

^b Geertekerkhof 14bis, 3511 XC Utrecht, The Netherlands

^c School of Geography, Earth and Environmental Sciences, University of Plymouth, Drake Circus, Plymouth PL4 8AA, UK

^d Geological Institute of Hungary, Budapest, Stefánia u. 14, H-1143, Hungary

^e Research Group for Paleontology, Hungarian Academy of Sciences–Hungarian Natural History Museum, POB 137, Budapest H-1431, Hungary

ARTICLE INFO

Article history:

Received 16 April 2010

Accepted in revised form 23 July 2010

Available online 29 July 2010

Keywords:

Lower Cretaceous

Biostratigraphy

Ammonite

Belemnite

Calpionellid

Stable isotopes

Weissert event

ABSTRACT

An integrated stratigraphic subdivision, on the basis of ammonites, belemnites, calpionellids and stable isotope ratios is proposed for the Lower Cretaceous carbonate succession of the Hárskút, Közöskút Ravine profile (HK-12), (Bakony Mts, Hungary). Abundant and diverse cephalopod assemblages occur in middle and late Berriasian Rosso Ammonitico facies, in a nearly complete sequence spanning the *Tirmovella occitanica* and *Fauriella boissieri* Zones. A new belemnite species, *Duvalia hungarica*, is described from this level. The overlying Lower Valanginian strata are condensed, but also yield rich assemblages of the *Thurmanniceras pertransiens* and *Busnardoites campylotoxus* Zones. The cephalopod fauna of the Late Valanginian *Saynoceras verrucosum* Zone is much less diverse. The overlying 19 m interval of Biancone-type marl yielded no megafossils. The uppermost part of the profile late Hauterivian cephalopods were found. Stable isotope analysis shows a well-defined positive $\delta^{13}\text{C}$ excursion in the Valanginian strata, identified for the first time in Hungary. Although correlated with a possible anoxic event (known as 'the Weissert event'), as in many other sections, no black shale or organic-rich level is recorded at Hárskút.

© 2010 Elsevier Ltd. All rights reserved.

1. Introduction

To date more than 30 sections are known globally where a significant positive carbon isotope excursion occurs in Valanginian (Lower Cretaceous) strata. The isotope excursion marks the first of several significant carbon cycle perturbations in the Cretaceous and by analogy to younger Cretaceous isotope anomalies, the event may be linked to an oceanic anoxic event (termed the 'Weissert event' by Erba et al., 2004). The lack of black shales calls into question the extent of anoxia (Westermann et al., 2010). However, the event is an episode of remarkable change in the Earth system, possibly causally related to the formation of the Paranà-Etendeka large igneous province (Erba et al., 2004).

Here we present, from the Transdanubian Range in Hungary, a new stable carbon isotope stratigraphy integrated with ammonite,

belemnite and calpionellid biostratigraphy. The independent biostratigraphic data corroborate the temporal framework and allow a global correlation of the isotope event and biotic change. The Lower Cretaceous formations of the Transdanubian Range have been studied since the mid-19th century, the early period of Hungarian geology (Hantken, 1868). A detailed account on the stratigraphy and palaeontology of the Cretaceous formations of the region was given by Fülöp (1964). It is in this monograph where the outcrop of the Közöskút Ravine near Hárskút was first described as an important Early Cretaceous fossil locality. The biostratigraphic evaluation of the succession was based on a rich invertebrate assemblage, which was collected in 1960–1962. The fauna contains hundreds of megafossils, mainly pelagic cephalopods (ammonites, belemnites and rare nautiloids) but also some benthic elements (brachiopods, crinoids, echinoids, trace fossils, and rare bivalves and gastropods). Although the collection was carried out bed-by-bed, the biostratigraphic assignments and conclusions of Fülöp (1964) were only approximate. No precise boundaries between zones, substages or stages were drawn, and the cephalopods collected from different levels were discussed together. The potential benefits of a modern revision of the fauna are therefore not restricted to a taxonomic

* Corresponding author.

E-mail addresses: fozy@nhmus.hu (I. Fózy), hibolithes@hotmail.com (N.M.M. Janssen), G.Price@plymouth.ac.uk (G.D. Price), knauer@mafi.hu (J. Knauer), palfy@nhmus.hu (J. Pálffy).

update but will also make full use of the stratigraphically controlled collection in establishing the biostratigraphic subdivisions within the section.

Therefore, the main aims of this paper are (a) to establish an integrated stratigraphy of the section, with a special focus on the abundant and diverse cephalopod (ammonite and belemnite) fauna, (b) to demonstrate the Valanginian carbon isotope excursion for the first time from Hungary, and (c) to contribute to a better understanding of the Weissert event and its biotic consequences on the basis of our new data.

2. Geological setting

The studied section is situated in the southwestern part of the central Bakony Mts, about 2.5 km east-southeast of the village of Hárskút. The geographical location and geological setting of the studied locality is shown in Fig. 1. The Bakony Mts belong to the Transdanubian Range, representing a key part of the Bakony Unit (Kázmér, 1986), which in turn is part of the AlCaPa composite terrane (Csontos and Vörös, 2004). Together with other units of Austroalpine affinities a Mesozoic stratigraphic sequence deposited on the southern passive margin of the Neotethys ocean is preserved.

The section is located on the northwestern side of a valley called Közöskút Ravine. Geographical coordinates for the section are 47°9′58.17″N, 17°47′11.48″E. The ravine itself provides a classical outcrop of a Lower to Middle Jurassic Rosso Ammonitico-type succession with repeated gaps due to non-deposition (Fülöp et al., 1969; Galács, 1975). The Upper Jurassic is represented by cherty layers of the Lókút Radiolarite Formation and the overlying Rosso Ammonitico-type Pálihálás Limestone Formation. The latter unit continuously passes upwards into the Upper Tithonian–Berriasian Szentivánhegy Limestone Formation which becomes gradually less nodular, more compact and whiter upsection. The Valanginian part of the succession is represented by cherty marls of Biancone-type, of the Mogyorósdomb Limestone Formation. The youngest exposed Mesozoic formations are the uppermost Hauterivian cephalopod-bearing marl and the Aptian (and perhaps even younger) beds of the Tata Limestone Formation. A brief description of these lithostratigraphic units is given by Császár (1997).

During the past 50 years different sections of the Mesozoic succession at the Közöskút Ravine were sampled in close proximity to each other by the team of the Hungarian Geological Institute. To avoid confusion, first it is necessary to clarify the published and unpublished names of the different outcrops. On the west side of the ravine, the Upper Jurassic–Lower Cretaceous strata form a prominent cliff known as Prédikálószék (“The Pulpit”). Its Tithonian–Berriasian ammonite succession was discussed by Horváth and Knauer (1986) and Fözy (1990) under the name Hárskút, Közöskút Ravine, Profile II. The section described in the present paper is situated a few hundred meters eastward, and has been referred to as section HK-12, Közöskút Ravine at Hárskút. This section is not the same as that described misleadingly by Fözy (1990, fig. 4) under the name Hárskút 12; which is another nearby section originally labelled as Hárskút 12/a.

3. Material and methods

3.1. Cephalopods

The rich fossil assemblage (about 800 ammonite and 100 belemnite specimens) of section HK-12 was collected between 1960 and 1962. The collection was supervised by József Fülöp, and the ammonite fauna was first studied by Anna Horváth. The original documentation of the collection (field notes and logs) is not available, but since the fossils were carefully labelled (i.e. the bed numbers

are indicated on each specimen), it is possible to unambiguously reconstruct the succession of the collected fossils. There is a condensed layer (Bed 10) which is extremely rich in Valanginian fossils and this serves as an easily identifiable guide horizon in the field (Fig. 2B). The level of Beds 30–32, packed with the characteristic Berriasian ammonite *Tirnovella occitanica*, offers another tie-point recognisable in the field. These identified horizons helped to confidently match our new geochemical sampling with the fossil collection which was obtained nearly 50 years ago.

Revisiting the HK-12 section proved that the reddish Berriasian ammonites were collected from the compact, moderately nodular limestone which crops out as steep cliffs in and around an artificially enlarged fissure (Fig. 2A). The underlying very hard and compact Tithonian beds were not sampled. The Valanginian ammonites were obtained from the lowermost part of the Biancone-type cherty marl which crops out above the nodular limestone at the beginning of a shallow artificial trench, excavated by the team of the Geological Institute of Hungary in the 1960s. Bed 10 of the trench contains a rich and well preserved fauna and is easy to recognise in the field, as it was intensively collected on a c. 6 m² large surface. The overlying Beds 1–9 yielded a less abundant fauna, whereas no megafossils have been recovered from the following 19 m thick stratigraphic interval exposed in the upper part of the trench (Fig. 2D). This part of the section is now largely covered by debris and soil. The topmost part of the trench crosses a forest track, and it ends in a small pit (Fig. 2E), from where poorly preserved latest Hauterivian ammonites were collected. The stratigraphy and the main features of section HK-12 are presented in Fig. 2.

Preservation of the ammonites is varying throughout the section. The lower (Berriasian) beds yielded strongly dissolved internal moulds only, which is typical for the Rosso Ammonitico-type facies. Large-sized, complete specimens and/or fragments of larger ones are common, whereas small-sized forms are missing. In the Valanginian strata the preservation is somewhat different: small-sized forms (including microconchs) are common and bigger specimens are mostly represented by fragments. Bed 10, which is densely fossiliferous, yielded internal moulds and also some exceptionally preserved specimens with permineralized shell remains. Phragmocones and separately preserved body chamber fragments occur together. Many of the ammonites from this level are eroded and only their lower side is preserved. These features suggest a strong condensation for Bed 10. The latest Hauterivian ammonite fauna collected from the marl pit situated at the top of the section comprises poor fragments of dissolved internal moulds only.

The preservation of the belemnites from section HK-12 is generally very good, except for some solution marks. Many of the guards are preserved with a part of their phragmocone. The majority of the guards belong to the family Duvaliidae, dominated by *Duvalia ex gr. lata* and *Pseudobelus ex gr. bipartitus*, representing typical off-shore species.

The association described herein consists mostly of mature forms. Juvenile and immature specimens of Duvaliidae, as well as Mesohibolitidae are virtually absent. Occasionally the presence of boring barnacles (*Acrothoracica*, Cirripedia) (Fig. 7J, 8R) is characteristic. The completeness of the material and the presence of alveolar remains would indicate a nearly complete lack of transport.

Other cephalopod remains found in section HK-12 include several aptychi, a few rhyncholiths and two nautiloid internal moulds with shell remains. The fossils from section HK-12 are deposited in the museum of the Hungarian Geological Institute. Most of the specimens which belong to the suborders Phylloceratina and Lytoceratina, the representatives of the genus *Neolissoceras*, and some other Ammonitina specimens were entered into the inventory under the successive inventory numbers K-11326–K-11501. The rest of the stratigraphically useful

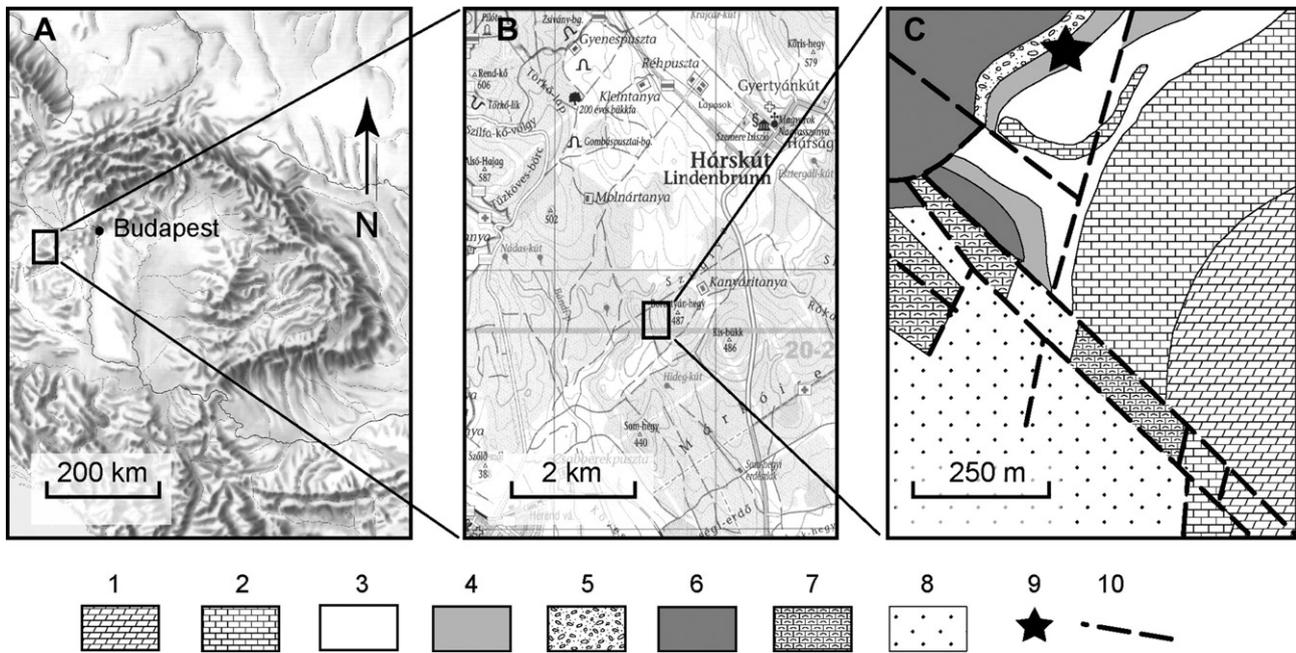


Fig. 1. A, B) The geographic position of the studied section (HK-12) in the Pannonian Basin and in the vicinity of Hárskút, respectively. (C) Simplified geological map of the surroundings of the section. 1: Triassic Dachstein type limestone, 2: Lower and Middle Jurassic carbonates, 3: Upper Jurassic cephalopod limestone, 4: Lower Cretaceous Biancone-type carbonate, 5: Lower Cretaceous cephalopod marl, 6: Aptian crinoidal Limestone, 7: Post-Aptian carbonates, 8: Tertiary deposits, 9: location of the section HK-12, 10: detected or supposed faults.

Ammonitina and belemnite specimens have successive inventory numbers between K 10.1.1. and K 10.327.1.

3.2. Other macrofauna

The most common benthic fossils are the brachiopods, represented by more than 200 specimens. The majority belongs to the genera *Pygites* and *Triangope*, whereas *Nucleata* is less common. At least two species are distinguished among the more than 30 specimens of irregular echinoids. Bivalves and gastropods are rare; none of the few, poorly preserved internal moulds can be identified. Irregular, branching trace fossils also occur in the section. The only vertebrate remains are isolated teeth of pycnodont and cartilaginous fishes.

3.3. Calpionellids

Calpionellids were studied in thin sections, which were made soon after collecting the samples in 1961. At least one thin section was prepared for each of the 45 beds. Some of the thin sections were made from ammonite internal moulds. When revisiting the section recently, further samples were taken and additional thin sections were prepared from Bed 10 and beds immediately below and above it, in order to better understand the changes of the microfacades and calpionellid succession in this critical interval.

3.4. Stable isotope studies

A total of 73 samples were taken from section HK-12. Average spacing of samples was ~0.2 m in the well exposed lower part (Beds 45–10). Above Bed 10, where outcrop conditions were generally poor, samples were obtained from evenly spaced pits, separated by ~0.6 m in stratigraphic thickness. Higher resolution sampling (15 samples over a thickness of 1.35 m) was carried out immediately below, within and above Bed 10, after analyses of the initial suite of samples located a major carbon isotope excursion in

this interval. Subsamples, avoiding macrofossils and sparry calcite veins, were then taken for stable isotopic analysis. Carbonate powders were analysed on a VG Instruments Optima Isotope Ratio Mass Spectrometer with a Multiprep Automated Carbonate System (at the University of Plymouth) using 200–300 micrograms of carbonate. Isotopic results were calibrated against NBS-19. Reproducibility for both $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ was better than $\pm 0.1\text{‰}$, based upon duplicate sample analyses.

4. Stratigraphical results

4.1. Ammonites

The stratigraphic distribution of the Berriasian to Valanginian ammonite fauna is given in Table 1. The biostratigraphy is primarily based on the standard Mediterranean ammonite zonal scheme (Reboullet et al., 2009), which is unambiguously applicable owing to the paleobiogeographical affinities of the studied assemblages. Some of the stratigraphically important ammonite taxa of this interval are illustrated in Figs. 3–6.

4.1.1. Berriasian

The Berriasian part of the profile yielded a moderately diverse assemblage of different berriasellids, and representatives of early olcostephanids. The revision of the fossils led to the recognition that the lower part of the section (Beds 45–13) represents a largely complete Middle and Upper Berriasian succession. The zonal indexes for the *T. occitanica* and *Fauriella boissieri* Zones were recognised in numerous successive beds. *T. occitanica* (Fig. 5F,G) is represented by many specimens. Most of them have a larger umbilicus than the type, some of them are extremely loosely coiled. *F. boissieri* (Fig. 4A,B) shows a wide variability in terms of ribbing density and style. It ranges up to the Valanginian as the latest representatives of the species were found in Bed 10. Specimens of the genus *Neolissoceras* (Fig. 5C) are also very frequent.

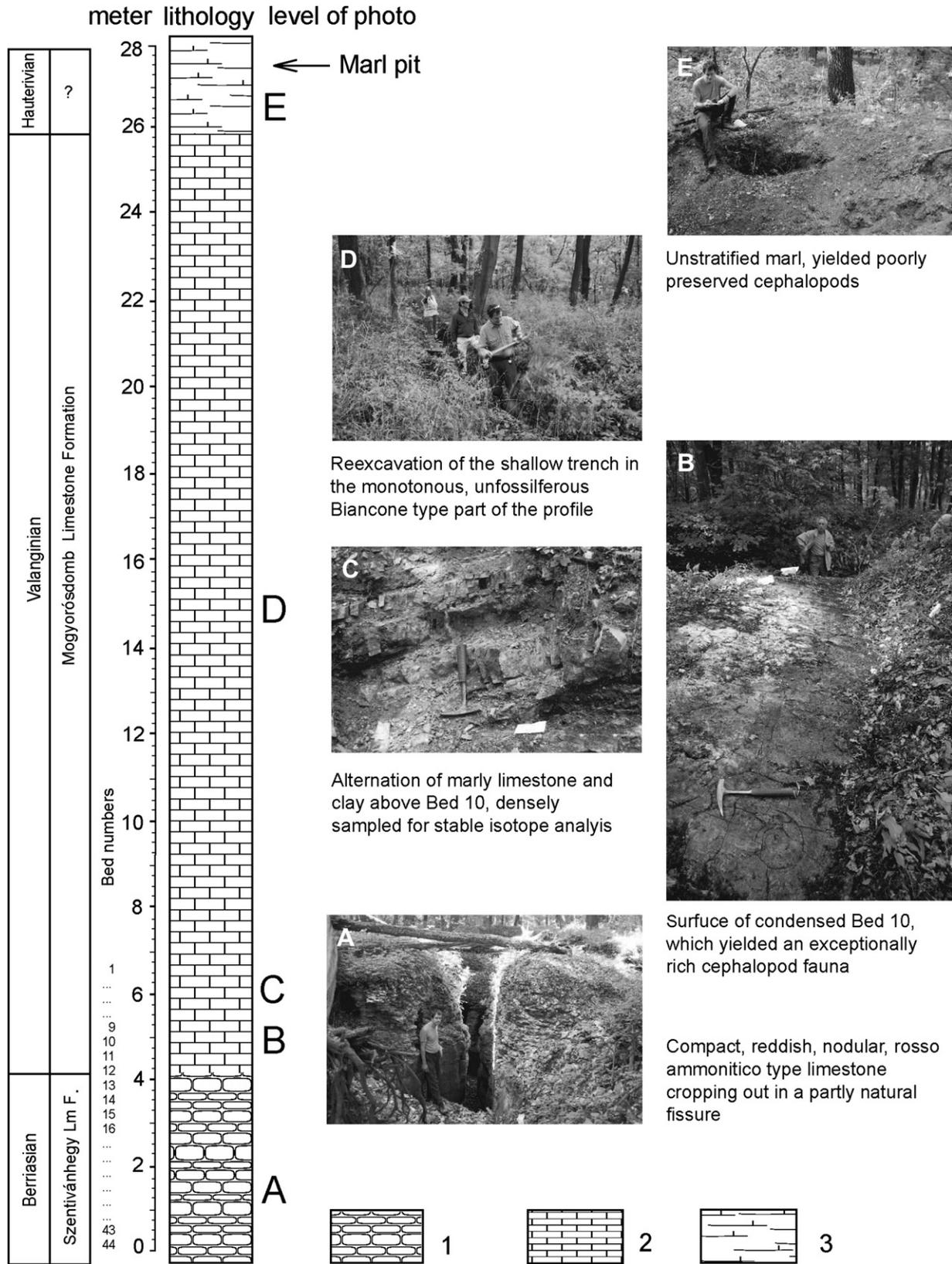


Fig. 2. Composite log of the Hárskút (HK-12) section with images on characteristic part of the profile. 1: Rosso Ammonitico type limestone, 2: Biancone type carbonate, 3: grey marl.

Haploceras elimatum, which is very common throughout the Tithonian, was also documented from the Middle Berriasian. This confirms the findings of Olóriz (1978) that this species is not restricted to the latest Jurassic.

4.1.2. Valanginian

Beds 12–10 yielded a condensed and rich Early Valanginian ammonite fauna in which *Olcostephanus drumensis* (Fig. 3C–H) is the most abundant species. Beds 12 and 11 are assigned to the

Table 1

Stratigraphical distribution and specimen numbers of the ammonite fauna in the Hárskút (HK-12) section. Phylloceratids and lycoceratids are indicated only for the Valanginian part of the section. H: Haploceratidae, O: Oosterelliidae, P: Protancyloceratidae.

Bed number	Stage	Substage	Ammonite zone	Phylloceratidae		Lycoceratidae		Haploceratidae		Oosterelliidae		Protancyloceratidae		Cocostephanidae		Berriassellinae		Neocomitinae		P.			
				H	O	H	O	H	O	H	O	H	O	H	O	H	O	H	O				
1	VALANGINIAN	Upper	Higher than E																				
2																							
3																							
4																							
5																							
6																							
7																							
8																							
9																							
10																							
11																							
12																							
13																							
14																							
15																							
16																							
17																							
18																							
19																							
20																							
21																							
22																							
23																							
24																							
25																							
26																							
27																							
28																							
29																							
30																							
31																							
32																							
33																							
34																							
35																							
36																							
37																							
38																							
39																							
40																							
41																							
42																							
43																							
44																							
45																							
46																							
47																							
48																							
49																							
50																							
51																							
52																							
53																							
54																							
55																							
56																							
57																							
58																							
59																							
60																							
61																							
62																							
63																							
64																							
65																							
66																							
67																							
68																							
69																							
70																							
71																							
72																							
73																							
74																							
75																							
76																							
77																							
78																							
79																							
80																							
81																							
82																							
83																							
84																							
85																							
86																							
87																							
88																							
89																							
90																							
91																							
92																							
93																							
94																							
95																							
96																							
97																							
98																							
99																							
100																							

Thurmanniceras pertransiens Zone whereas the strongly condensed Bed 10, which still contains some elements of the Pertransiens Zone, represents at least some levels of the *Busnardoites campyloptoxus* Zone. The typical Pertransiens Zone ammonites—e.g., numerous specimens of the zonal index (Figs. 3Q and 5D,E,H) and the rich *Kilianella* fauna (Figs. 3B,I and 4D)—are represented by internal moulds preserved with both sides intact in most cases, while many of the *Campyloptoxus* Zone ammonites occur as eroded specimens, with only their lower part preserved. This taphonomic difference suggests that the fauna of Bed 10 is not mixed but condensed, and the fossils were not separated according to their position within the bed during collection.

Beds 9–1 are assigned to the early Late Valanginian *Saynoceras verrucosum* Zone. Albeit the index species is missing, the age of these strata is proved by the first appearance of *Oosterella* (Fig. 3M) and the oldest neocomitids, including various species of *Rodighierites*, (Fig. 3L) *Sabbaiceras* (Fig. 3A) and *Neohoplaceras*. The rich *Kilianella* assemblage found in the underlying beds is absent here. The change in the olostephanid fauna is also characteristic: the late Early Valanginian *O. drumensis* is missing and only *O. guebhardi* (Fig. 3R) persists. The typical Late Valanginian *Valanginites* is rare. Although the upper part of the Biancone-type marl contains no megafossils, it is thought to represent the higher part of the Late Valanginian.

4.1.3. Hauterivian

The rich ammonite assemblage collected from a marl pit at the top of the section most probably indicates a latest Hauterivian age. Beside the very common phylloceratids (Fig. 6A,B) and lycoceratids, it contains numerous desmoceratids, crioceratids, hamulinids and ptychoceratids (Fig. 6D). Representatives of *Neolissoceras* and early pulchelliids (*Discoidella* spp.) (Fig. 6C) are rare, but their presence also supports the Hauterivian age. Fülöp (1964) assigned the whole assemblage to the

Barremian, and listed also *Silesites cf. vulpes* (a typical early Barremian form) and *Spitidiscus* sp. (this may refer to an early Barremian holco-discid ammonite). During our revision of the fauna none of these Early Barremian taxa were recognized, we therefore cannot confirm a Barremian age. On the other hand, some belemnites, like *Hibolithes* sp. and *Duvalia ex gr. grasiata* (Fig. 6G–L) collected from section HK-12 (unfortunately without precise indication of occurrence) may indicate Late Hauterivian or Early Barremian age.

4.2. Belemnites

The stratigraphic distribution of the Berriasian to Valanginian belemnite fauna is given in Table 2. Some of the characteristic taxa of this interval are shown in Figs. 7 and 8. Taxonomic remarks and the description of a new species are given in Appendix 1. Because a widely accepted belemnite-based biozonation is lacking for the Early Cretaceous, the studied section is subdivided into successive local associations of belemnite faunas, the characteristics of which are described herein. These associations are numbered from BA-I (oldest) to BA-VI (youngest) (Table 2), and their age and correlation is discussed below.

BA-I includes Beds 42–19 and is pre-Middle Berriasian to early Late Berriasian in age. It is dominated by *Duvalia ex gr. lata*. The first occurrence of *Duvalia aff. guillantonae* (Fig. 8U,V) is recorded in Bed 32, that of *Duvalia miravetesensis* (Fig. 8S,T,Z,W) is in Bed 25. The first occurrence of *Pseudobelus bipartitus* in Bed 20 indicates the Late Berriasian, possibly the level of *Berriasella picteti* Subzone (Janssen, 2003, p. 131).

BA-II includes Beds 18–15 and is mid-Late Berriasian in age. This unit commonly yields *P. bipartitus*, besides other characteristic elements such as *Conobelus (?) piradoensis* (Fig. 8AA,BB), *Conobelus*

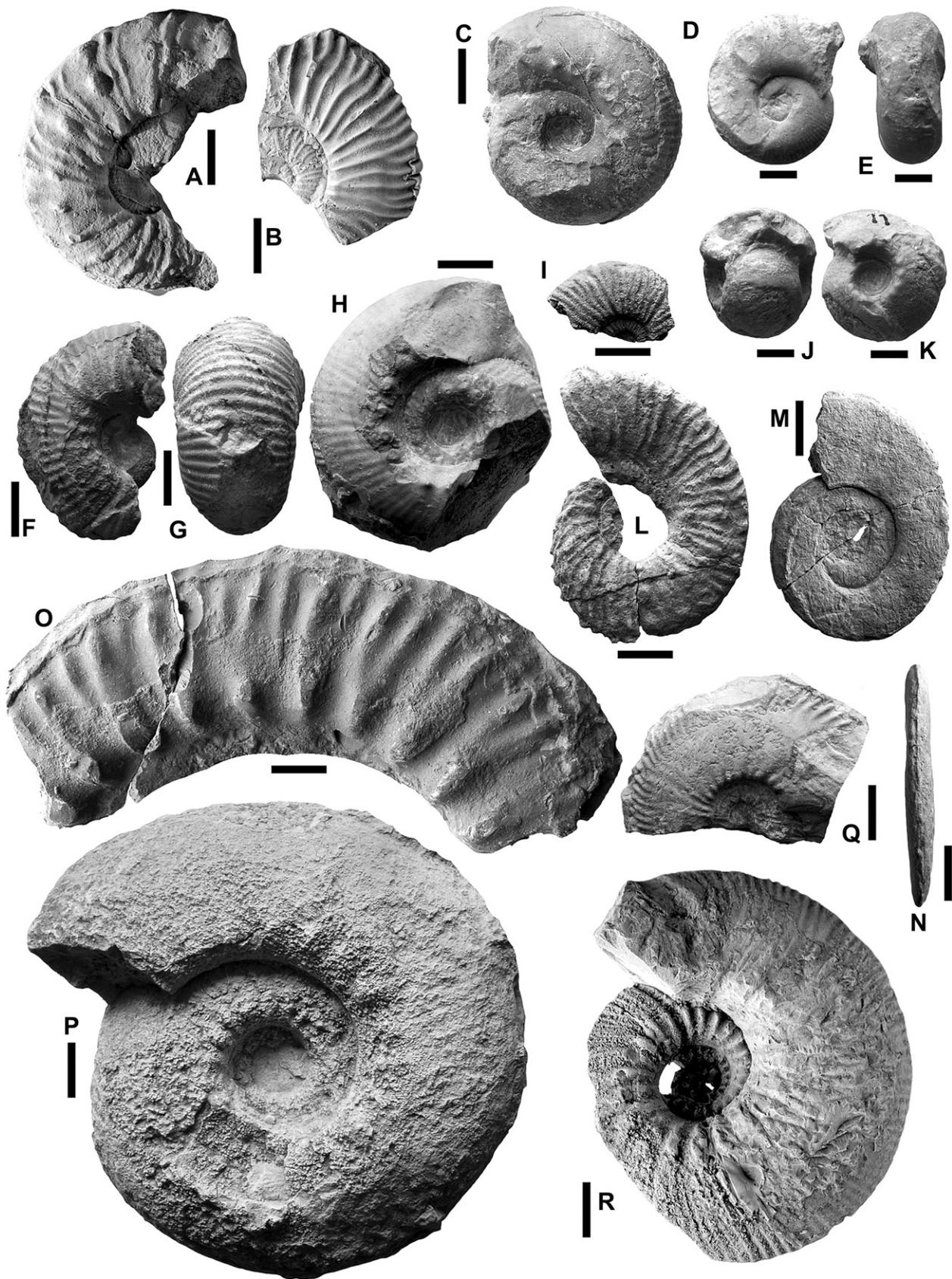


Fig. 3. Representative Berriasian and Valanginian ammonites from the Hárskút section (HK-12). (A) *Sabbaiceras stefanescui* Avram and Gradinaru, 1993 (inventory no: K 10.1.1.) Bed 6, (B) *Kilianella roubaudiana* (d'Orbigny, 1850) (K 10.2.1.) Bed 10, (C) *Olcostephanus drumensis* (Kilian, 1910) macroconch (K 10.3.1.) Bed 10, (D), (E) *Olcostephanus drumensis* (Kilian, 1910) microconch (K 10.4.1.) Bed 11, (F), (G) *Olcostephanus drumensis* (Kilian, 1910) macroconch, thickly ribbed morphotype (K 10.5.1.) Bed 11, (H) *Olcostephanus drumensis* (Kilian, 1910) macroconch (K 10.6.1.) Bed 10, (I) *Kilianella roubaudiana* (d'Orbigny, 1850) (K 10.7.1.) Bed 10, (J), (K) *Olcostephanus stephanophorus* (Matheron, 1878)?microconch (K 10.8.1.) Bed 11, (L) *Rodighierites belimensis* (Mandov, 1976) (K 10.9.1.) Bed 6, (M), (N) *Oosterella begastrensis* Company, 1987 (K 15223) Bed 6, (O) *Kilianiceras gratianopolitense* (Kilian, 1890), plasticine mould (K 10.10.1.) Bed 10, (P) "*Spiticeras*" cf. *gevreyi* Djanelidzé, 1922 (K 10.11.1.) Bed 20, (Q) *Thurmanniceras pertransiens* (Sayn, 1907) (K 10.12.1.) Bed 11, (R) *Olcostephanus guebhardi* (Kilian, 1902) (K 10.13.1.) Bed 10. Scale bar: 10 mm.



Fig. 4. Representative Berriasian and Valanginian ammonites from the Hárskút section (HK-12). (A), (B) *Fauriella boissieri* (Pictet, 1867) (inventory no: K 10.14.1.) Bed 17, (C) *Berriassella privasensis* (Pictet, 1867) (K 10.15.1.) Bed 20, (D) *Kilianella roubaudiana* (d'Orbigny, 1850) (K 10.16.1.) Bed 11, (E) *Neocomites premolicus* Sayn, 1907 (K 10.17.1.) Bed 11, (F) *Busnardoites* aff. *campylotoxus* (Uhlig, 1902) (K 10.18.1.) Bed 10. Scale bar: 10 mm.



Fig. 5. Representative Valanginian ammonites from the Hárskút section (HK-12). (A) *Busnardoites neocomiensiformis* (Uhlig, 1902) (inventory no: K 10.19.1.) Bed 10, (B) *Busnardoites neocomiensiformis* (Uhlig, 1902) (K 10.20.1.) Bed 10, (C) *Neolissoceras grasianum* (d'Orbigny, 1841) (K 11384) Bed 10, (D), (E) *Thurmanniceras pertransiens* (Sayn, 1907) microconch (K 11327) Bed 10, (F), (G) *Tirnovella occitanica* (Pictet, 1867) (K 10.21.1.) Bed 30, (H) *Thurmanniceras pertransiens* (Sayn, 1907) macroconch (K 11326) Bed 10. Scale bar: 10 mm.

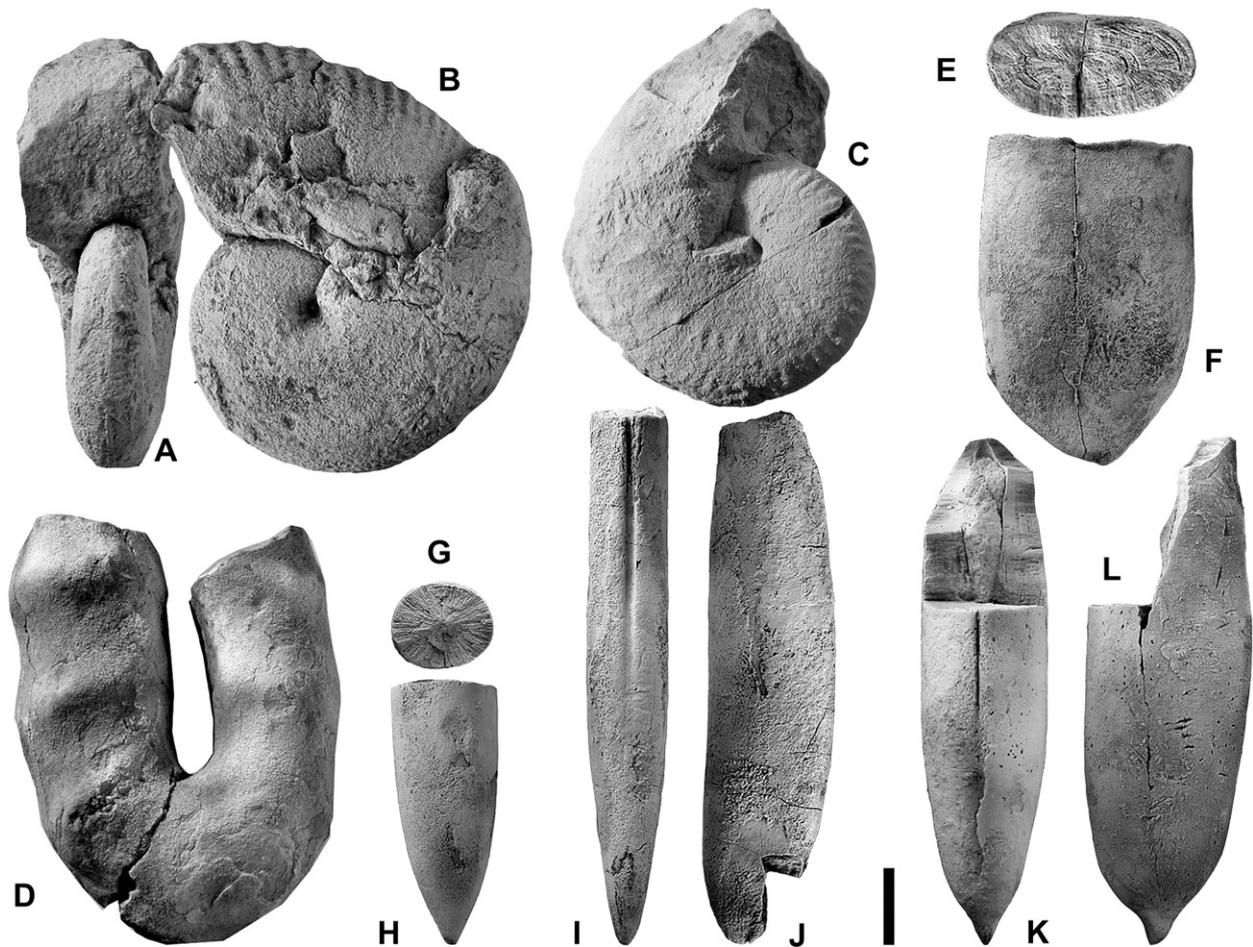


Fig. 6. Representative Hauterivian ammonites and Hauterivian or Barremian belemnites from the Hárskút section (HK-12), possibly from the marl pit, or above it. (A), (B) *Phyllopacyceras winkleri* (Uhlig, 1882) (inventory no: K 10.22.1.), (C) *Discoidella vermeuleni* (Cecca, Faraoni and Marini, 1998) (K 10.23.1.), (D) *Ptychoceras biassalense* Karakasch, 1907 (K 10.24.1.), (E), (F) *Duvalia dilatata dilatata* (de Blainville, 1827) (K 10.25.1.), (G), (H) *Hibolithes* sp. (ex gr. *jaculiformis*? Shvetsov, 1913) (K 10.26.1.) cross section and lateral view, (I), (J) *Duvalia* ex gr. *grasiana* (Duval-Jouve, 1841) (K 10.27.1.) dorsal and lateral views respectively, (K), (L) *Duvalia* ex gr. *grasiana* (Duval-Jouve, 1841) (K 10.28.1.) dorsal and lateral views respectively. Scale bar: 10 mm.

incertus (Fig. 8N,O), *Duvalia* aff. *lata lata* and *Duvalia hungarica* sp. nov.

BA-III includes Beds 14–11, straddling the ammonite-based Berriasian-Valanginian boundary as defined by the first occurrence of the *T. pertransiens*. *Berriasibelus kabanovi* (Fig. 7M,N,P,Q) is a common species, whereas the characteristic elements of BA-II are absent. This unit is regarded as a low-diversity transitional interval between two associations with higher diversity, BA-II and BA-IV.

BA-IV comprises the condensed Bed 10 only. The belemnite assemblage contains some conservative faunal elements which persist from older assemblages. The last occurrence of *D. ex gr. lata* (Fig. 7J,K) is recorded here. This unit also contains the first clear indications of attenuation of the *P. bipartitus*-stock which continues throughout the succeeding assemblage and the diminishing of previously important taxa such as *Berriasibelus*.

BA-V is restricted to Bed 9 and possibly Bed 8. It is characterised by the last occurrence of *Duvalia lata*, *Berriasibelus*, *Castellanibelus* (Fig. 7C,D), *Duvalia emericii* and *Pseudobelus* sp. 2 are confined to this unit.

BA-VI includes Beds 6 and 5. In the studied section this is a monospecific association of *Pseudobelus* sp. 1 (Fig. 8A–C). Elsewhere, this species is known to occur in low diversity and high abundance faunas, associated with *Duvalia* ex gr. *binervia* and *Hibolithes jaculoides* (Janssen and Clément, 2002, fig. 3).

4.3. Calpionellids

More than 20 calpionellid taxa have been identified from section HK-12, allowing an independent biostratigraphic subdivision, where calpionellid distribution serves as the basis of correlation using the zonal scheme of Remane et al. (1986) which superseded that of Allemann et al. (1971), or one of the more recently published, refined zonations (Grün and Blau, 1997; Pop, 1994, 1997; Reháková and Michalík, 1997). The most characteristic calpionellid taxa of the section are shown in Fig. 9.

Calpionella elliptica (Fig. 9U), represented by specimens of varying size, is the most abundant species in the lowermost interval of Beds 44–41. Small forms of the *Calpionella alpina* group and *Remaniella colomi* are also common, whereas *Remaniella cadischiana* (Fig. 9K) and *Tintinnopsella longa* (Fig. 9Q) are rare, but their occurrence is stratigraphically important. These strata are assigned to the *Calpionella* Zone. At the subzone level, correlation with the *C. elliptica* Subzone (Reháková and Michalík, 1997), *T. longa* Subzone (Pop, 1994, 1997) or the *Remaniella cadischiana* Subzone (Grün and Blau, 1997) is justifiable, suggesting a Middle Berriasian age of these beds.

The overlying interval of Beds 40–11 is correlated with standard *Calpionellopsis* Zone (or Zone D in the older terminology), based on the common, or at some levels predominant, occurrence of the

Table 2
Stratigraphical distribution and specimen numbers of the belemnite fauna in the Hárskút (HK-12) section.

Bed number	Stage	Substage	Ammonite zone	Calpionellid zone	Belemnite association (BA)	Duvaliidae		Mesoh.			
						Upper	Lower				
1	VALANGINIAN	Upper	Verrucosum	higher than E	VI						
2											
3											
4											
5											
6											
7											
8											
9											
10	BERRIASIAN	Lower	P.+C. P.	D/E	IV						
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											
21											
22											
23											
24											
25											
26											
27											
28											
29											
30											
31											
32											
33											
34											
35											
36											
37											
38											
39											
40											
41											
42											
43											
44											
45											

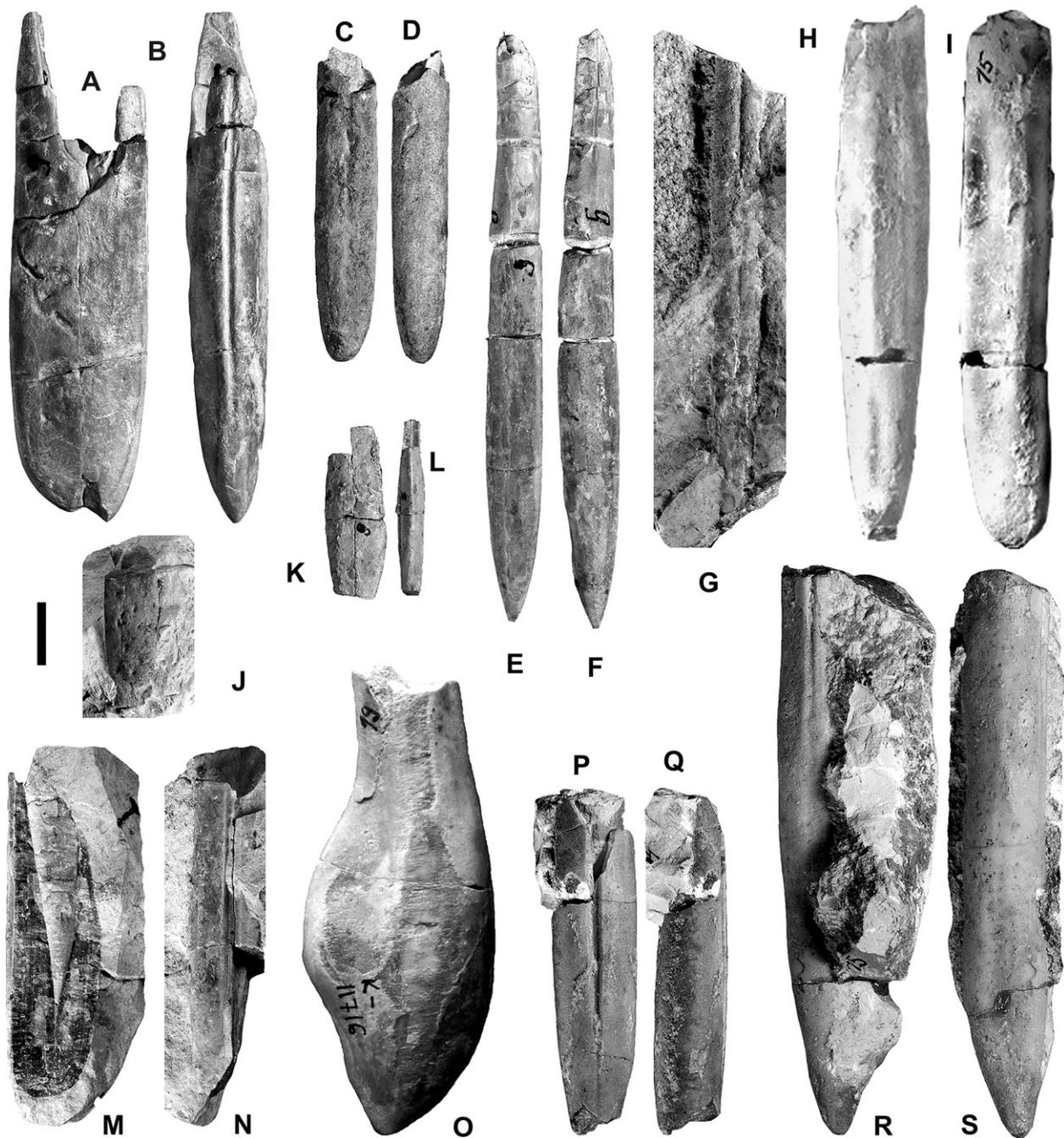


Fig. 7. Representative Berriasian and Valanginian belemnites from the Hárskút section (HK-12). (A), (B) *Duvalia lata lata* (de Blainville, 1827). (Inventory no: K 10.29.1.) lateral and dorsal views, respectively Bed 9, (C), (D) *Castellaniibelus* aff. *orbignyanus* (Duval-Jouve, 1841) (K 10.30.1.) dorsal and lateral views, respectively Bed 9, (E), (F) *Hibolithes laryi*? (Mayer, 1866) (K 10.31.1.) lateral and ventral views, respectively Bed 9, (G) *Pseudobelus* cf. *bipartitus* de Blainville, 1827. (K 10.32.1.) lateral view of alveolar part only, Bed 11, (H), (I) *Duvalia hungarica* sp. nov. (holotype), (K 10.33.1.) dorsal and lateral views respectively, Bed 15, (J) *Berriasibelus* gr. *conicus* (de Blainville, 1827) with *Acrothoracica* pits (K 10.34.1.) dorsal view, Bed 10, (K), (L) *Duvalia emericii* (Raspail, 1829) (imm.) (K 10.35.1.) lateral and dorsal views, respectively Bed 9, (M), (N) *Berriasibelus kabanovi* Weiss, 1991 (K 10.36.1.) Internal lateral and dorsal views, respectively Bed 10, (O) *Duvalia emericii* (Raspail, 1829) (K 11716) lateral view, Bed 9, (P), (Q) *Berriasibelus kabanovi* Weiss, 1991 (K 10.37.1.) dorsal and lateral views, respectively Bed 14, (R), (S) *Duvalia hungarica* sp. nov. (paratype) (K 10.38.1.) dorsal and ventral views, respectively Bed 15. Scale bar: 10 mm.

genus *Calpionellopsis*, which suggests a Late Berriasian age. Further subdivision at the subzone level is also possible. Beds 40–34 are assigned to the *Calpionellopsis simplex* Subzone (previously referred to as Subzone D₁), well-established in all subzonal schemes, on the basis of the range of its index species. Several forms, including *C. elliptica*, persist up to here from the underlying unit. Beds 33–19 are assigned to the *Calpionellopsis oblonga* Subzone (*sensu* Pop, 1994, 1997; Reháková and Michalík, 1997) or Subzone D₂, where the

index species is rare in the lower beds and is accompanied by *Lorenziella plicata* in the uppermost bed of this interval. Beds 18–11 are best assigned to Subzone D₃, using the original standard zonation of Allemann et al. (1971). Diagnostic is the first occurrence of *Lorenziella hungarica* (Fig. 9F). There is a general decrease in calpionellid abundance from Bed 13 upwards, with the decline of *Tintinnopsella* and *Remaniella* being especially noticeable. Neither *Praecalpionellites murgenausii*, nor *P. dadayi* is recorded in our

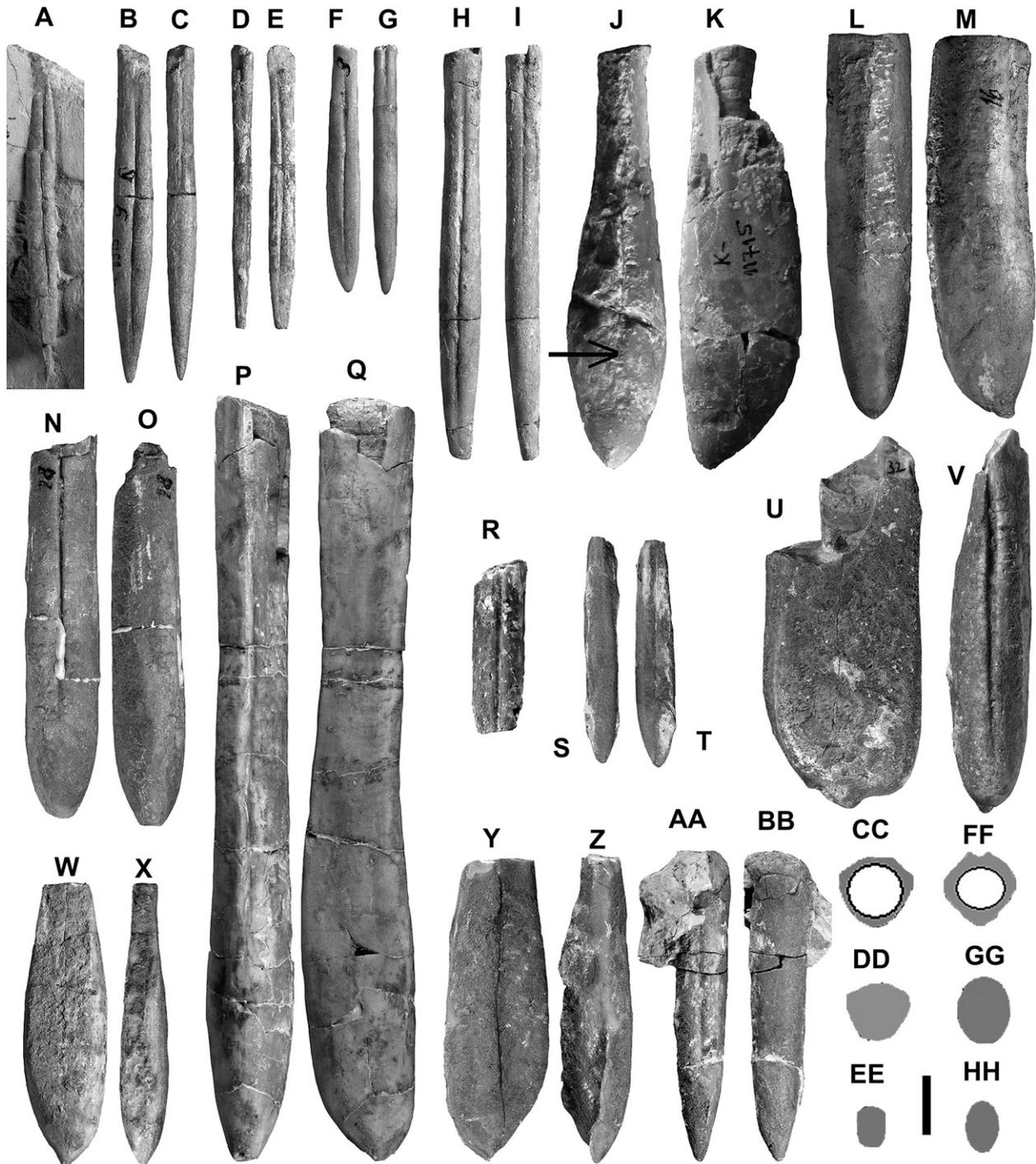


Fig. 8. Representative Berriasian and Valanginian belemnites from the Hárskút section (HK-12). (A) *Pseudobelus* sp. 1 (= *jantikensis*? Nerodenko, 1986). (Inventory no.: K 10.39.1.) lateral view, Bed 5, (B), (C) *Pseudobelus* sp. 1 (= *jantikensis*? Nerodenko, 1986) (K 10.40.1.) lateral and dorsal views, respectively Bed 5, (D), (E) *Pseudobelus* sp. 2 (imm.) (= ? *sultanovkaensis* Nerodenko, 1986; = *gr. bipartitus*) (K 10.41.1.) dorsal and lateral views, respectively Bed 9, (F), (G) *Pseudobelus* sp. 3. (K 10.42.1.) lateral and dorsal views, respectively Bed 9, (H), (I) *Pseudobelus* sp. 2 (= ? *sultanovkaensis* Nerodenko, 1986; = *gr. bipartitus*) (K 10.43.1.) lateral and dorsal views, respectively Bed 9, (J), (K) *Duvalia* aff. *lata constricta* Uhlig, 1902 (K 11715) dorsal and lateral views, respectively Bed 10, arrow indicates the length of the groove, (L), (M) *Duvalia* cf. *lata constricta* Uhlig, 1902 (K 10.44.1.) dorsal and lateral views, respectively Bed 16, (N), (O) *Conobelus incertus* Weiss, 1991 (K 10.45.1.) dorsal and lateral views, respectively Bed 25, (P), (Q) *Duvalia lata constricta* Uhlig, 1902 (K 10.46.1.) dorsal and lateral views, respectively Bed 25, (R) *Berriasibelus* gr. *conicus* (de Blainville, 1827) with *Acrothoracia* pits (K 10.47.1.) dorsal view, Bed 10, (S), (T) *Duvalia miravetesensis*? Janssen, 2003 (juv.) (K 10.48.1.) dorsal and lateral views, respectively Bed 25, (U), (V) *Duvalia* aff. *guillantonae* Besairie, 1930 (K 10.49.1.) lateral and dorsal views, respectively Bed 32, (W), (X) *Duvalia miravetesensis* Janssen, 2003 (K 10.50.1.) lateral and dorsal views, respectively Bed 19, (Y), (Z) *Duvalia miravetesensis* Janssen, 2003 (K 10.51.1.) lateral and dorsal views, respectively Bed 25, (AA), (BB) *Conobelus* (?) *piradoensis* Janssen, 2003 (K 10.52.1.) dorsal and lateral views, respectively Bed 18, (CC), (DD), (EE) cross-sections through *Duvalia hungarica* sp. nov. (holotype) Bed 15, (FF), (GG), (HH) idealised cross-sections through *Duvalia lata constricta*. Scale bar: 10 mm.

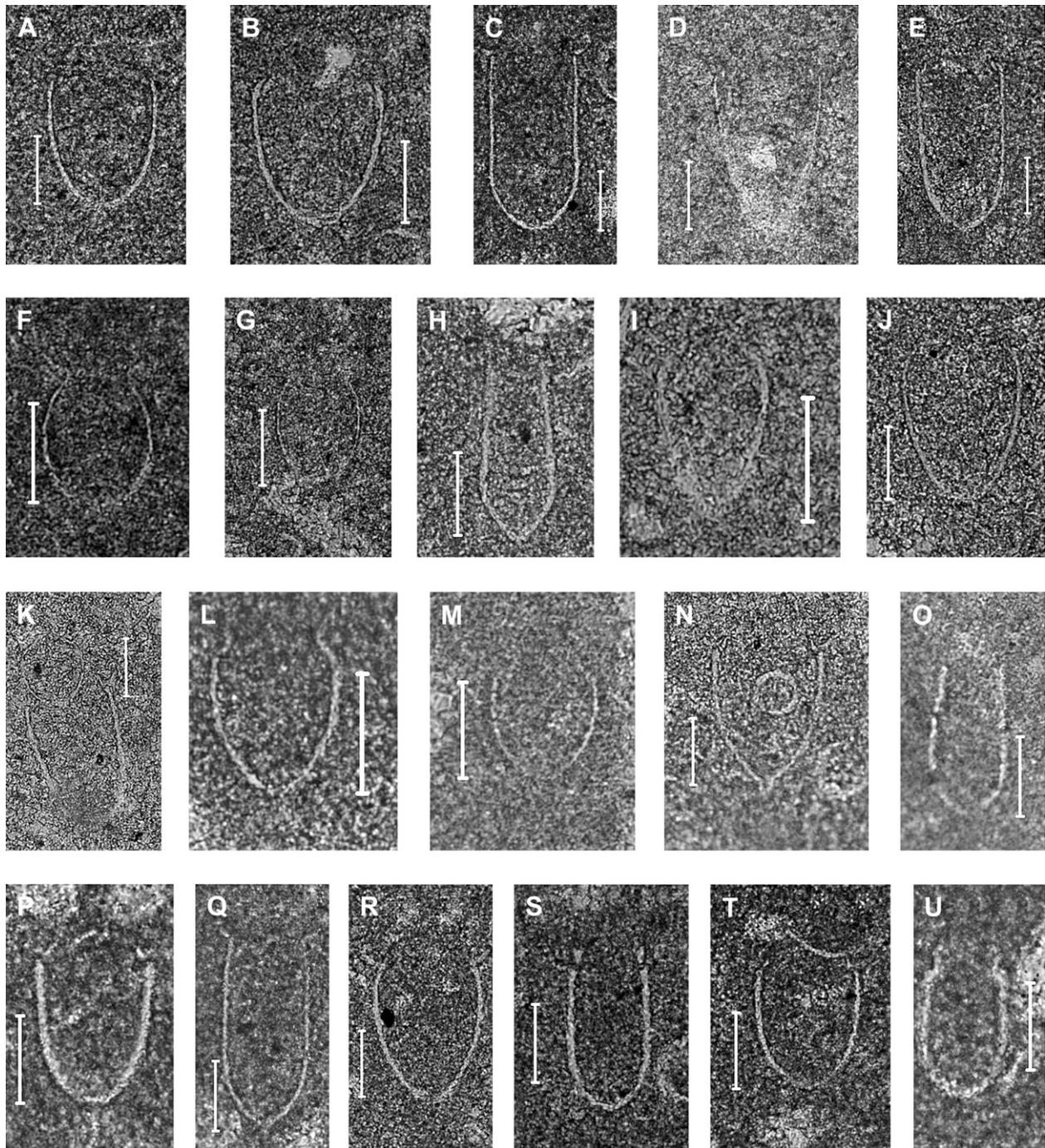


Fig. 9. Characteristic calpionellids from the section HK-12. (A), (B) *Calpionellites darderi* (Colom, 1934), Bed 10, Zone E, (C) *Praecalpionellites dadayi* (Knauer, 1963), Bed 10, Zone E, (D) *Praecalpionellites murgeanui* Pop, 1974, Bed 10, Zone E, (E) *Praecalpionellites siriniaensis* Pop, 1986, Bed 10, Zone E, (F) *Lorenziella hungarica* Knauer et Nagy, 1964, Bed 10, Zone E, (G) *Lorenziella plicata* Le Hégarat et Remane, 1968, Bed 10, Zone E, (H) *Calpionellopsis conoblunga* Nagy, 1986, Bed 14, Zone D₃, (I) *Sopianella* aff. *minuta* Nagy, 1989, Bed 16, Zone D₃, (J) *Borzaiella atava* Grün et Blau, 1996, Bed 16, Zone D₃, (K) *Remaniella cadischiana* (Colom, 1948), Bed 16, Zone D₃, (L) *Lorenziella plicata* Le Hégarat et Remane, 1968, Bed 18, Zone D₃, (M) *Lorenziella hungarica* Knauer et Nagy 1964, Bed 18, Zone D₃, (N) *Praecalpionellites filipescui* (Pop, 1994), Bed 18, Zone D₃, (O) *Calpionellopsis oblonga* (Cadisch, 1932), Bed 33, Zone D₂, (P) *Remaniella colomi* Pop, 1996, Bed 33, Zone D₂, (Q) *Tintinnopsella longa* (Colom, 1939), Bed 33, Zone D₂, (R) *Praecalpionellites filipescui* (Pop, 1994), Bed 36, Zone D₁, (S) *Calpionellopsis simplex* (Colom, 1948), Bed 40, Zone D₁, (T) *Praecalpionellites* aff. *filipescui* (Pop, 1994), Bed 41, elliptica Subzone, (U) *Calpionella elliptica* (Cadisch, 1932), Bed 45, elliptica Subzone. Scale bar: 0.05 mm

samples, thereby the topmost subzones of the *Calpionellopsis* Zone cannot be identified using their index species in the zonation of Pop (1994, 1997), Reháková and Michalík (1997) and Grün and Blau (1997).

Bed 10, where condensation is suspected on the ground of macrofossils, has been sampled at higher resolution. The

lowermost part of the layer is rather poor in calpionellids. Abundance and diversity increases higher up, where *Calpionellites darderi* (Fig. 9A,B), *Calpionellites* aff. *uncinata*, *Calpionellopsis oblonga*, *Praecalpionellites dadayi* (Fig. 9C), *P. murgeanui* (Fig. 9D), *C. alpina*, *T. longa* and *Lorenziella* occur together. This assemblage is assigned to the *Calpionellites darderi* Subzone of the standard *Calpionellites*

Zone (or Zone E in the older terminology), suggesting the Early Valanginian. The subzonal index species is rare near the base of the bed but becomes common in higher samples.

The topmost few centimeters of this layer, labelled for sampling as Bed 10d, differs in containing scarce calpionellids only, including *Lorenziella* spp., *Tintinnopsella carpathica* and *T. laticarpathica* and *Remaniella cadischiana*. This assemblage is assigned to the *Calpionellites hungarica* Subzone (Grün and Blau, 1997) of the standard *Tintinnopsella* Zone (or Zone F in the older terminology), corresponding to the early Late Valanginian.

No calpionellids have been found in any of the higher samples from Beds 9–1, even though their microfacies is otherwise similar to the underlying Bed 10 in containing planktic foraminifers, stomiospheres and biotrital grains.

4.4. Stable isotopes

Measurement of carbon isotope composition of bulk carbonate yielded positive $\delta^{13}\text{C}$ values throughout the section examined (Figs. 10–12). Values around 1.4‰ characterise the lower part of the section, before a rapid 1.6‰ positive shift, reaching a maximum of

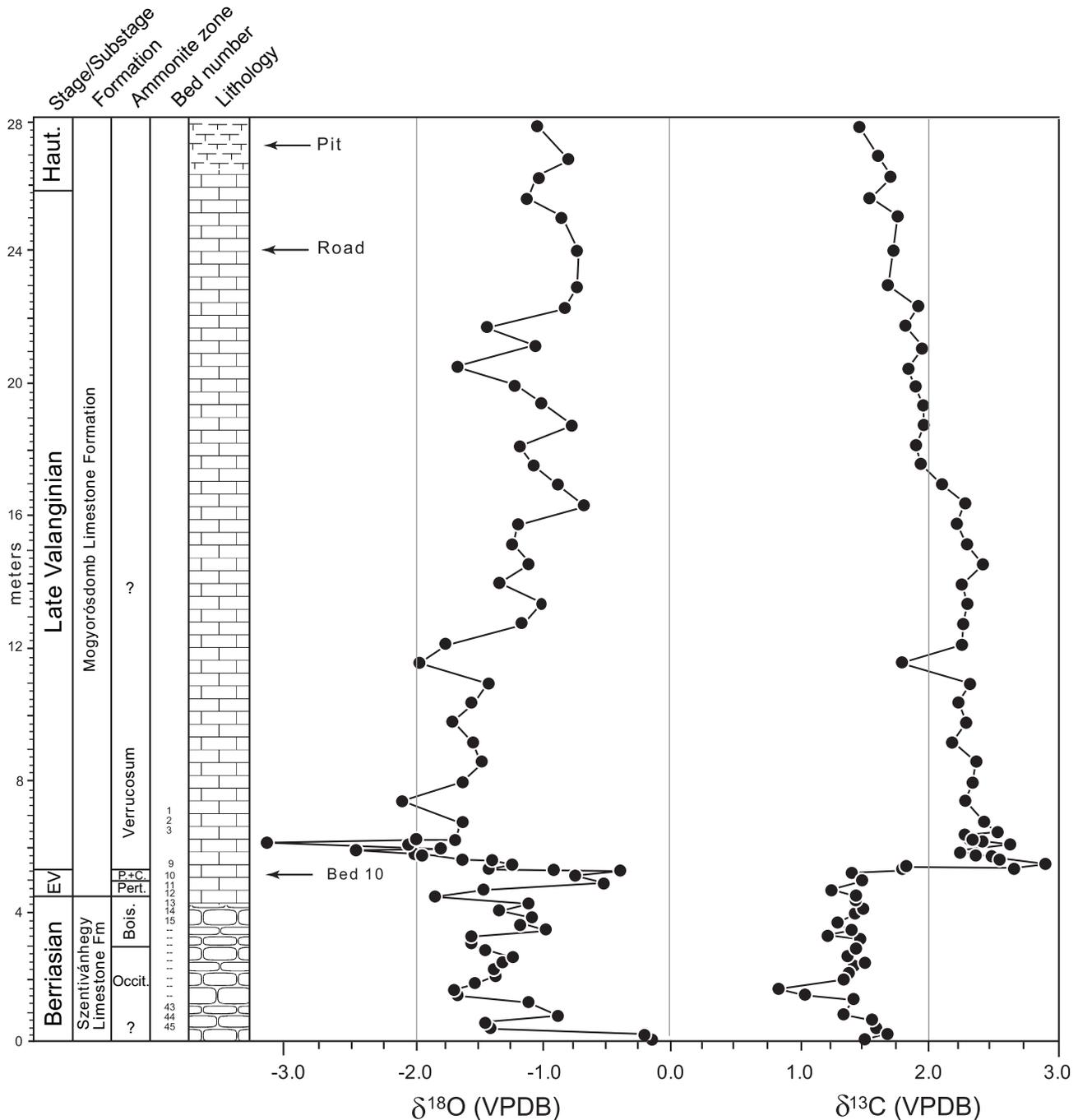


Fig. 10. Simplified sedimentary log of HK-12 section, showing the $\delta^{13}\text{C}$ vs. $\delta^{18}\text{O}$ stratigraphy. EV = Early Valanginian, P + C. = Pertransiens and Campylotoxus; Pert. = Pertransiens, Bois. = Boissieri.

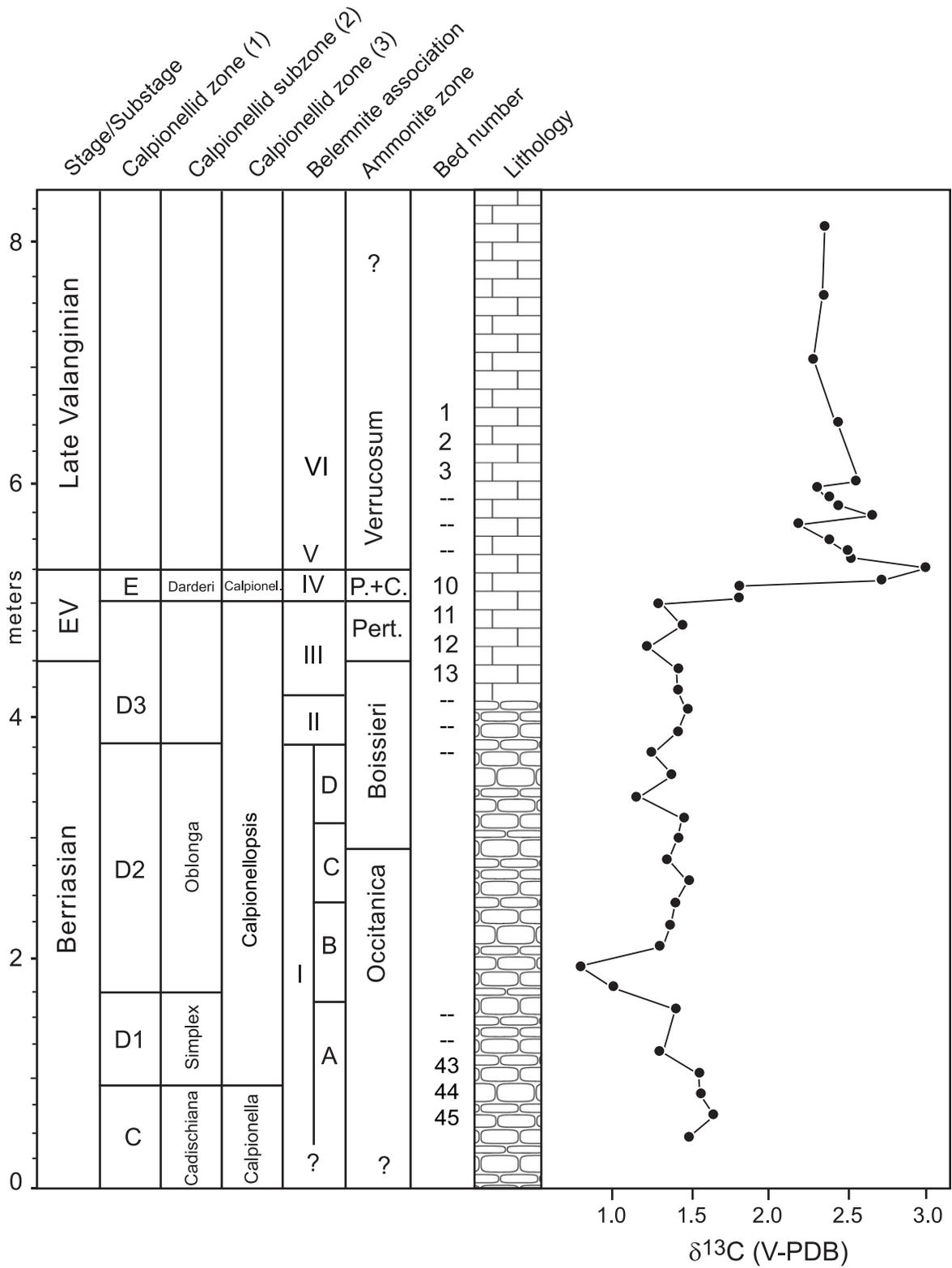


Fig. 11. Simplified sedimentary log and integrated biostratigraphical results for the lower, cephalopod rich part of the HK-12 section, showing the $\delta^{13}\text{C}$ stratigraphy. Abbreviations as for Fig. 10. Calpionellid biostratigraphical schemes after (1) Remane (1963), (2) Grün and Blau (1997), (3) Allemann et al. (1971). Scale does not permit to show Zone F which is restricted to the topmost centimeters of Bed 10, above Zone E.

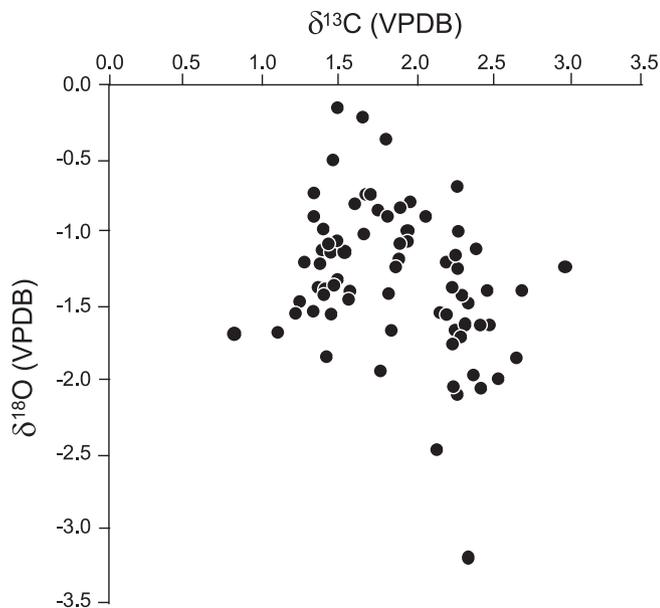


Fig. 12. Cross plot of $\delta^{13}\text{C}$ vs. $\delta^{18}\text{O}$ for bulk carbonate samples from section HK-12 near Hárskút

3.0‰. Following this event a return towards more negative values is observed. Hence at the top of the section a carbon isotope value of 1.4‰ is once again recorded.

Detailed sampling around the positive shift revealed that pre-excursion steady-state values (between 1.2 and 1.5‰) persist into the lower part of Bed 10, increasing to 1.8‰ in the topmost 15 cm of Bed 10, before jumping to values up to 3.0‰, but typically between 2.4 and 2.7‰ in the first meter of sediments above Bed 10.

For the examined interval, a number of works provide more than 30 comparable $\delta^{13}\text{C}$ curves from various Early Cretaceous basins (e.g. Föllmi et al., 1994; Gröcke et al., 2005; Hennig et al., 1999; Weissert et al., 1998; Duchamp-Alphonse et al., 2007). The overall fit of the Hárskút data with existing curves is remarkable. The well-defined positive shift can be unequivocally correlated with the Valanginian event. Minor but significant differences seen are that the positive excursion at Hárskút has a sharp base and the following platform possibly suppressed reflecting either a hiatus or some degree of stratigraphic condensation, as independently suggested by ammonoid biostratigraphic and taphonomic evidence.

The oxygen isotope data vary from ~ -0.2 to -3.2 ‰. The most negative $\delta^{18}\text{O}$ values are seen within the middle part of the section above the positive carbon isotope event. Although showing a degree of scatter, isotope values become increasingly more positive, reaching a value of ~ -0.8 ‰ towards the top of the section. Fluid-rock interactions during diagenesis commonly result in decreasing $\delta^{18}\text{O}_{\text{carb}}$ values (Hudson, 1977). A diagenetic overprint affecting the samples analysed cannot be excluded, hence the oxygen isotope profile is not examined any further. However, the preservation of primary $\delta^{13}\text{C}_{\text{carb}}$ values during diagenesis is quite typical, and is likely due to the buffering effect of carbonate carbon on the diagenetic system, as this is the largest carbon reservoir.

Given the relative abundance of belemnites it was hoped that via isotope analyses further details regarding the palaeoenvironmental conditions at Hárskút could be obtained. The oxygen isotopes of the belemnite rostra ($n = 10$) (*Duvalia cf. lata constricta* and *Pseudobelus* sp.) show only modest variability ranging from -0.75 to 0.96 ‰ (V-PDB), whilst carbon isotopes ranged from -2.05 to 1.78 ‰ (V-PDB). The major potential process that may destroy a primary isotopic signature is diagenetic alteration. Trace elemental analysis

(determined using an ICP-AES) revealed modest Fe (10–1100 ppm) and Mn (5–300 ppm) concentrations within the belemnite rostra which indicates, however, a generally poor state of preservation of these fossils (cf. Price and Mutterlose, 2004; Price et al., 2009). The presence of high levels of Fe and Mn is used as indicator of diagenesis and therefore our preliminary isotope analysis of the belemnites does not provide any further data regarding the palaeoenvironmental setting.

5. Discussion

5.1. Biostratigraphic correlation

5.1.1. Ammonites

The ammonite assemblages are composed exclusively of Mediterranean forms. The dominance of suborders Phylloceratina and Lytoceratina is conspicuous. In Bed 10, the most fossiliferous layer in the section, nearly 50% of the specimens belong to these two groups. The faunal succession agrees well with those known from the other parts of the Mediterranean Province, e.g. the Subbetics in Spain (Aguado et al., 2000; Company, 1987) and Morocco (Wippich, 2003), therefore the standard ammonite zonal scheme (Reboulet et al., 2009) was followed.

The Middle and Late Berriasian fauna can be characterized by a moderately diverse assemblage of representatives of the following genera: *Berriasella*, *Malboscieras*, *Euthymiceras*, *Tirnovella*, *Fauriella*, *Dalmasiceras*, *Kilianiceras* and *Spiticeras*. Many of the species belonging to these ammonite genera are little known and their stratigraphical distribution is uncertain, since most of them are known from the classical monographs only. A thorough revision of these groups – especially the genus *Spiticeras*, which is very common in Hárskút – is badly needed.

T. pertransiens is represented by dozens of well preserved specimens. Both micro- and macroconchs were found and the assemblage shows great variability in coiling and ornamentation which was already demonstrated by Company (1987). According to Wippich (2003), the first appearance of *Neocomites premolicus* is simultaneous with that of *T. pertransiens*, therefore it can be used as an alternative index for the zone. *N. premolicus* (Fig. 4E) is also present in section HK-12. It appears in Bed 11, whereas the first occurrence of *T. pertransiens* is in Bed 12.

The Pertransiens Zone also contains the latest representatives of *Kilianiceras gratianopolitense* (Fig. 3O), and a rich *Olcostephanus* fauna. *O. drumensis* is very common. The distinctive, depressed, small-sized *Olcostephanus stephanophorus* (Fig. 3J,K) is represented by a single specimen. This taxon was chosen by Bulot and Thieuloy (1995) as the index for the interval between Pertransiens and Inostranzewi Zones. According to Bulot and Thieuloy (1995), the latter zone contains three horizons, including the topmost *B. campylotoxus* Horizon. On the other hand, according to one of us (N.J.) the first appearance of *O. stephanophorus* in the Vergol section (France) (V43-44 and V45-46) is in the Pertransiens Zone, consequently it cannot mark the beginning of a distinct, subsequent zone. *O. stephanophorus* – although not well known outside SE France and Switzerland – was figured also from Baluchistan (Fatmi and Rawson, 1993), suggesting a wide geographical range.

The diverse forms assigned to *Kilianella* include some large-sized, coarsely ribbed, poorly known macroconchs in the Lower Valanginian beds which resemble those reported from Morocco by Ettachfani (2004). The most distinctive feature of Bed 10 is the well preserved Neocomitidae fauna, which contains some little known forms and new taxa. Some specimens are identified as *B. campylotoxus*, and many others as *Busnardoites neocomiensiformis* (Fig. 5A,B). The latter species has been misinterpreted by nearly all ammonite workers (for details see Klein, 2005, p. 323) since it was first described

by Uhlig (1902). The species was chosen as the type species of the Early Hauterivian subgenus *Neocomites* (*Teschenites*) by Thieuloy (1971). Recently Busnardo et al. (2003) proposed a new type species (*Teschenites flucticulus* Thieuloy, 1977) for the Hauterivian taxon, and applied the name *B. neocomiensiformis* for the Valanginian forms which are restricted to the Campylotoxus Zone. This view was accepted by Klein (2005) and is also followed herein.

A few specimens from Bed 10 are referred here as *Busnardoites* aff. *campylotoxus* (Fig. 4F), representing little known adult macroconchs, in which the part of the body chamber is also preserved. These forms are close to those described by Uhlig (1902) under the name *Protacantodiscus*.

5.1.2. *Belemnites*

In the studied section HK-12, the lowermost belemnite association (BA-I) contains some characteristic belemnites that previously were only known from southeast Spain (Janssen, 2003), where they were collected from strata from the *Malbosiceras paramimounum* Subzone up to the base of the *Alpillensis* Ammonite Subzone. BA-II contains belemnites (e.g. *Conobelus* (?) *piradoensis*) that were previously described from the *Berriasella alpillensis* Subzone in southeast Spain, and also from Morocco (described as *Hibolithes* in section A18 bed 120, in Mutterlose and Wiedenroth, 2008, p. 817, 822). BA-III contains *B. kabanovi* which occurs from the latest *Alpillensis* Subzone to the *Pertransiens* Zone. The condensed Bed 10 represents BA-IV; it contains *Duvalia* aff. *lata constricta* (Fig. 8J,K). The latter species typically occurs in the Vocontian Basin in the younger part of the *Pertransiens* Zone (beds with *Barronites hirsutus*) and the boundary levels between the *Pertransiens* and the *Campylotoxus* Zones.

Bed 9 yielded *Duvalia emericii* (Fig. 7K,L,O) which is elsewhere characteristic to the top of the *Campylotoxus* Zone and the base of the *Verrucosum* Zone. The last occurrences of *D. ex gr. lata*, *Berriasibelus* and *D. emericii* characterise the so-called *Verrucosum* event, the disappearance of almost all early Valanginian belemnite species and genera (Janssen and Clément, 2002) just above the *Verrucosum* Horizon (= basal part of the *Verrucosum* Subzone). *Pseudobelus* sp. 1 is a typical post-*Verrucosum* event element. *Pseudobelus* sp. 2 (Fig. 8D,E,H,I) is common in the Early-Late Valanginian boundary strata and evolves into *Pseudobelus* sp. 1 in the middle part of the *Verrucosum* Subzone. The beds above did not yield any belemnites.

5.2. Carbon isotope excursion

The Valanginian carbon isotope excursion is a pronounced excursion in marine carbonate, and marine and terrestrial organic carbon-isotope records (e.g. Gröcke et al., 2005; Lini et al., 1992; Weissert et al., 1998; Duchamp-Alphonse et al., 2007). It has been identified throughout the Tethyan area, and has subsequently been located in many other regions of the Northern Hemisphere (e.g. western North Atlantic: Adatte et al., 2001; Bornemann and Mutterlose, 2008; Central Pacific: Erba et al., 2004; Boreal Arctic basin: Price and Mutterlose, 2004) and more recently in the southern hemisphere (Neuquén Basin: Aguirre-Urreta et al., 2008). Given the paleogeographic position of Hárskút in a pelagic basin in the southern margin of the western Tethys, it comes as no surprise to identify the event.

One of the most complete records of the Valanginian carbon isotope event is from the Capriolo section in the Southern Alps (Channell et al., 1993; Lini et al., 1992), which effectively serves as an unofficial reference section (Weissert and Erba, 2004). The shape of the $\delta^{13}\text{C}$ curve is characterized by a rapid, quasi-linear rise from the pre-excursion background, a brief plateau with peak values of $\sim 1.6\text{‰}$ above the pre-excursion level, and a less steep decline to

a new steady-state which is slightly more positive than prior to the event. Primary stratigraphic constraints are provided there by nannofossils and magnetostratigraphy: the *C. oblongata* Zone includes the positive shift, starting in magnetochron CM12, and peak of carbon isotope, falling into CM11. Additional stratigraphic constraints in the Southern Alps are provided by radiolaria (Dumitrica-Jud, 1995) and calpionellids (Channell et al., 1987). The highest record of the latter group, representing Zone E, occurs below the start of the carbon isotope excursion. At Hárskút, nannofossil preservation is poor and precludes reliable identification (M. Báldi-Beke and O. Szives, pers. comm. 2009) and magnetostratigraphy is not available at present. Timing of the local record of the event thus possible through the ammonite, belemnite and calpionellid biostratigraphic framework established above, which in turn can be compared with other sections where similar constraints exist for the Valanginian carbon isotope excursion.

The start of the excursion in the topmost part of the condensed Bed 10 represents the *Campylotoxus* Zone. At the same level, calpionellids suggest the *Lorenziella gr. hungarica* Subzone of Zone F. Significantly, at every ammonite-bearing Tethyan section the carbon isotope shift starts within the *Campylotoxus* Zone (Duchamp-Alphonse et al., 2007; Hennig et al., 1999; Kuhn et al., 2005; Sprovieri et al., 2006). There is some apparent diachronism in the end of positive shift when a plateau of high values is reached, dated by ammonite biostratigraphy as near the top of the *Campylotoxus* Zone (Carajuan, Vocontian Basin: Hennig et al., 1999; Barranco del Garranchal, Betic Cordillera: Kuhn et al., 2005), at the boundary of *Campylotoxus* and *Verrucosum* Zones (Vergol, Vocontian Basin: McArthur et al., 2007), or about one third of the *Verrucosum* Zone (Angles, Vocontian Basin: Duchamp-Alphonse et al., 2007). At Hárskút, the highest $\delta^{13}\text{C}$ values are clearly just above Bed 10 (and assigned to the *Verrucosum* Zone).

The Valanginian carbon isotope event has been interpreted as the expression of a global perturbation of the carbon cycle, resulting in a crisis of carbonate-producing biota (Lini et al., 1992; Erba et al., 2004; Duchamp-Alphonse et al., 2007). Many triggering processes have been proposed to explain this change in the carbon cycle, such as an increase in CO_2 input into the atmosphere due to the emissions of the Paranà-Etendeka large igneous province (Lini et al., 1992; Erba et al., 2004), leading to warming which enhances continental weathering, increases in marine primary productivity and increased storage of organic matter and the drawdown of atmospheric CO_2 , which lead to subsequent cooling (Föllmi et al., 1994). Indeed, different lines of evidence suggest that climate may have become cooler during the Valanginian $\delta^{13}\text{C}$ event (Brassell, 2009; McArthur et al., 2007; Price and Mutterlose, 2004; Pucéat et al., 2003).

5.3. Connection of the Weissert event and the sedimentary and faunal changes

The start of the positive carbon isotope excursion in the studied section coincides with a horizon of stratigraphic condensation, possibly followed by a gap. Bed 10 represents both the *Pertransiens* and *Campylotoxus* Zones and calpionellid zones E and F. There is evidence that the younger zones are confined to the topmost layer within this bed. The sudden jump to peak positive values in the overlying beds in the *Verrucosum* Zone differ from the shape of the carbon isotope curve in complete stratigraphic sections elsewhere (e.g. Duchamp-Alphonse et al., 2007), but the ammonite biostratigraphic resolution does not permit estimation of the gap. Astrochronological constraints from the Chiaserna Monte Acuto section in the Apennines (Sprovieri et al., 2006) suggest a nearly 1 Ma duration for the steep positive excursion on the curve, thereby the hiatus above Bed 10 at Hárskút may

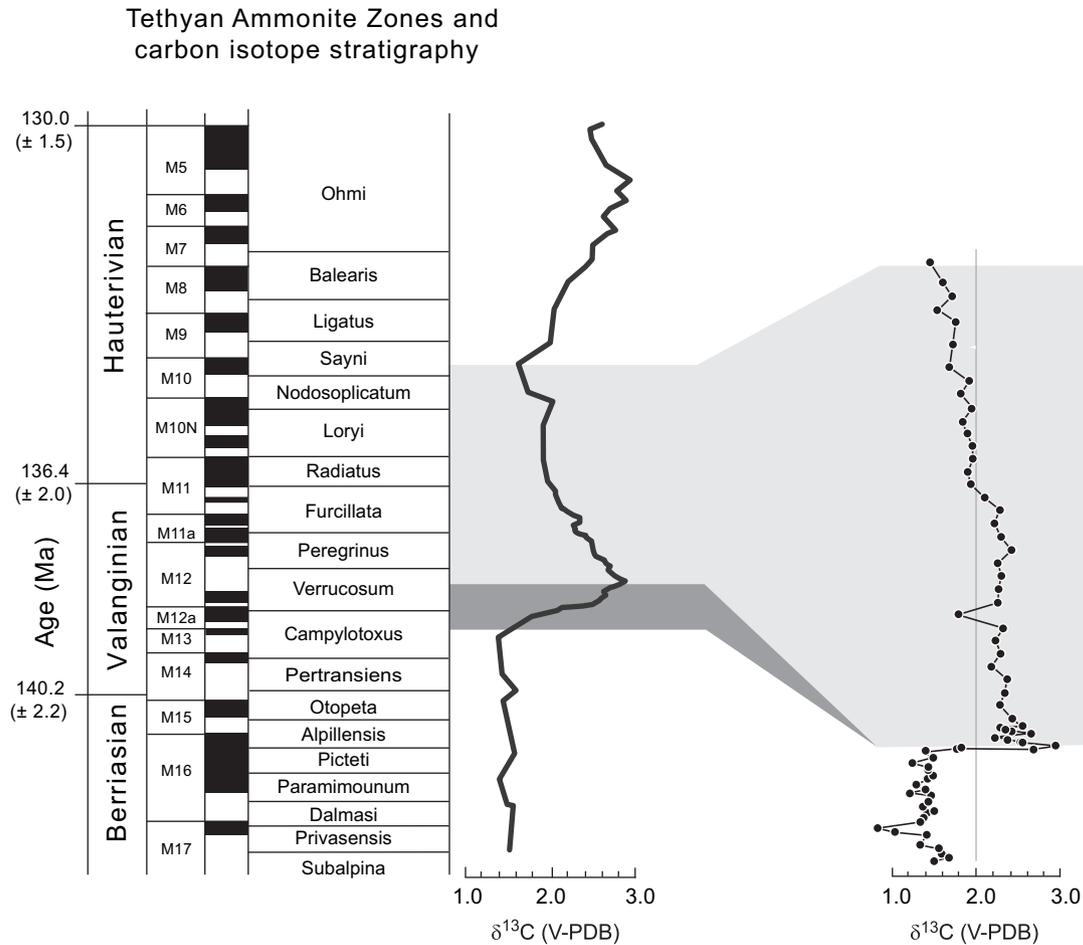


Fig. 13. Late Berriasian–late Hauterivian correlation between the Tethyan $\delta^{13}\text{C}_{\text{carb}}$ curve and the $\delta^{13}\text{C}_{\text{carb}}$ curve from HK-12 section. The Tethyan reference curve is from Weissert et al. (1998). The correlation with ammonite zones is based on a number other sources (e.g.; Hennig et al., 1999; Erba et al., 2004; Weissert and Erba, 2004). Magnetostratigraphy from Channell et al. (1993). Note how stratigraphic condensation and/or gaps in the Campylotoxus and Verrucosum Zones at Hárskút is reflected in the different shapes of the positive carbon isotope excursion.

represent several hundred thousand years. It is interesting to note that the Campylotoxus Zone is also condensed to a single, richly fossiliferous ammonite-bearing bed in the Kacha River section in Crimea, below the start of the isotope shift (Gröcke et al., 2005). A condensed phosphatic interval is also found on the northern Tethyan margin in platform sediments of the Helvetic Alps (Föllmi et al., 2007). In the Southern Carpathians, a more extensive gap exists between the uppermost Berriasian to the mid-Valanginian, thought to be related to the nutrification crisis related to the Weissert event (Barbu and Melinte-Dobrinescu, 2008). A decline in abundance of nannoconids and other changes in the nannofossil assemblages point to a mid-Valanginian fertilization episode as a manifestation of the Weissert event (Erba et al., 2004). We speculate that condensation and hiatus at Hárskút may reflect the nutrification and calcification crises observed elsewhere. If volcanic activity indeed contributed excess amounts of CO_2 to the atmosphere–ocean system, then rising volcanic CO_2 pulses may have caused a decrease in pH and carbonate ion concentration of surface waters (Weissert and Erba, 2004). Related changes in shallow marine environments include widespread platform drowning (Föllmi et al., 1994; Weissert et al., 1998).

In contrast to other Cretaceous OAEs, marine sediments deposited during the Valanginian carbon isotope event lack the widespread occurrence of well developed organic-carbon rich levels. Organic-rich deposits are limited to only a few localities (e.g.

Bersezio et al., 2002). As with many other sections, no black shale or organic-rich level is recorded at Hárskút. Geochemical evidence gathered by Westermann et al. (2010) casts further doubt at the veracity of an OAE during the Valanginian.

Although the Weissert event is not associated with a mass extinction, the attendant environmental changes did influence the biota. In the Hárskút section we note that the disappearance of calpionellids is synchronous with the onset of the carbon isotope excursion. Although it is not the case everywhere, there are many other localities where a significant calpionellid extinction appears to be related to the Weissert event (e.g. Erba et al., 2004). Belemnite faunas locally also show a major turnover and decline above Bed 10 (unit BA-IV). This pattern corresponds to a major belemnite extinction observed in the Verrucosum Zone in the Vocontian Basin and Betic Cordillera (Janssen and Clément, 2002), possibly also causally related to the Weissert event. An early Late Valanginian crisis is also noted in the bryozoan faunas in the Jura Mtn. (Walter, 1989).

6. Conclusions

The Hárskút HK-12 section exposes 28 m of Lower Cretaceous pelagic carbonates which comprise Rosso Ammonitico facies passing upwards into Biancone facies, overlain by marlstones. The locality is within the Bakony Unit of the AlCaPa terrane, its

sedimentary sequence was deposited in deep water environments on the southern margin of the Neotethys. Fossiliferous strata in the lower part of the section contain abundant ammonites and belemnites, whereas its microfauna includes calpionellids. The lithology is amenable to bulk carbonate stable isotope analyses. The key results of our integrated stratigraphic study are the following:

- 1) The succession of 76 ammonite taxa permits the use of the Mediterranean standard ammonite zonal scheme (Reboulet et al., 2009). The basal 6.5 m is subdivided into five zones, from the Middle Berriasian Occitanica Zone to the Upper Valanginian Verrucosum Zone. Beds 12–10, representing the Pertransiens and Campylotoxus Zones are condensed, especially Bed 10 which contains taphonomically distinct ammonites of the Campylotoxus Zone only in its upper part. Above an unfossiliferous interval, the top of the section yielded a Late Hauterivian assemblage.
- 2) More than 100 belemnite specimens from the lowermost >6 m are assigned to 20 taxa. Their stratigraphic distribution permit the recognition of six local belemnite associations, the lowermost of them is further subdivided into four subunits. Calibration of belemnite biostratigraphic units with co-occurring ammonite faunas confirm that the lower part of Hárskút section spans the Middle Berriasian through Upper Valanginian interval. Notably, belemnite-based correlation of the condensed Bed 10 supports its assignment to the Pertransiens and Campylotoxus Zones.
- 3) Distribution of over 20 calpionellid taxa is restricted to the lower part of the section, up to Bed 10. These strata are assigned to calpionellid zones C through F. Six subzones of the more detailed schemes are also recognized. The Berriasian-Valanginian boundary falls within Subzone D3. The lower part of condensed Bed 10 belongs to the *darderi* Subzone of *Calpionellites* (=E) Zone, implying that the D–E zonal boundary falls within the Pertransiens Zone. The topmost part of Bed 10 is assigned to the *hungarica* Subzone, the second subzone of the *Tintinnopsella* (=F) Zone, correlated elsewhere with the Verrucosum Zone. Thus calpionellid biostratigraphy also indicates a significant condensation in Bed 10.
- 4) Carbon isotope ratios measured in bulk carbonate show a four-stage evolution throughout the section. Nearly constant positive values of ~1.3‰ persist up to the Pertransiens Zone, jump rapidly up to 3‰ across a few centimetre thick condensed interval of the late Early Valanginian Campylotoxus Zone and the lowermost layers of the overlying early Late Valanginian Verrucosum Zone, positive values above 2.5‰ are maintained across a narrow interval before a long and gradual decline approximates pre-excursion values by the Late Hauterivian. This carbon isotope curve is confidently correlated with the other carbon isotope records, deviating from its well-established pattern only in the highly condensed nature of its rising segment. Oxygen isotope data obtained from both bulk carbonate and belemnite calcite do not reflect primary values.
- 5) The condensation of the Campylotoxus Zone and the hiatus at the base of Verrucosum Zone at the onset of the carbon isotope excursion is regarded as the unique local manifestation of the Weissert event. It might be causally related to the calcification crisis and nitrification event reported from elsewhere. Disappearance of the calpionellid fauna and the major turnover and decline in belemnite associations are also thought to reflect the local biotic response to the cascade of environmental changes that characterize the Weissert event (Fig. 13).

Acknowledgements

We thank László Kordos (Geological Institute of Hungary) for access to the old cephalopod collection of the Hárskút section, and we are grateful to Miguel Company (Granada) for providing literature and for consulting on ammonite taxonomy and biostratigraphy. Ottilia Szives, Mariann Bosnakoff and Péter Oszvárt are thanked for their assistance during field work. Balázs Koroknai is thanked for his kind help preparing photos on calpionellids. The paper benefited from the comments of Karl Föllmi and an anonymous reviewer. This work was supported by the Hungarian Scientific Research Fund (grants OTKA K68453 and K72633). This is MTA–MTM Paleo contribution No. 113.

References

- Adatte, T., Stinnesbeck, W., Hubberten, H., Remane, J., Lopez-Oliva, J.G., 2001. Correlation of a Valanginian stable isotopic excursion in northeastern Mexico with the European Tethys. In: Bartoline, C., Buffler, R.T., Cantu-Chapa, A. (Eds.), *The Western Gulf of Mexico Basin: Tectonics, Sedimentary Basins, and Petroleum Systems*. AAPG Memoir, vol. 75, pp. 371–388.
- Aguado, R., Company, M., Tavera, J., 2000. The Berriasian/Valanginian boundary in the Mediterranean region: new data from the Caravaca and Chehegin sections, SE Spain. *Cretaceous Research* 21, 1–21.
- Aguirre-Urreta, M.B., Price, G.D., Ruffell, A.H., Lazo, D.G., Kalin, R.M., Ogle, N., Rawson, P.F., 2008. Southern hemisphere early Cretaceous (Valanginian–Early Barremian) carbon and oxygen isotope curves from the Neuquén basin, Argentina. *Cretaceous Research* 29, 87–99.
- Allemann, F., Catalano, R., Farés, F., Remane, J., 1971. Standard Calpionellid Zonation (Upper Tithonian–Valanginian) of the Western Mediterranean Province. In: *Proceedings of the Second Plankton Conference, Roma 1970*, 2, pp. 1337–1340.
- Barbu, V., Melinte-Dobrinescu, M.C., 2008. Latest Jurassic to earliest Cretaceous paleoenvironmental changes in the Southern Carpathians, Romania: regional record of the late Valanginian nitrification event. *Cretaceous Research* 29, 790–802.
- Bersezio, R., Erba, E., Gorza, M., Riva, A., 2002. Berriasian–Aptian black shales of the Maiolica formation (Lombardian basin, southern Alps, northern Italy): local to global events. *Palaeogeography Palaeoclimatology Palaeoecology* 180, 253–275.
- Bornemann, A., Mutterlose, J., 2008. Calcareous nannofossil and $\delta^{13}\text{C}$ records from the early Cretaceous of the western Atlantic Ocean: evidence for enhanced fertilization across the Berriasian–Valanginian transition. *Palaios* 23, 821–832.
- Brassell, S.C., 2009. Steryl ethers in a Valanginian claystone: molecular evidence for cooler waters in the central Pacific during the Early Cretaceous? *Palaeogeography Palaeoclimatology Palaeoecology* 282, 45–57.
- Bulot, L.G., Thieuloy, J.P., 1995. Les biohorizons du Valanginien du Sud-Est de la France: un outil fondamental pour les corrélations au sein de la Téthys occidentale. *Géologie Alpine Mémoire HS 20* (1994), 15–41.
- Busnardo, R., Charollais, J., Weidmann, M., Clave, B., 2003. Le Crétacé inférieur de la Veveyse de Chatel (Ultrasahélienne des Préalpes externes; canton de Fribourg, Suisse). *Revue de Paléobiologie* 22, 1–174.
- Channell, J.E.T., Bralower, T.J., Grandesso, P., 1987. Biostratigraphic correlation of Mesozoic polarity chrons CM1 to CM23 at Capriolo and Xausa (Southern Alps, Italy). *Earth and Planetary Science Letters* 85, 203–221.
- Channell, J.E.T., Erba, E., Lini, A., 1993. Magnetostratigraphic calibration of the Late Valanginian carbon isotope event in pelagic limestones from Northern Italy and Switzerland. *Earth and Planetary Science Letters* 118, 145–166.
- Company, M., 1987. Los ammonites del Valanginiense del sector oriental de las Cordilleras Béticas (SE de España). PhD thesis, Universidad de Granada, p. 294.
- Császár, G. (Ed.), 1997. *Basic Lithostratigraphic Units of Hungary*. Hungarian Geological Institute, Budapest, p. 114.
- Csontos, L., Vörös, A., 2004. Mesozoic plate tectonic reconstruction of the Carpathian region. *Palaeogeography Palaeoclimatology Palaeoecology* 210, 1–56.
- Duchamp-Alphonse, S., Gardin, S., Fiet, N., Bartolini, A., Blamart, D., Pagel, M., 2007. Fertilization of the northwestern Tethys (Vocontian basin, SE France) during the Valanginian carbon isotope perturbation: evidence from calcareous nanofossils and trace element data. *Palaeogeography Palaeoclimatology Palaeoecology* 243, 132–151.
- Dumitrica-Jud, R., 1995. Early Cretaceous Radiolarian Biostratigraphy of Umbria–Marche Apennines (Italy), Southern Alps (Italy and Switzerland) and Hawasina Nappes (Oman). In: Baumgartner, P.O., et al. (Eds.), *Middle Jurassic to Lower Cretaceous Radiolaria of Thethys: Occurrences, Synthesis, Biochronology*. Mémoires de Géologie (Lausanne), vol. 23, pp. 751–797.
- Erba, E., Bartolini, A., Larson, R.L., 2004. Valanginian Weissert oceanic anoxic event. *Geology* 32, 149–152.
- Ettachfini, M., 2004. Les ammonites neocomiensis dans l'Atlas Atlantique (Maroc). *Strata, Mémoire* 43, 1–225.
- Fatmi, A., Rawson, P., 1993. The first Early Cretaceous ammonite faunas from Baluchistan. *Cretaceous Research* 14, 91–100.

- Föllmi, K.B., Weissert, H., Bisping, M., Funk, H., 1994. Phosphogenesis, carbon-isotope stratigraphy, and carbonate-platform evolution along the Lower Cretaceous northern Tethyan margin. *Geological Society of America Bulletin* 106, 729–746.
- Föllmi, K.B., Bodin, S., Godet, A., Linder, P., Van De Schootbrugge, B., 2007. Unlocking paleo-environmental information from Early Cretaceous shelf sediments in the Helvetic Alps: stratigraphy is the key! *Swiss Journal of Geosciences* 100, 349–369.
- Fözy, I., 1990. Ammonite succession from three upper Jurassic sections in the Bakony Mts. (Hungary). In: Comitato Centenario Raffaele Piccinini (Ed.), *Atti del secondo convegno internazionale Fossili, Evoluzione, Ambiente*, Pergola, pp. 323–329.
- Fülöp, J., Géczy, B., Konda, J., Nagy, E., 1969. Földtani kirándulás a Mecsek hegységben, a Villányi-hegységben és a Dunántúli-középhegységben. (Excursion Guide) *Mediterrán Jura Kollokvium Budapest 1969*. The Hungarian Geological Institute, pp. 1–68.
- Fülöp, J., 1964. Unterkreide Bildungen (Berrias–Apt) des Bakony-Gebirges. *Geologica Hungarica Series Geologica* 13, 79–118.
- Galácz, A., 1975. Bajóci szelvények az Északi Bakonyból. *Földtani Közlöny* 105, 208–219.
- Gröcke, D.R., Price, G.D., Robinson, S.A., Baraboshkin, E., Ruffell, A.H., Mutterlose, J., 2005. The Valanginian (Early Cretaceous) positive carbon-isotope event recorded in terrestrial plants. *Earth and Planetary Science Letters* 240, 495–509.
- Grün, B., Blau, J., 1997. New aspects of calpionellid biochronology: proposal for a revised calpionellid zonal and subzonal division. *Revue de Paléobiologie* 16, 197–214.
- Hantken, M., 1868. Lábatlan vidékének földtani viszonyai. *A Magyarhoni Földtani Társulat Munkálatai* 4, 48–56.
- Hennig, S., Weissert, H., Bulot, L., 1999. C-isotope stratigraphy, a calibration tool between ammonite- and magnetostratigraphy: the Valanginian-Hauterivian transition. *Geologica Carpathica* 50, 91–96.
- Horváth, A., Knauer, J., 1986. Biostratigraphy of the Jurassic–Cretaceous boundary beds in the profile Közöskút ravine II at Hárskút. *Acta Geologica Hungarica* 29, 65–87.
- Hudson, J.D., 1977. Stable isotopes and limestone lithification. *Journal of the Geological Society, London* 133, 637–660.
- Janssen, N.M.M., 1997. Mediterranean Neocomian belemnites, part 1: Rio Argos sequence (province of Murcia, Spain): the Berriasian – Valanginian and the Hauterivian – Barremian boundaries. *Scripta Geologica* 114, 1–55.
- Janssen, N.M.M., 2003. Mediterranean Neocomian belemnites, part 2: the Berriasian–Valanginian boundary in southeast Spain (Río Argos, Cañada Lengua and Tornajo). *Scripta Geologica* 126, 121–183.
- Janssen, N.M.M., Clément, A., 2002. Extinction and renewal patterns among Tethyan belemnites in the Verrucosum Subzone (Valanginian) of southeast France. *Cretaceous Research* 23, 509–522.
- Kázmér, M., 1986. Tectonic units of Hungary: their boundaries and stratigraphy (A bibliographic guide). *Annales Universitatis Scientiarum Budapestiensis de Rolando Eötvös Nominatae, sectio Geologica* 26, 45–120.
- Klein, J., 2005. Lower Cretaceous Ammonites I, Perisphinctaceae 1, Himalayitidae, Olcostephanidae, Holcodiscidae, Neocomitidae, Oosterellidae. *Fossilium Catalogus I: Animalia*, 139. Backhuys Publishers, Leiden, p. 484.
- Kuhn, O., Weissert, H., Föllmi, K.B., Hennig, S., 2005. Altered carbon cycling and trace-metal enrichment during the late Valanginian and early Hauterivian. *Eclogae Geologicae Helvetiae* 98, 333–344.
- Lini, A., Weissert, H., Erba, E., 1992. The Valanginian carbon isotope event: a first episode of greenhouse climate condition during the Cretaceous. *Terra Nova* 4, 374–384.
- McArthur, J.M., Janssen, N.M.M., Reboulet, S., Leng, M.J., Thirlwall, M.F., Van de Schootbrugge, B., 2007. Palaeo-temperatures, polar ice-volume, and isotope stratigraphy (Mg/Ca, $\delta^{18}\text{O}$, $\delta^{13}\text{C}$, $^{87}\text{Sr}/^{86}\text{Sr}$): the early Cretaceous (Berriasian, Valanginian, Hauterivian). *Palaeogeography Palaeoclimatology Palaeoecology* 202, 252–272.
- Mutterlose, J., Wiedenroth, K., 2008. Early Cretaceous (Valanginian–Hauterivian) belemnites from western Morocco: stratigraphy and palaeoecology. *Cretaceous Research* 29, 814–829.
- Olóriz, F.S., 1978. Kimmeridgiense-Tithonico inferior en el sector central de las Cordilleras Béticas (Zona Subbética). Tesis doctoral de la Universidad de Granada 184, 1–758.
- Pop, G., 1994. Calpionellid evolutive events and their use in biostratigraphy. *Romanian Journal of Stratigraphy* 76, 7–24.
- Pop, G., 1997. Tithonian to Hauterivian praecalpionellids and calpionellids: bio-events and biozones. *Mineralia Slovaca* 29, 304–305.
- Price, G.D., Mutterlose, J., 2004. Isotopic signals from late Jurassic–early Cretaceous (Volgian–Valanginian) subarctic belemnites, Yatria River, western Siberia. *Journal of the Geological Society, London* 161, 959–968.
- Price, G.D., Wilkinson, D., Hart, M.B., Page, K.N., Grimes, S.T., 2009. Isotopic analysis of co-existing late Jurassic fish otoliths and molluscs: implications for upper ocean water temperature estimates. *Geology* 37, 215–218.
- Pucéat, E., Lecuyer, C., Sheppard, S.M.F., Dromart, G., Reboulet, S., Grandjean, P., 2003. Thermal evolution of Cretaceous Tethyan marine waters inferred from oxygen isotope composition of fish tooth enamels. *Paleoceanography* 18, 1029.
- Reboulet, S., Klein, J., (reporters) and 10 others, 2009. Report on the 3rd International Meeting of IUGS lower Cretaceous ammonite working group, the “Kilian group” (Vienna, Austria, 15th April 2008). *Cretaceous Research* 30, 496–502.
- Rehakova, D., Michalík, J., 1997. Evolution and distribution of calpionellids – The most characteristic constituents of Lower Cretaceous Tethyan microplankton. *Cretaceous Research* 18, 493–504.
- Remane, J., 1963. Les Calpionelles dans les couches de passage jurassique–crétacé de la fosse vocontienne. *Travaux du Laboratoire de la Géologie de l’Université de Grenoble* 39, 25–82.
- Remane, J., Bakalova-Ivanova, D., Borza, K., Knauer, J., Nagy, I., Pop, G., Tardi-Filácz, E., 1986. Agreement on the subdivision of the standard calpionellid zones defined at the 11nd Planktonic Conference, Roma 1970. *Acta Geologica Hungarica* 29, 5–14.
- Sprovieri, M., Cocconeri, R., Lirer, F., Pelosi, N., Lozar, F., 2006. Orbital tuning of a lower Cretaceous composite record (Maiolica Formation, central Italy). *Paleoceanography* 21, PA4212.
- Thieuloy, J.-P., 1971. Reflexions sur le genre *Lytoceras* Hyatt, 1900 (Ammonoidea). *Comptes Rendus des Séances de l’Académie des Sciences* 272, 2297–3000.
- Uhlig, V., 1902. Ueber die Cephalopodenfauna der Teschener und Grodischer Schichten. *Denkschriften der kaiserlichen Akademie der Wissenschaften zu Wien (mathematisch-naturwissenschaftliche Classe)* 72 (for 1901), 1–87.
- Walter, B., 1989. A crisis in the bryozoan fauna, in the Upper Valanginian – Indication of an important cooling in the Jura. *Palaeogeography Palaeoclimatology Palaeoecology* 74, 255–263.
- Weissert, H., Erba, E., 2004. Volcanism, CO₂ and palaeoclimate: a Late Jurassic–Early Cretaceous carbon and oxygen isotope record. *Journal of the Geological Society* 161, 695–702.
- Weissert, H., Lini, A., Föllmi, K.B., Kuhn, O., 1998. Correlation of Early Cretaceous carbon isotope stratigraphy and platform drowning events: a possible link? *Palaeogeography Palaeoclimatology Palaeoecology* 137, 189–203.
- Westermann, S., Föllmi, K.B., Adatte, T., Matera, V., Schnyder, J., Fleitmann, D., Fiet, N., Ploch, I., Duchamp-Alphonse, S., 2010. The Valanginian $\delta^{13}\text{C}$ excursion may not be an expression of a global oceanic anoxic event. *Earth and Planetary Science Letters* 290, 118–131.
- Wipplach, M.G.E., 2003. Valanginian (Early Cretaceous) ammonite faunas from the western High Atlas, Morocco, and the recognition of western Mediterranean ‘standard’ zones. *Cretaceous Research* 24, 357–374.

Appendix. Taxonomic remarks on selected belemnites with description of a new species (by N.M.M. Janssen)

Family Duvaliidae Pavlow, 1914
Genus *Castellanibelus* Combémoré, 1972

Castellanibelus aff. *orbignyianus* (Duval-Jouve, 1841): a species which differs from the nominal one, due to its strong dorso-ventral compression.

Genus *Duvalia* Bayle, 1878

Duvalia aff. *guillantonae* Besairie, 1930 (cf. Janssen, 2003, pl. 6, figs. 10 and 11): a laterally very compressed medium-sized species with a deep alveolus and very long alveolar groove. It is morphologically close to certain morphs of the Hauterivian *Duvalia dilatata*-group or *D. miravetesensis*.

Duvalia aff. *lata constricta* Uhlig, 1902: a species that is characterized by a very strong constriction (“superconstricted”) of the alveolar region. Also immature specimens (data from southeast France) show the same morphology. Both the relative short stratigraphical occurrence and its characteristic morphology make it a suitable marker.

Duvalia aff. *lata lata* (de Blainville, 1827): a species only described from the southeast of Spain (Janssen, 2003, p. 152). It might be a species with stratigraphical importance.

Duvalia hungaria sp. nov. (see below): previously, this new species was known from Río Argos section (west of Caravaca, province of Murcia, southeast of Spain). It was described as *Duvalia* aff. *deeckeri* (Kilian, 1889), (cf. Janssen, 1997, 2003). The latter author provisionally placed this species in the Mesohibolitidae. The material from Hungary definitely proves the new species to belong to the Duvaliidae, being a species close to, and related to the *D. gr. lata*. The incomplete material from Spain, two pieces of the rostrum solidum, originated from between beds Y231–232 and Y244–251, i.e. the Alpilisensis Subzone (latest Berriasian).

Family Pseudobelidae Nerodenko, 1983

Genus *Pseudobelus* de Blainville, 1827: in general, the genus develops into progressively smaller species. Prior to *Pseudobelus* sp. 2, the last of the so-called “longer and bigger” pseudobeloids, *Pseudobelus gr. brevis* Paquier, 1900 occurs, which eventually disappears in the late Hauterivian. The latter group does show laterally compressed cross-sections in all ontogenetic stages, while the older *bipartitus*-group tends to show square-like cross-sections in mature to gerontic specimens.

Pseudobelus sp. 1 (= ? *jantikensis* Nerodenko, 1986): a species intermediate between the long *bipartitus* and the small *brevis*-group. It is characterized by a spindle-shaped outline and very clear, relative deep, lateral grooves. Generally, the apex is pointed and more or less centrally placed.

Pseudobelus sp. 2 (= ? *sultanovkaensis* Nerodenko, 1986): a species very much comparable to *P. bipartitus*. However, differences are only marginal as mature to gerontic species tend to be less long and generally do show a shorter alveolar groove.

Pseudobelus sp. 3: an atypical species, both due to its relative small size but especially for its asymmetrical lateral view (Fig. 8F,G). The apex shifted towards the dorsal side.

Family Duvaliidae, Pavlov, 1914

Genus *Duvalia* Bayle, 1878

Duvalia hungarica sp. nov.

Figs. 7H,I (holotype), 7R,S (paratype), 8CC–EE.

1997 *Duvalia* aff. *deecke*i Kilian: Janssen, p. 15–16, pl. 5, figs. 1–4.

2003 aff. *Duvalia deecke*i Kilian: Janssen, p. 141–142.

Derivation of name. The species is named after the country where the most complete material originates from.

Holotype. The specimen (K 10.33.1.) collected from the Hárskút (HK-12, Bed 15) is stored in the Geological Institute of Hungary (Budapest). A cast of it is stored in the collection of Naturalis (Leiden).

Paratypes. One specimen (K 10.38.1.) from the same section and same bed as the holotype, stored also in the Hungarian Geological Institute. A cast of it is stored in Leiden. Two further, incomplete specimens from Río Argos section (Spain) stored also in Leiden.

Type locality. Section HK-12, Hárskút, Közöskút Ravine, Bakony Mts, Hungary.

Stratigraphic horizon. The holotype and the paratypes were collected from a HK-12, Bed 15, which was assigned to the upper part of the Late Berriasian Boissieri Zone. The Spanish specimens were obtained from beds belonging to the Alpillensis Subzone.

Diagnosis. Medium-sized, rather robust latatoid rostrum with characteristic hexagonal to octagonal cross-sections.

Description. The alveolar groove is relative short and running into a characteristic flattened area, not known from other species of the *Duvalia lata*-group. Lateral expulsions are well developed and shifted towards the dorsal (alveolar) side (Fig. 8CC,DD). The apex appears pointed to blunt and orientated at the dorsal side. The alveolus is very shallow, not reaching beyond the length of the alveolar groove. Both dorsal and ventral side appear to be near parallel for most part, and do not show a constriction towards the alveolar region.

Remarks. Reminiscent of *Duvalia deecke*i Kilian, 1889. The latter species was described from a lithostratigraphical unit in the southeast of Spain that straddles the Jurassic-Cretaceous boundary. It is a junior synonym of *Duvalia tithonia* (Opell, 1865). The latter shows a comparable dorsal groove but not the flattened area on the dorsal side, nor the irregular outline in lateral view, nor reaches it the size of the new species. The closely related, and probable ancestor *D. lata constricta* (Fig. 8P,Q) never shows a hexagonal to octagonal outline but is always rounded, with a well developed alveolar groove but no characteristic flattened dorsal area.

Geographical distribution. The species is known from the Mediterranean Realm, from the territory of Hungary and Spain.

Associated belemnites. The new species occurs with *Duvalia* gr. *lata* and *Pseudobelus bipartitus*. Less common species, including *Conobelus incertus* and *Conobelus* (?) *piradoensis*, occur in the same stratigraphical interval.