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The Early Cretaceous *Karsteniceras* Level in the Vienna Woods (Northern Calcareous Alps, Lower Austria)

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Abstract: Detailed paleontological and lithological studies of Lower Cretaceous sediments from the Northern Calcareous Alps in Lower Austria uncovered spectra of Lower Barremian macrofaunal elements (e.g. ammonoids). Within the Sparbach section, these investigations also uncovered an equivalent of the *Karsteniceras* Level, which is characterized by the abundance of *Karsteniceras ternbergense* Lukeneder and was initially described 150 km away in the Ternberg Nappe. Striking similarities in faunal spectra, lithology and geochemistry between these two laterally correlated occurrences are reported. The newly detected ammonoid mass-occurrence (Sparbach section) dominated by *Karsteniceras ternbergense* is of Early Barremian age (*Coronites darsi* Zone). About 250 specimens of *K. ternbergense* between 7 and 29 mm in diameter were investigated. The geochemical results indicate that the *Karsteniceras* mass-occurrence within this Lower Cretaceous succession was deposited under intermittent oxygen-depleted conditions. Due to the additional finding of the *Karsteniceras* Level at Sparbach, the formerly described *Karsteniceras* Level (KB1-B section, Upper Austria) takes on the status of a more widespread, laterally, biostratigraphically significant 'horizon', at least for the Northern Calcareous Alps. Its potential status as a stratigraphic horizon and its potential for correlation is underlined by its broad geographic range. The cephalopod fauna at the outcrop belongs exclusively to the Mediterranean Province.

Key words: Early Cretaceous (Early Barremian), Northern Calcareous Alps, ammonoids, ammonoid mass-occurrence, *Karsteniceras* Level.

Introduction

Lower Cretaceous pelagic sediments are well known to form a major element of the northernmost tectonic units of the Northern Calcareous Alps (e.g. Frankenfels, Lunz, Ternberg, and Reichraming Nappes). They cover wide areas both within the latter (e.g. Flössel, Rossfeld, Losenstein, Schneeberg, Anzenbach, and Ebenforst Synclines) and in various other European areas (e.g. Vocontian Basin, Dolomites, Umbria, Western Carpathians, Gerecse and Mecsek Mountains, and others).

The most recent publications by Immel (1987), Faupl et al. (1994), Vašíček & Faupl (1998), and Lukeneder (1998, 1999, 2001, 2003a,b) deal with the stratigraphy of the Lower Cretaceous synclines in the Reichraming, Frankenfels and Lunz Nappes.

The discovery of a Lower Cretaceous cephalopod mass-occurrence in the Losenstein Syncline (KB1-B section, Ternberg Nappe, Northern Calcareous Alps, Upper Austria), of Early Barremian age, was recently published by Lukeneder (2003b). A *Karsteniceras* mass-occurrence in two beds only 150 mm thick was reported in the latter paper. An invasion of an opportunistic (r-strategist) *Karsteniceras* biocoenosis during unfavourable conditions over the sea-bed during the Early Barremian was proposed for the KB1-B section. As noted by Lukeneder (2003b), the deposition of the limestones in this interval occurred in an unstable environment and was controlled by short- and long-term fluctuations in oxygen levels. The author therefore assumed that *Karsteniceras* inhabited areas of stagnant water with low dissolved oxygen.

Such 'ammonoid beds' are the result of bio-events often manifested by an abundance or mass-occurrence of ammonoids. The *Karsteniceras* Level described herein is also observable some 150 km west in the Ternberg Nappe. This indicates that both mass-occurrences were formed by the same bio-event and that the former is therefore an equivalent of the Upper Austrian occurrence. The present paper argues for the lateral correlation of such ammonoid mass-occurrences and for the establishment of ammonoid abundance zones in stratigraphic correlations within the Northern Calcareous Alps.

Study area and tectonic position

The outcrop is situated in the Frankenfels-Lunz Nappe System (Höllenstein Unit) in Lower Austria, about 1.5 km north of Sparbach (350 m, ÖK 1:50,000, sheet 58 Baden; Fig. 1). This outcrop is located in the south-easternmost part of the northeast-southwest striking Flössel Syncline, running between the Höppelberg (700 m) to the west and near the Heuberg (680 m) to the east. It lies at the southern side of the Sparbach stream, 300 m west of the Johannstein ruin within the nature park of Sparbach. The exact position of the ammonoid-occurrence was determined by GPS (global positioning system): N 48°05′15″ and E 16°11′00″ (Fig. 2).

The fossiliferous beds are part of the Schrambach Formation within the Flössel Syncline. The general tectonic style is that of steep synclines and anticlines (e.g. Höllenstein Anticline, Flössel Syncline) (see Toula 1886; Richarz 1905, 1908;

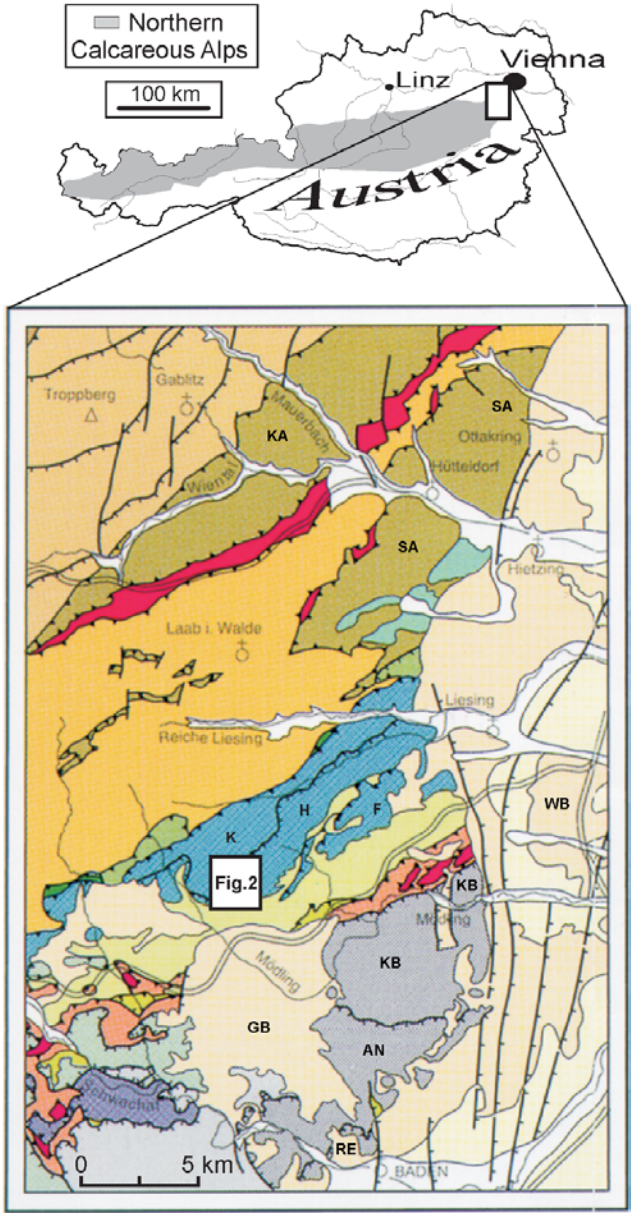

Fig. 1. Sketch map of the excavation site N of Sparbach. The Upper Austroalpine Northern Calcareous Alps extend from the Austrian western border to the city area of Vienna. The white square indicates the geological area of the sketch map below. Sketch map of the NE spur of the Northern Calcareous Alps: **WB** — Vienna Basin, **GB** — Gaadener Basin; Flysch Zone: **KA** — Kahlenberg Ridge, **SA** — Satzberg Ridge; Frankenfels–Lunz Nappe System: **K** — Kalksburger Unit, **H** — Höllenstein Unit, **F** — Föhrenberg Wasserspreng Unit; Ötscher Nappe System: **KB** — Kalenderberg Scale, **AN** — Anninger Scale, **RE** — Rauheneck Scale (scale 1:400,000). Map after ÖK 1:50,000, sheet 58 Baden (Geological Survey Vienna, 1997). White square indicates the area of sketch map Fig. 2.

Spitz 1910; Schwinghammer 1975). The Flössel Syncline is formed of Upper Triassic dolomite, followed by a reduced Jurassic sequence (see also Rosenberg 1965; Plöchinger & Prey 1993). The core of the Flössel Syncline consists of the Lower Cretaceous Schrambach Formation, which occurs throughout the Northern Calcareous Alps. Within the Lunz Nappe the Schrambach Formation comprises Upper Valanginian to Lower Barremian sediments.

Material and ammonoid fauna

Bed-by-bed collecting and a systematic-taxonomic study provide the basic data for statistical analysis of the investigated ammonite faunas. Paleontological and paleoecological investigations, combined with studies of lithofacies in thin sections, peels from polished rock surfaces and geochemical investigations, yielded information about the environmental conditions in the area of deposition.

Carefully selected and washed samples of distinct laminated limestones contain primarily fine silt-sized, angular quartz grains, some pyrite and phosphatic material (fish scales, teeth and bones, ichthyoliths). The rare, generally poorly preserved micro-invertebrate fauna consists of a few arenaceous fora-

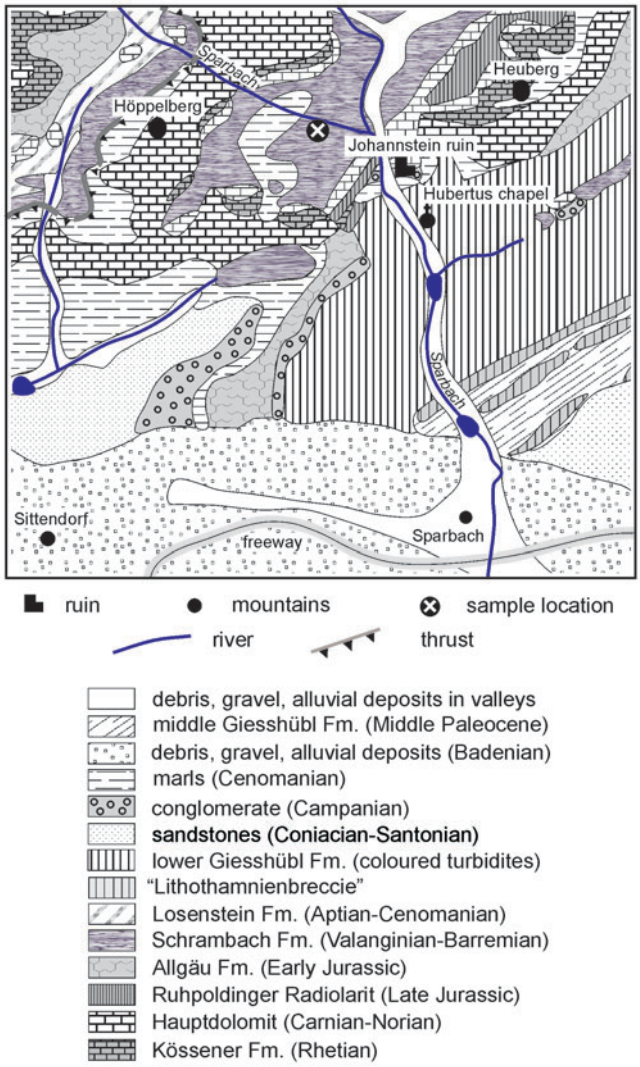

Fig. 2. Geological situation and sediments of the Flössel Syncline with indicated position of the Sparbach locality.

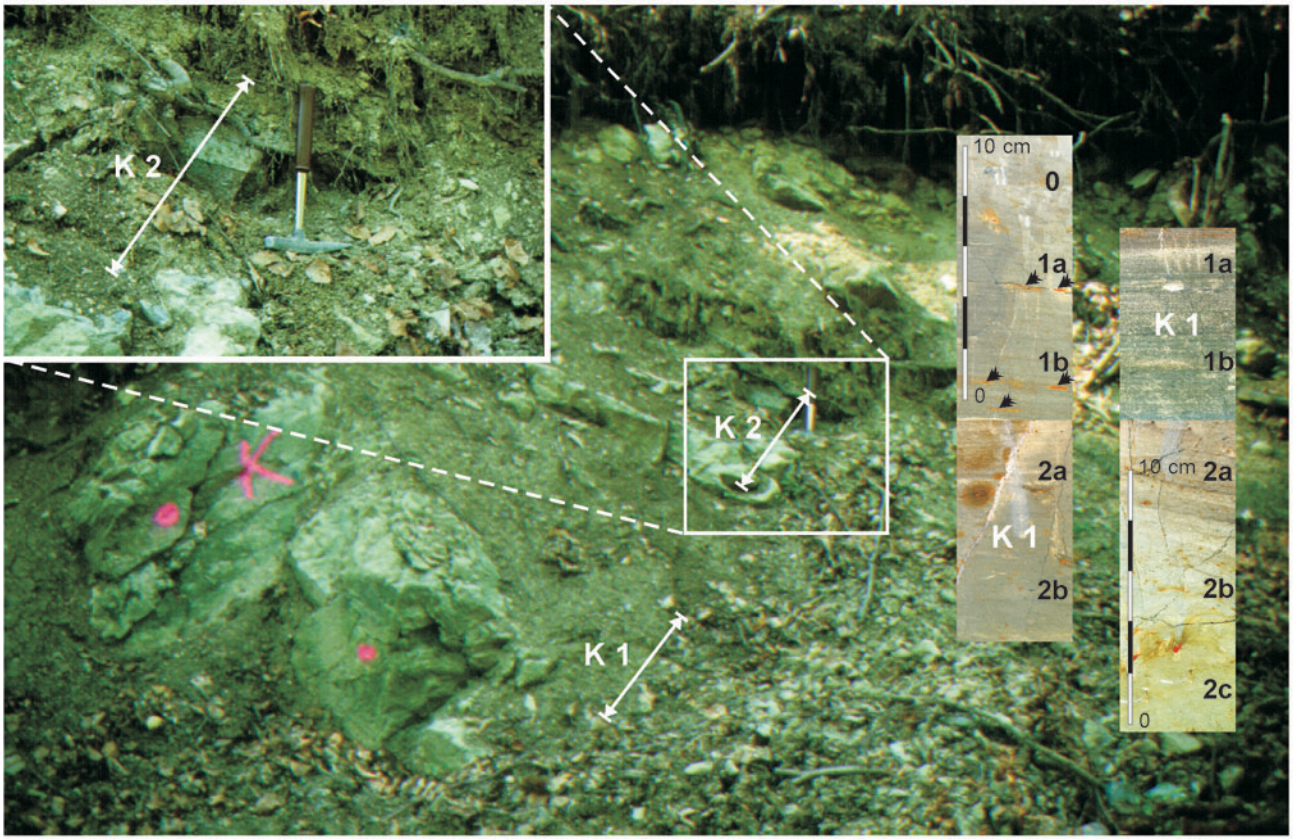

Fig. 3. The locality with indicated position of the *Karsteniceras* Level (K1–K2). On the right side, two longitudinal scans of the polished surface of the beds 0–2c from the abundance beds. Note the indistinct lamination of beds 1a–2a. Beds 2b and 2c are not laminated due to bioturbation. Black arrows indicate positions of limonitic specimens of *Karsteniceras*.

minifers (planktonic), radiolarians, ostracods, and sponge spicules (investigated in thin sections).

The macrofauna from bed K1 (beds 1–2; samples 1a–2c) and K2 (bed A; sample Aa) (Figs. 3 and 4) is predominated by sculpture-moulds of cephalopods. The poorly preserved limonitic ammonite moulds are accompanied by a single lamellaptychus-like ammonoid jaw.

Six genera of Ammonitina and Ancyloceratina (suborders), comprising 3 different species, are reported in this paper. The cephalopod fauna at the outcrop covers exclusively forms of the Mediterranean Province, which are typical for the Northern Calcareous Alps. The cephalopods can be found in the whole sequence but seem to be concentrated at a certain level.

About 250 specimens of *Karsteniceras ternbergense* between 7 and 29 mm in diameter were investigated (122 specimens were measured). Most of the specimens are observable on one side only; they are entire and show no fragmentation. Juvenile stages and the ventral area can be observed in just a few specimens. The very abundant small heteromorphs are generally poorly preserved. Their casts (sculpture moulds), with perfectly preserved sculpture, are usually pyritized. The current paper follows the classification of the Cretaceous Ammonoidea summarized by Wright et al. (1996).

The *Karsteniceras* Level at Sparbach yields important ammonoid taxa such as *Eulytoceras* sp., *Barremites (Barremites)* cf. *difficilis* (d'Orbigny, 1841), *Pulchellia* sp., *Holcodiscus* sp., *Anahamulina* cf. *subcincta* (Uhlig, 1883) and *Karsteniceras ternbergense* Lukeneder (in Lukeneder & Tanabe 2002). The cephalopod fauna is accompanied by aptychi (*Lamellaptychus*) and bivalves (*Propeamusium*) (Figs. 5 and 6).

The analysis of the fauna supports the interpretation of a soft to level bottom paleoenvironment with a cephalopod-dominated community living near the epicontinental (epeiric) sea floor.

Lithology of the *Karsteniceras* Level

The Lower Cretaceous Schrambach Formation is a sequence of deep-water limestones and marls marked by rhythmically intercalated turbiditic sandstones, sedimented under relatively deep-water conditions. A short-term sedimentation is proposed for the sandstone layers, whereas the limestone- and marl-beds reflect 'normal' sedimentation rates.

Dark marls and grey, spotted limestones are highly bioturbated biogenic mudstones to wackestones. The occurrence of chrome spinel supports the correlation with the turbiditic intercalations in the Schrambach Formation of the Reichraming Nappe (Upper Austria), a western equivalent of the Lunz Nappe, and supports the interpretation that the sandstone in-

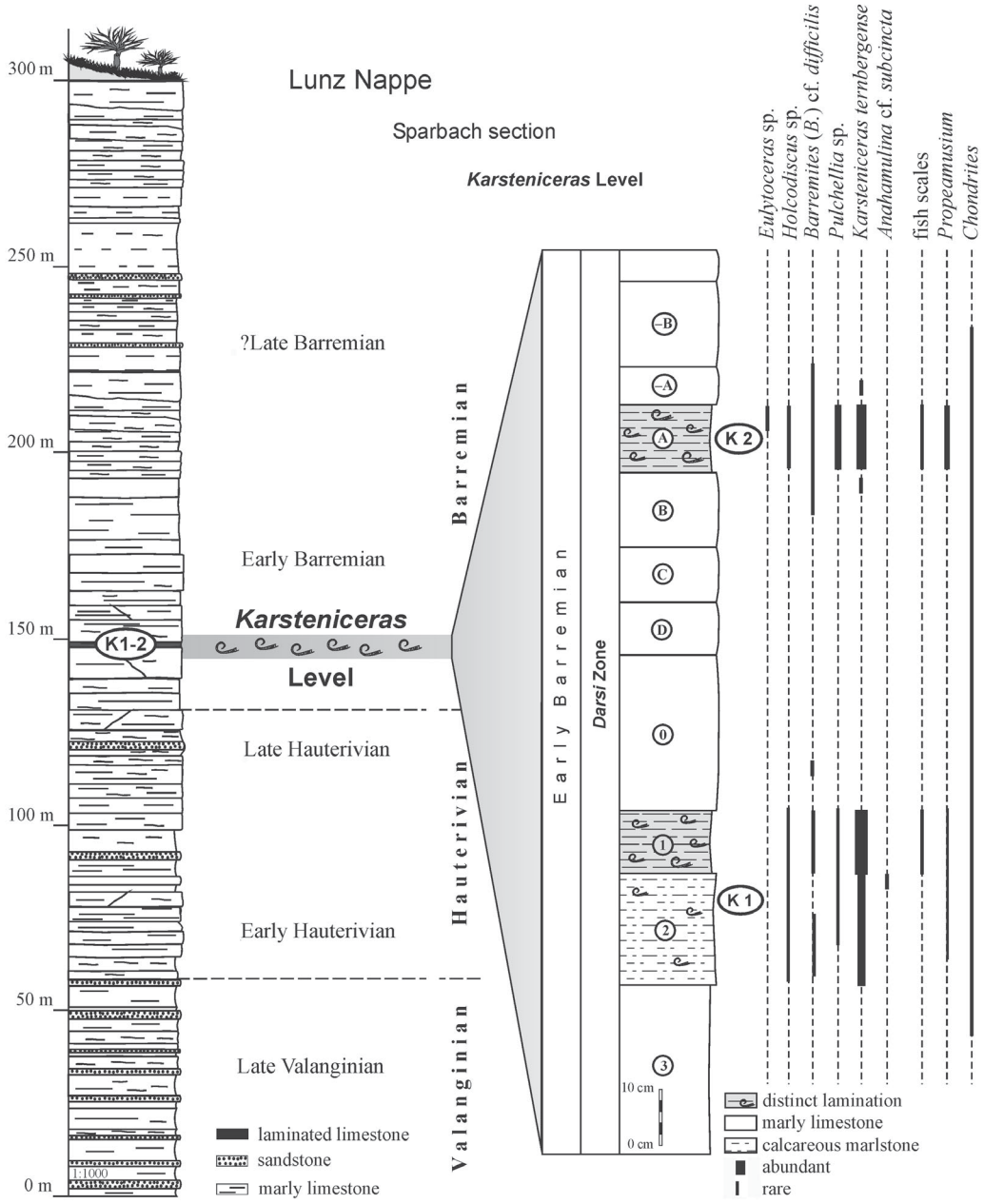

Fig. 4. Fauna and position of the *Karsteniceras* Level within the log (Schrambach Formation).

tercalations are derived from a more southerly situated landswell (Vašíček et al. 1994).

The calcium carbonate contents within the *Karsteniceras* Level (K1 and K2; Fig. 4) ($CaCO_3$ equivalents calculated from total inorganic carbon) vary between 73 and 83 %. The wt. % TOC (Total Organic Carbon) values vary between 0.03 and 0.52 %. Sulphur ranges from 0.27 to 0.57 mg/g (Fig. 7).

The distinct-laminated appearance of the rock is a result of wispy, discontinuous, flaser-like laminae of dark (organic) material and some sorting of radiolarian tests into the layers. Many of these tests have been partly to completely replaced by pyrite (secondarily limonitic) in a micritic carbonate matrix. Pyritized radiolarians seem to be predominantly preserved around ammonoid tests. This could be due to the altered 'micro-environment', specifically the higher organic content (soft-body). The laminae range in thickness from 0.07–0.1 mm to 0.7–2.4 mm. Contacts between them are gradational to sharp. Phosphatic debris is abundant and consists mainly of fish scales, bones and teeth. Laminated brown-black mudstone is rich in organic carbon. Dark material is wispy amorphous organic matter. Pale areas are laminae of flattened radiolaria now replaced by microcrystalline chalcedony.

Systematic paleontology

Conventions: The standard dimensions for *Karsteniceras ternbergense* are given in millimeters. The following abbrevi-

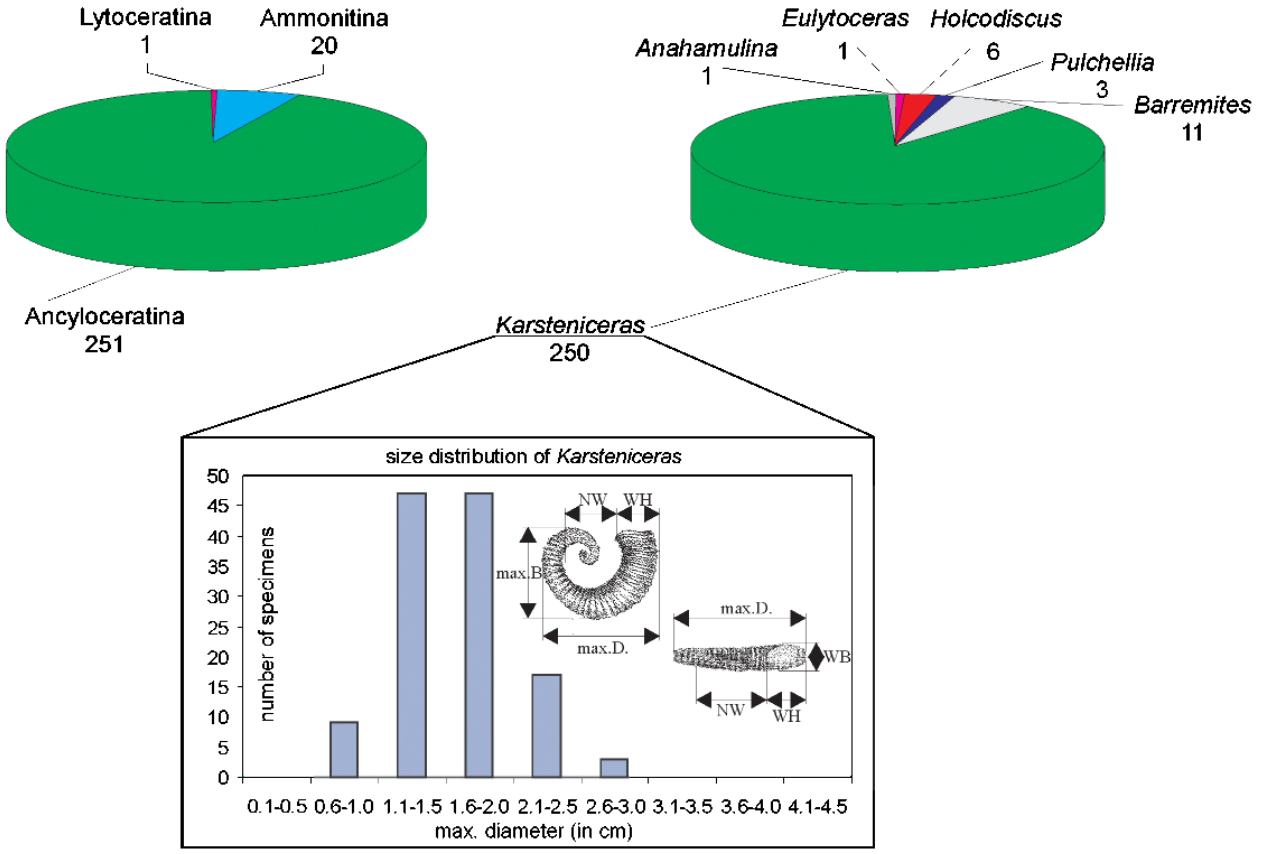

Fig. 5. Ammonoid spectrum from the Sparbach locality. Note the dominance of the genus *Karsteniceras* (Ancyloceratina). Size distribution (below) of the species *Karsteniceras ternbergense*. Conventions: **max. D.** — shell diameter, **max. B.** — maximum breadth, **WH** — maximum whorl height, **NW** — umbilicus width, **WB** — whorl breadth.

ations have been used (Fig. 5): max. D. — shell diameter; max. B. — maximum breadth; WH — maximum whorl height; NW — umbilicus width; WB — maximum whorl breadth; NHMW — Naturhistorisches Museum Wien. The author follows the classification of the Cretaceous Ammonoidea by Wright et al. (1996). Only specimens of the species *Karsteniceras ternbergense*, which are the dominant element of the fauna and the eponymous element of the investigated level, are described systematically herein. The measurements include only those from almost complete or well-preserved specimens.

Order: **Ammonoidea** Zittel, 1884
Suborder: **Ancyloceratina** Wiedmann, 1966
Superfamily: **Ancyloceratacea**e Gill, 1871
Family: **Ancyloceratidae** Gill, 1871
Subfamily: **Leptoceratoidinae** Thieuloy, 1966
Genus: *Karsteniceras* Royo y Gomez, 1945
Type species: *Ancyloceras beyrichi* Karsten, 1858

Karsteniceras ternbergense Lukeneder *in* Lukeneder & Tanabe 2002
Fig. 6.7–15

2002 *Karsteniceras ternbergense* Lukeneder — Lukeneder & Tanabe, p. 18, Figs. 3A–C, 5–6
2003b *Karsteniceras ternbergense* Lukeneder — Lukeneder, p. 96, Pl. 10, Figs. 1–13

Material: 250 crushed and mainly limonitic specimens (sculpture moulds) from the locality near Sparbach, beds K1 and K2 (Figs. 3 and 4). Most specimens are entire and show no fragmentation. Juvenile stages and the ventral area can be observed in a few specimens. The suture line is not visible. The whorl height (WH) varies from 2–7 mm, whereas the whorl breadth (WB) values are relatively constant from 0.6–2 mm due to compaction.

Description: The small, criocone shells probably show weak torsions (trochospiral coiling). The spire becomes criocone after an advolute embryonal and juvenile stage. Some specimens become advolute in the middle of one whorl and revert to a criocone whorl later. A few specimens seem to be advolute over most of the whorl-distance. The species apparently has a highly variable coiling (Lukeneder 2003b). The sculpture comprises relative dense, sharp and simple ribs (Lukeneder & Tanabe 2002; Lukeneder 2003b) intercepted by stronger main ribs on the body chambers (only visible in few specimens). The largest specimen reaches a diameter of 39 mm. Single, sharp, uniform ribs cross the venter without a ventral depression or furrow. Up to 45–50 single ribs are present on one whorl. No tubercles occur.

Remarks: *Karsteniceras ternbergense* differs from all other descendant species of the genus *Karsteniceras* in its clear and distinct main ribs on the body chamber of adult specimens, different maximum size and number of ribs per whorl (Lukeneder & Tanabe 2002; Lukeneder 2003b). A detailed

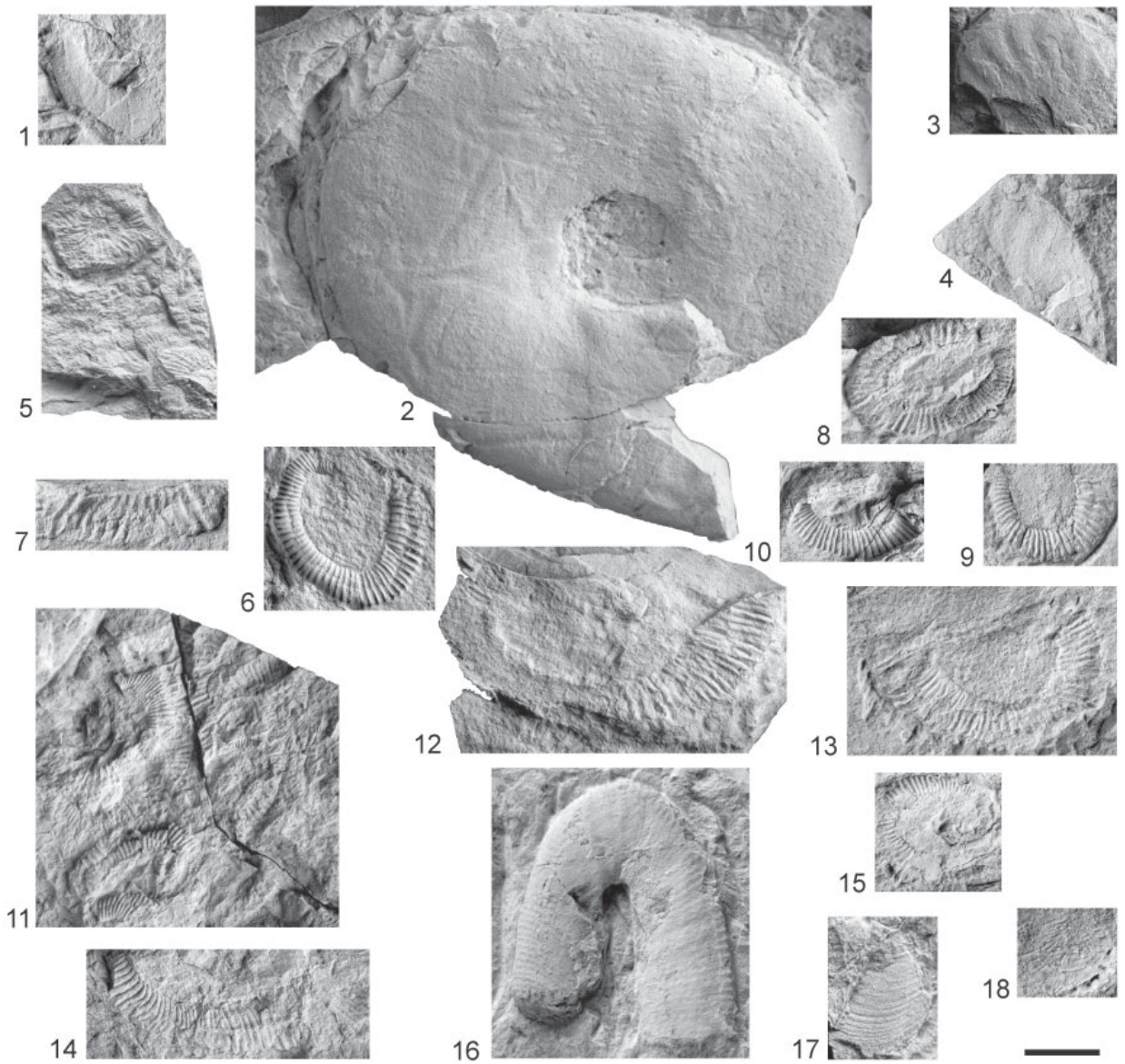

Fig. 6. Early Barremian Lytoceratina, Ancyloceratina, aptychi and bivalves from the Flössel Syncline (Schrambach Formaion). Typical representatives of the Sparbach assemblage. **1** — *Eulytoceras* sp.; 2004z00/0001. **2** — *Barremites (Barremites)* cf. *difficilis* (d'Orbigny, 1841), 2004z00/0002. **3–4** — *Pulchellia* sp., 2004z00/0003-04. **5** — *Holcodiscus* sp., 2004z0045/0005. **6–15** — *Karsteniceras ternbergense* Lukeneder, 2002, 2004z0045/0006-15. **16** — *Anahamulina* cf. *subcincta* (Uhlig, 1883), 2004z00/0016. **17** — *Lamellaptychus* sp., 2004z00/0017. **18** — *Prepeamusium* sp. (bivalve), 2004z00/0018. All specimens were collected at the Sparbach section, coated with ammonium chloride before photographing and are stored at the Museum of Natural History Vienna. Scale bar for 1–16, 18 = 10 mm; for 17 = 2.5 mm.

discussion of the genus *Karsteniceras* and morphological details of its members is given in Vašíček & Wiedmann (1994) (see also Vašíček & Klajmon 1998).

Stratigraphic range: *Karsteniceras ternbergense* has been found in one level (two beds) of Early Barremian age in the Sparbach section of the Lunz Nappe (Lower Austria, Northern Calcareous Alps). Due to the earlier-mentioned stratigraphically important taxa, the stratigraphic range of *Karsteniceras ternbergense* Lukeneder is proposed to be the *Coronites darsi* Zone (former *Moutoniceras moutonianum* Zone) (Lukeneder 2003b). The same *Karsteniceras* Level was detected and described by Lukeneder (2003b) about 150 km west in the KB1-B section and in rock material from the KB2 section (200 m west of KB1) of the Ternberg Nappe (Upper Austria, Northern Calcareous Alps). The *Karsteniceras balernaense* occurrence (Rieber 1977) in the Barremian of the Breggia Gorge (south Switzerland) shows some similarities in the field occurrence, but not in density of specimens.

Biostratigraphy — the *Karsteniceras* 'Abundance Zone'

An abundance zone is a stratum or rock-body in which the abundance of a particular taxon or specified group of taxa is significantly greater than is usual in the adjacent parts of the

section (Salvador 1994). Its boundaries consist of biohorizons and the name is given by the abundant taxon or taxa.

Biohorizons are for example characterized by a sharp and significant biostratigraphic change within the fossil assemblage and/or a change in the frequency of its members (see Salvador 1994; Steininger & Piller 1999). Such biohorizons are of great importance for lateral correlation (see Lukeneder 2003a).

The presence of abundance zones ('ammonoid-beds'; characterized by abundance or mass-occurrence of ammonoids) seems to be related with sea-level rises or falls (see also Hoedemaeker 1994; Aguirre-Urreta & Rawson 1998, 1999). Abundance of ammonoids generally occurs in condensed parts of sediment successions. Condensation occurs at the maximum flooding levels of depositional sequences (pers. comm. Hoedemaeker). These abundance zones are of exceptional value for the interregional correlation in the Early Cretaceous. For a review of such Lower Cretaceous 'uniformity-beds' formed by a monotonous ammonoid assemblage over at least a single bed up to a few meters thickness see Lukeneder (2003a).

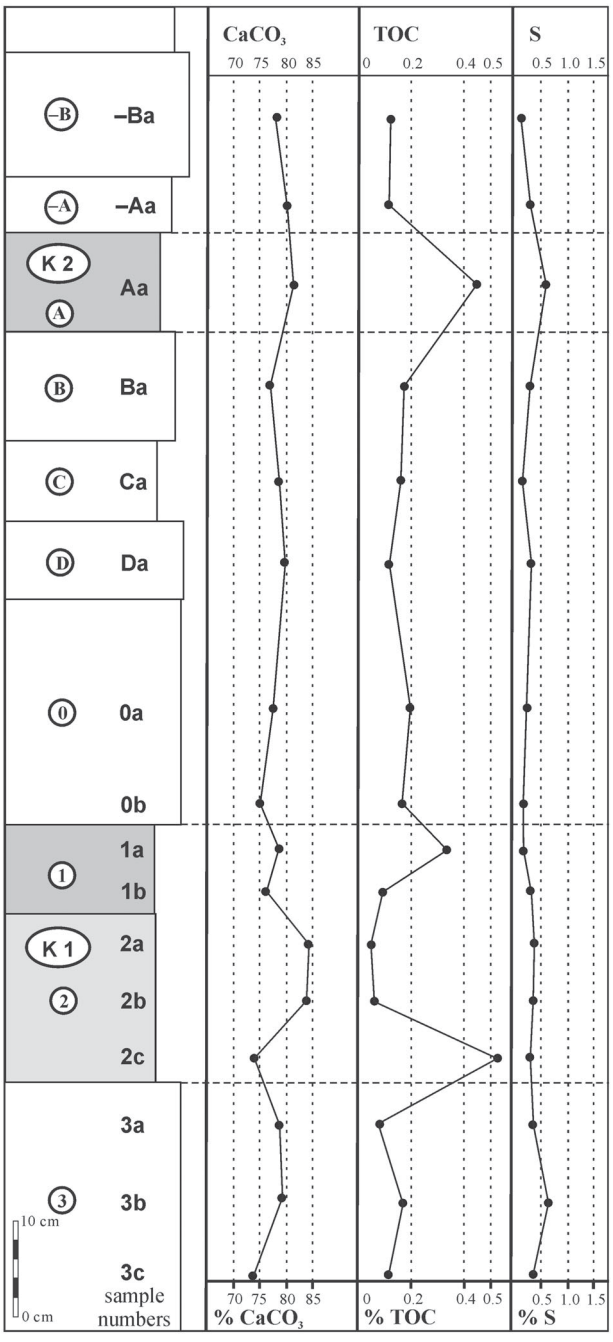

Fig. 7. Geochemical parameters from the Sparbach section within and around the *Karsteniceras* Level.

At the Sparbach section, the following ammonoid abundance zone (characterized by abundance or mass-occurrence of ammonoids) was detected. The names of the separated beds reflect the dominating genus or species (Fig. 3).

Karsteniceras-Abundance Zone (Early Barremian), at meter 160, 0.3 m thickness, dark grey, distinctly laminated, marly limestones, dipping 320/40°, dominated by the occurrence of *Karsteniceras ternbergense* (Fig. 6).

The ammonoid association indicates that the cephalopod-bearing beds in the Schrambach Formation belong to the latest Early Barremian (e.g. *Moutoniceras moutonianum* Ammonoid Zone; according to the results of the Vienna meeting of the Lower Cretaceous Ammonite Working Group of the IUGS; Hoedemaeker & Rawson 2000; see also Lukeneder 2001) (Fig. 8). The *M. moutonianum* Zone was recently replaced (according to the results of the Lyon meeting of the Lower Cretaceous Ammonite Working Group of the IUGS) by the *Coronites darsi* Zone (Hoedemaeker et al. 2003) (Fig. 8). Due of its noticeable similarities with the KB1-B occurrence (*Karsteniceras* Level; Lukeneder 2003b), although *Moutoniceras moutonianum* and *Coronites darsi* are missing, the typical association hints to the latest Early Barremian.

Sparbach versus KB1-B — differences and affinities

Remarkable similarities between the Sparbach (Lower Austria) and the KB1-B setion (Upper Austria) are observable in age, fabric, lithology, thin sections and faunal spectra.

The number and thickness of abundance beds can be correlated precisely over a distance of more than 150 kilometers.

One of the few apparent differences lies in the geochemical results. The sulphur and TOC contents within beds of the

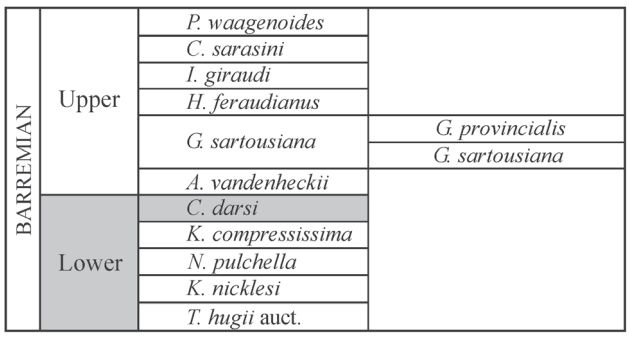

Fig. 8. Stratigraphic position within the Early Barremian (*C. darsi* Zone) of the Sparbach fauna (in grey). Table modified after Hoedemaeker et al. (2003).

Karsteniceras Level at Sparbach are considerably lower than in corresponding beds of the equivalent at the KB1-B section (see list below); this yields brighter colors of the sediments at the Sparbach locality.

compiled reference stratigraphy papers by Hoedemaeker & Rawson (2000), but basically adheres to Hoedemaeker et al. (2003). Only ammonoid species of Mediterranean character were observed at the Sparbach section.

Sparbach	***KB1-B***
Age: Early Barremian, *Coronites darsi* Zone	**Age:** Early Barremian, *Coronites darsi* Zone
Thickness: 2 beds a 0.15 m	**Thickness:** 2 beds a 0.15 m
Colour: light grey	**Colour:** dark grey to black
Fabric: indistinctly laminated	**Fabric:** indistinctly laminated
Lithology: marly limestones	**Lithology:** marly limestones
Geochemistry:	**Geochemistry:**
$CaCO_3$ varies between 73 and 83 %	$CaCO_3$ varies between 66 and 80 %
TOC varies between 0.03 and 0.52 %	TOC varies between 1.6 and 4.6 %
Sulphur 0.27 to 0.57 %	Sulphur 0.33 to 1.4 %
Environment: (less) dysoxic	**Environment:** dysoxic
Dipping: 320/40°	**Dipping:** 080/70°
Cephalopod fauna: *Eulytoceras* sp., *Barremites (Barremites)* cf. *difficilis*, *Pulchellia* sp., *Holcodiscus* sp., *Anahamulina* cf. *subcincta*, *Karsteniceras ternbergense*	**Cephalopod fauna:** *Phylloceras* sp., *Eulytoceras* cf. *phestum*, *Holcodiscus* sp., *Barremites* cf. *difficilis*, *Pseudohaploceras* sp., *Pulchellia* sp., *Moutoniceras moutonianum*, *Karsteniceras ternbergense*, aptychi (*in situ* in *Karsteniceras*) and *Rhynchoteuthis* sp.
Specimens of Karsteniceras: n = 250 (7–29 mm)	**Specimens of Karsteniceras:** n = 326 (5–37 mm)
Benthic forms: *Propeamusium*	**Benthic forms:** *Inoceramus*
Thin section: Laminated radiolarian wackestone, calcified radiolarians, sponge spicules, aptychi, ostracods, crinoids, roveacrinids, rhyncholite fragments *Colomisphaera heliosphaera* (Vogler), *Spirillina* sp.	**Thin section:** Laminated radiolarian wackestone, calcified radiolarians, sponge spicules, aptychi, ostracods, crinoids

Results and conclusions

The macrofauna of the Lower Cretaceous beds in the Sparbach Succession (Flössel Syncline), as already stated, is represented especially by ammonoids, aptychi and bivalves. The frequency of one ammonoid species (*Karsteniceras ternbergense*) and the typical composition of the cephalopod assemblage makes this section especially suited for an accurate study of the vertical ammonoid distribution. In the whole section, a total of 270 ammonoids were found. About 250 specimens of *Karsteniceras ternbergense* between 7 mm and 29 mm in diameter were investigated. Juveniles and adults could be separated. The limonitic ammonoid moulds are restricted to the distinctly laminated beds. Due to the bad preservation (limonitic steinkerns) of the ammonoids and the lithologic character of the Schrambach Formation, they are difficult to collect. Nevertheless, one ammonoid zone defined by Hoedemaeker et al. (2003) can be recognized. The stratigraphic investigation of the ammonoid fauna revealed that the Sparbach section comprises Lower Barremian sediments. Whether the Valanginian to Hauterivian are represented at the Sparbach section remains unclear due to the bad outcrop-situation along the rest of the sequence and are correlated moreover under the appliance of the characteristic sediments and their lithology. The Early Cretaceous of the Flössel Syncline is considered to range from the Late Valanginian to the Early Barremian. The stratigraphy within this paper follows the

Due to the additional finding of the *Karsteniceras* Level at Sparbach, the *Karsteniceras* Level (KB1-B section, Upper Austria) proposed by Lukeneder (2003b) currently has the status of a more widespread, laterally, biostratigraphically significant 'horizon', at least for the Northern Calcareous Alps. Its potential status as a stratigraphic horizon and its potential for correlation is manifested due to its extension over a wide geographical area (approx. 180 km).

The geochemical results indicate that the assemblage was deposited under conditions of intermittent oxygen-depletion associated with stable water masses. The accumulation of the sediments of the *Karsteniceras* Level was promoted by a highly dynamic environment controlled by short- and long-term fluctuations in oxygen content, coupled with a poor circulation of bottom-water currents within an isolated, basin-like region. The brighter colour of the sediment and the lower content of TOC and sulphur at the Sparbach section indicate a less dysoxic environment than assumed for the KB1-B sequence. No evidence for condensation can be found.

Based on the described features from the Sparbach section, the KB1-A and literature data, *Karsteniceras* probably had an opportunistic (r-strategist) mode of life and was adapted to dysaerobic seawater (Lukeneder 2003b). *Karsteniceras* probably inhabited areas of water stagnation with low dissolved oxygen; it showing abundance peaks during times of oxygen depletion, which hindered other invertebrates from colonising such environments.

The evidence for an oxygen-depleted formation of this mass-occurrence needs to be supplemented by additional analysis of the micropaleontological record (e.g. benthic foraminifers, nannofossils) and further investigations on the organic carbon material (e.g. type and producers).

The present paper is a further step in correlating abundance zones (layers of ammonoid mass-occurrences) in Lower Cretaceous sediments within the Northern Calcareous Alps. Most of the ammonoids found at the Sparbach section were apparently abundant or accumulated in the following bed over the whole eastern part of the Northern Calcareous Alps: *Karsteniceras* Level (*Karsteniceras*-Abundance Zone).

Future work on these ammonoid abundance zones and biohorizons within the above-described framework will concentrate on the paleoecological, paleobiogeographical and biostratigraphic development of Lower Cretaceous ammonoid-beds within the Northern Calcareous Alps.

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