

# Ammonoid stratigraphy of Lower Cretaceous successions within the Vienna Woods (Kaltenleutgeben section, Lunz Nappe, Northern Calcareous Alps, Lower Austria)

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**Abstract:** Detailed palaeontological, lithological and sedimentological studies of the Lower Cretaceous of the Lunz Nappe (Kaltenleutgeben section, Northern Calcareous Alps, Lower Austria) uncovered spectra of Upper Valanginian to Barremian macrofaunal elements (e.g., ammonoids, belemnites). Cephalopod-bearing strata of the *trinodosum* Zone (middle Late Valanginian) to *angulicostata* auctorum Zone (*angulicostata* auct. Subzone, latest Hauterivian) have been investigated. The Barremian ammonoids could only be recognized in isolated blocks. The outcrop is situated in an abandoned quarry within the Flössel Syncline (part of the Lunz Nappe), which is formed of Upper Triassic dolomite, followed by a reduced Jurassic sequence. The core of the Flössel Syncline consists of the Lower Cretaceous Schrambach Formation.

Several significant ammonoid abundance zones are presented, and a few of them are suggested to be of major importance for stratigraphic correlation. The '*Bochianites/Phyllopachyceras*-abundance zone', the '*Bochianites*-abundance zone', the '*Olcostephanus* (*J.*) *jeannoti*-abundance zone', the '*Euptychoceras*-abundance zone', and the '*Crioceratites krenkeli*-abundance zone' can be recognized at the investigated outcrop. The '*Pseudothurmannia*-beds' and the '*Olcostephanus* (*J.*) *jeannoti*-Subzone' are important abundance zones ('marker-beds') at the investigated section. The cephalopod fauna at the investigated quarry belongs exclusively to the Mediterranean Province.

**Zusammenfassung:** Detaillierte paläontologische, lithologische und sedimentologische Untersuchungen der Unterkreide in der Lunzer Decke (Kaltenleutgeben, Nördliche Kalkalpen, Niederösterreich) erbrachten faunistische Spektren von Ober-Valanginium bis Barremium, welche sich durch eine reiche Makro- und Mikrofauna auszeichnen (i.e. Ammoniten, Belemniten). Cephalopoden führende Schichten der *trinodosum* Zone (mittleres Ober-Valanginium) bis in die *angulicostata* auctorum Zone (*angulicostata* auct. Subzone, oberstes Ober-Hauterivium) wurden untersucht. Die Ammoniten des Barremiums stammen aus Blockmaterial. Der Aufschluß liegt in einem aufgelassenen Steinbruch innerhalb der Flössel Mulde (Teil der Lunzer Decke), welche von obertriadischen Dolomiten, gefolgt von einer reduzierten jurassischen Sequenz gebildet wird und deren Kern aus der unterkretazischen Schrambach-Formation besteht.

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Einige signifikante Ammoniten Häufigkeits-Zonen werden präsentiert, von welchen manche von enormer Wichtigkeit für die stratigraphische Korrelation sind. Die ‚*Bochianites/Phyllopachyceras*-Häufigkeits-Zone‘, die ‚*Bochianites*-Häufigkeits-Zone‘ die ‚*Olcostephanus (J.) jeannoti*-Häufigkeits-Zone‘, die ‚*Euptychoceras*-Häufigkeits-Zone‘ und die ‚*Crioceratites krenkeli*-Häufigkeits-Zone‘ können im untersuchten Aufschluss nachgewiesen werden. Die ‚*Pseudothurmannia*-Schichten‘ und die ‚*Olcostephanus (J.) jeannoti*-Subzone‘ konnten als wichtige Leithorizonte dokumentiert und nachgewiesen werden. Die Cephalopodenfauna des untersuchten Steinbruches enthält ausschliesslich Formen der mediterranen Provinz.

**Key words:** Ammonoids, Stratigraphy, Abundance Zone, Palaeoecology, Lithology

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## 1. 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., Ternberg-, Reichraming-, Frankenfels-, and Lunz Nappes). They cover wide areas both within the latter (e.g., Rossfeld, Losenstein, Schneeberg, Anzenbach, Ebenforst, and Flössel Synclines) and in various other European areas (e.g., Vocontian basin, Dolomites, Umbria, Western Carpathians, Gerecse and Mecsek Mountains, and others).

During the Early Cretaceous the Mediterranean palaeogeographic domain was characterized by the presence of microplates located in the middle of the Tethyan oceanic corridor between the African and European landmasses. As noted by many authors (for example CECCA, 1997, 1998; VAŠÍČEK & MICHALÍK, 1999; STAMPFLI & MOSAR, 1999), the region (Northern Calcareous Alps) on which the investigated areas were situated during the Early Cretaceous was formed at the eastern border of the Alpine-Carpathian Block, which was located at the western margin of the Tethys.

One of the first publications dealing with the section at Kaltenleutgeben was by RICHARZ (1905). SCHWINGHAMMER (1975) reported a small fauna and gives a description of the sequence from the same locality.

More recently, IMMEL (1987) provided an overview of the Cretaceous ammonoids of the Northern Calcareous Alps, yet without local descriptions or ecological aspects. The most recent publications by FAUPL et al. (1994), FAUPL & VAŠÍČEK (1998), and LUKENEDER (1998, 2001) deal with the stratigraphy of the Lower Cretaceous synclines in the Reichraming, Frankenfels and Lunz Nappes.

Upper Valanginian to Hauterivian cephalopod-bearing deposits of the Northern Calcareous Alps have been recorded and separated in two different facies known as the Rossfeld Formation and the Schrambach Formation.

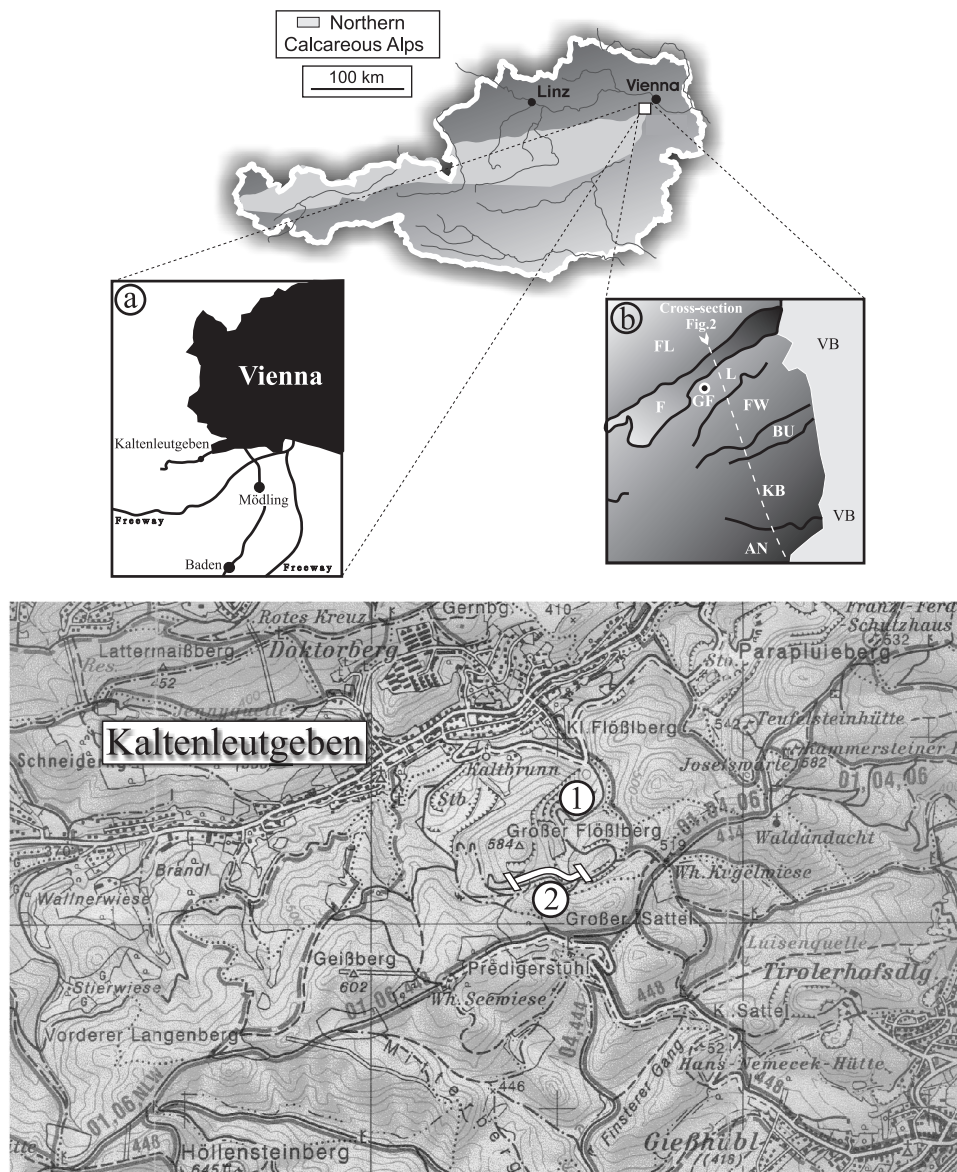


Fig. 1: Sketch map of the excavation site S of Kaltenleutgeben. The Upper Austroalpine Northern Calcareous Alps extend from the Austrian western border to the city area of Vienna. The square indicates the area of sketch maps below. Detailed map of the area around Kaltenleutgeben; Scale: 1:25000; marked position of the logs of 1 SCHWINGHAMMER (1975) and 2 LUKENER (this paper). Inset maps show the geographic position (a) and the geological setting (b) of the study area.

Sketch map of the NE spur of the Northern Calcareous Alps. FL – Flysch Nappes, F – Frankenfels Nappe and L – Lunz Nappe (NCA), FW – Föhrenberg – Wassergspreng System, BU – Basal unit of the Göller Nappe, AN – Anninger Syncline, KB – Kalenderberg Syncline, GF – Großer Flösslberg. BU, KB, AN are parts of the Göller Nappe. VB – Vienna Basin.

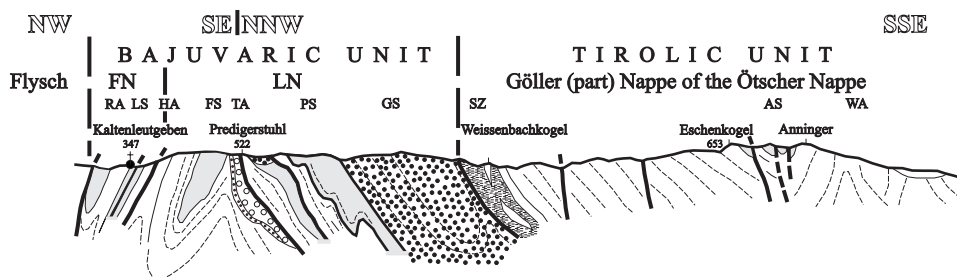


Fig. 2: Cross-section through Northern Calcareous Alps (marked in Fig. 1b): FN – Frankenfels Nappe, LN – Lunz Nappe, FS – Flössel Syncline, RA – ‘Rand-Anticline’, LS – Liesing Syncline, HA – Höllenstein Anticline, TA – Teufelstein Anticline, PS – Perchdorfer Syncline, GS – Gießhübler Syncline, SZ – ‘Schürflingszone’, AS – Anninger Syncline, WA – Wetterkreuz Anticline (redrawn after PLÖCHINGER & PREY, 1993).

The outcrop and logs described in this paper, as we can observe the quarry today, lie 100 metres above the location described by SCHWINGHAMMER (1975) (Figs. 1, 3).

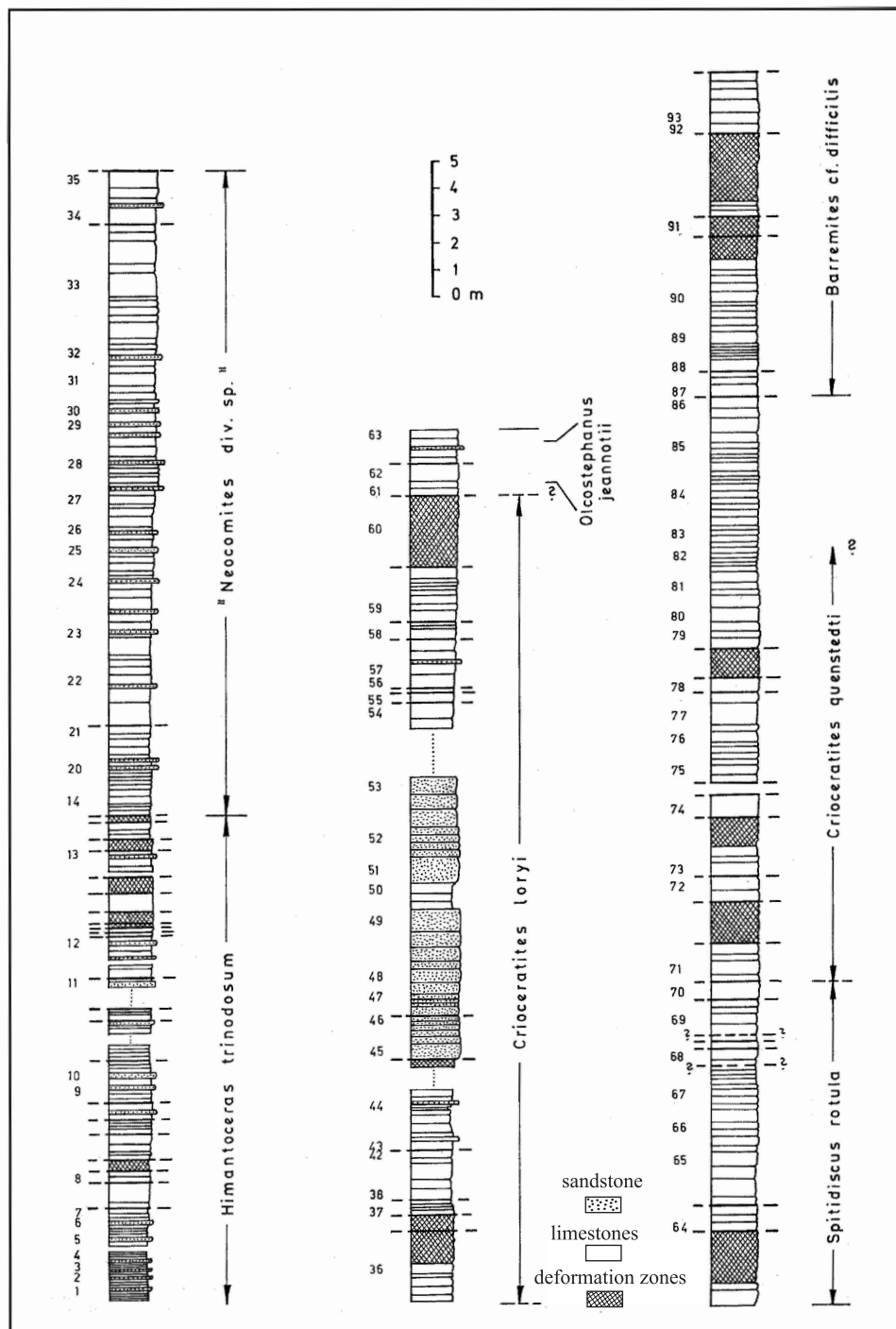
Available data reveal remarkable differences in Lower Cretaceous ammonoid associations of different formations (e.g., Schrambach- vs Rossfeld Formation) and different tectonic units of the Northern Calcareous Alps. The reasons for these differences have, however, been studied insufficiently (see VAŠÍČEK & FAUPL, 1996). Although some comparisons of the taxonomic composition of different occurrences were made geodynamic and palaeobiogeographic implications have not yet been studied in detail.

For this reason investigations have been made at the Kaltenleutgeben section. The result is a detailed sequence of abundance zones (separated layers with ammonoid mass-occurrences) in the Lower Cretaceous of the Kaltenleutgeben section. Such ‘ammonoid-beds’ are the result of bio-events, which are often manifested by the abundance or mass-occurrence of ammonoids. The presented paper is a first step and the initial point for the lateral correlation of such ammonoid mass-occurrences and establishment of ammonoid abundance zones within the Northern Calcareous Alps.

## 2. STUDY AREA AND TECTONIC POSITION OF THE FLÖSSELBERG QUARRY

The investigated outcrop is an abandoned quarry at the Flösselberg near Kaltenleutgeben (Figs. 1, 2, 4). It is situated in the Lunz Nappe, one of the northern tectonic units of the Northern Calcareous Alps (Bajuvaric Unit, NCA) (LUKENEDER, 1999). The general tectonic style is that of steep synclines and anticlines (e.g., Höllenstein Anticline, Flössel Syncline). The Flössel Syncline is formed of Upper Triassic dolomite, followed by a reduced Jurassic sequence (see also ROSENBERG, 1965; PLÖCHINGER & PREY, 1993) (Fig. 2). The core of the Flössel Syncline consists of the Lower Cretaceous Schrambach Forma-

Fig. 3: Log of the investigated section of SCHWINGHAMMER (1975) in the abandoned part of the quarry Kaltenleutgeben. ➔



tion, which occurs throughout the Northern Calcareous Alps. Within the Lunz Nappe the Schrambach Formation comprises Upper Valanginian to Lower Barremian sediments.

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 greyspotted limestones are highly bioturbated biogenic mudstones to wackestones. Occurrence of chrome spinel supports the correlation with the turbiditic

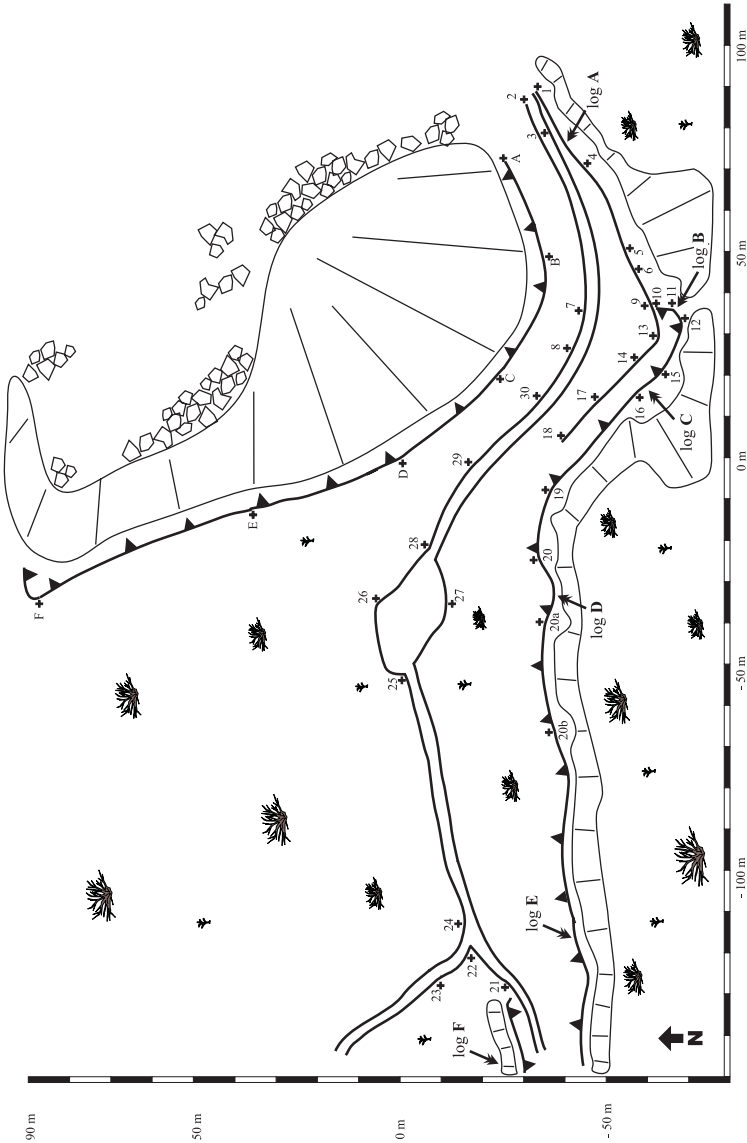


Fig. 4:  
Horizontal projection of the abandoned quarry Kaltenleutgeben with indicated positions of logs A – F.

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-intercalations derived from a more southerly situated land-swell (VAŠÍČEK et al., 1994).

The palaeogeographical reconstruction of the investigated area through the Lower Cretaceous shows that the sedimentation of the sandstone intercalations in the internal and eastern parts of the Northern Calcareous Alps (southernmost parts of the Bajuvaric Unit) is apparently connected with an uplift of the most southern parts; this reflects either beginning subduction of the Penninic Ocean in the North or the obduction of oceanic crust of the former Vardar Ocean at the boundary Austroalpine/Southern Alps (SCHLAGINTWEIT, 1991). As reported by FAUPL (1979), three turbidite intervals occur within the Cretaceous sequence of the Austroalpine unit during three different time periods, representing characteristic phases in the Alpine orogeny: 1) in the lower part of the Lower Cretaceous, 2) in the uppermost part of the Lower Cretaceous to the Mid-Cretaceous and 3) within the Upper Cretaceous (Gosau) (see also DECKER et al., 1987).

The Schrambach Formation has been exploited extensively for many years for cement production (TOULA, 1886). Therefore the term 'Zementmergel', which has now been abandoned, was used in older literature (SPITZ, 1910) for the Schrambach Formation. Another outdated name is '*Cryptoceras* Mergel'. According to SCHWINGHAMMER (1975), however, the ammonite *Ammonites cryptoceras* d'ORBIGNY does not occur in the section of the Flösselberg (Figs. 4, 5).

The basal part of the sequence differs by its higher content of sandy intercalations; based on the occurrences in the western parts of the NCA, it has (Geol. Map 1:50,000, sheet 58 Baden) been separated as the Rossfeld Formation, an interpretation, which is not followed by the author. The 'real' Rossfeld Formation is situated more to the south (southern parts of the Reichraming Nappe, not in the northernmost parts of the NCA) and the sandstone beds are interpreted as intercalations within the limestone section. The author follows the interpretation of VAŠÍČEK et al. (1994), who included these parts into the Schrambach Formation (located in the northern Reichraming Nappe), and not Rossfeld Formation due to its sandstone layers. SCHWINGHAMMER formerly combined both parts of the sequence as 'Neokome Serie'. The investigations on his bed-by-bed collecting were never completed and a good deal of his information has been lost. Despite the difficult situation at the abandoned quarry, a new position of the log shown in this paper could be found 100 metres above the log of SCHWINGHAMMER (1975) (Fig. 3).

### 3. AMMONOID FAUNA AND MATERIAL

The faunal list is compiled from the author's recent collections, but also from data in SCHWINGHAMMER (1975), IMMEL (1987), and VAŠÍČEK et al. (1994). During recent explorations the author found about 120 ammonoids at the whole Kaltenleugeben section.

Twentythree genera of *Lytoceratina*, *Phylloceratina*, *Ammonitina* and *Ancyloceratina* (suborders), comprising 25 different species, are reported in this paper. The determinations of 20 species are based on own findings. The cephalopod fauna at the outcrop covers exclusively forms of the Mediterranean Province (VAŠÍČEK et al., 1994), which are typical for the Northern Calcareous Alps. The cephalopods can be found in the whole sequence but seem to be concentrated in certain levels (see chapter 4: 'Ammonoid-beds') (Fig. 5).

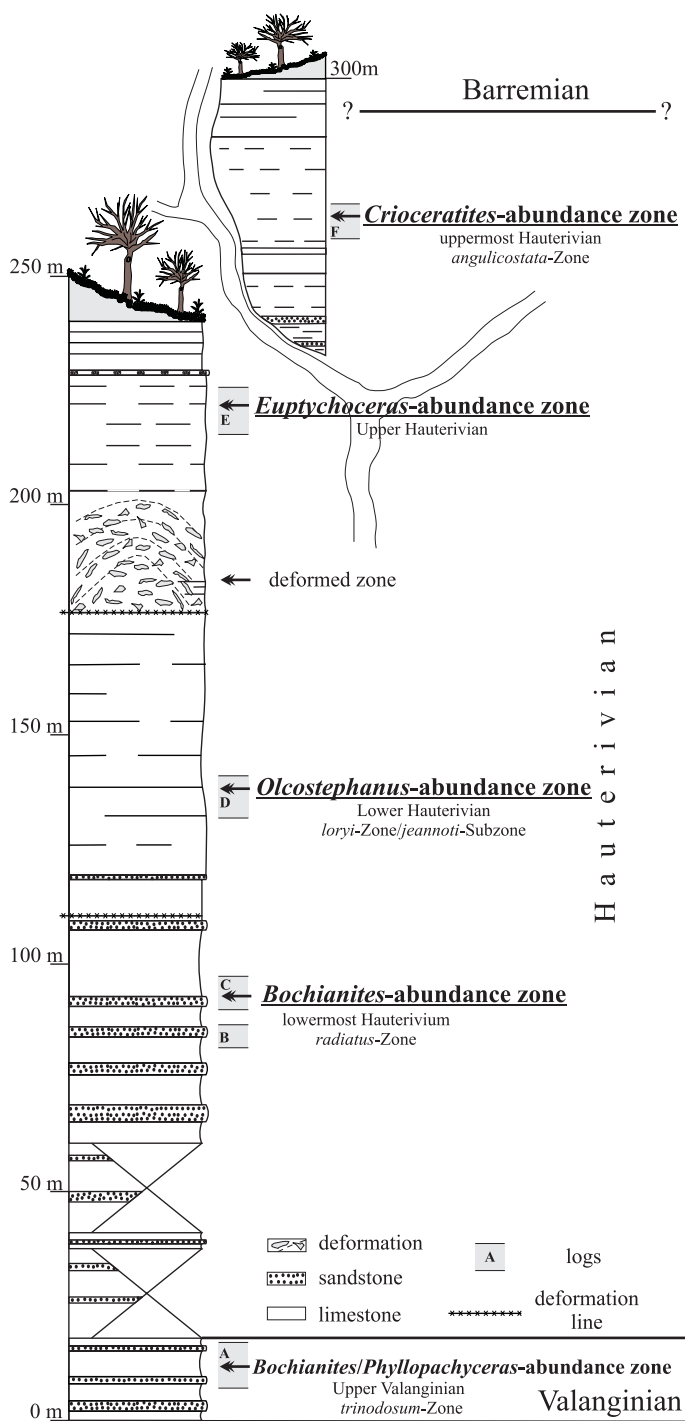


Fig. 5:  
Composite log of the whole section Kaltenleutgeben with indicated stratigraphy and positions of the ammonoid-abundance zones and detailed logs A-F.

RICHARZ (1905, 1908) described ammonoids from the Valanginian and the Hauterivian of this locality. SCHWINGHAMMER (1975) compiled a list of 37 ammonoid species, although this number may be much too high. Moreover, bad preservation and the poor status of the SCHWINGHAMMER collection do not enable clear allocation of the collection material. Thus, IMMEL (1987) mentioned a comparatively small list of 12 ammonoid species.

The macrofauna of the Schrambach Formation (approx. 300 m in thickness) is predominated by sculpture-moulds of cephalopods, rare belemnites and scattered echinoderms. Only poorly preserved limonitic ammonoid moulds are preserved and often only aptychi are present. The echinoderms are represented by regular and irregular echinids and by numerous calices of the crinoid *Phyllocrinus*.

The current paper follows the classification of the Cretaceous Ammonoidea summarized by WRIGHT et al. (1996).

The analysis of the fauna supports the interpretation of a soft to level bottom palaeoenvironment with a cephalopod-dominated community living near the epicontinental (epeiric) sea floor: these forms were demersal ('nektobenthic') (e.g., WESTERMANN, 1990). Based on the suggested palaeogeographical position of the studied section, influences of turbiditic redeposition can be assumed and a mixed autochthonous/allochthonous origin of the fauna is proposed.

Recognized cephalopods are (own findings marked with \*): *\*Lytoceras subfimbriatum* (d'ORBIGNY), *\*Lytoceras* sp., *\*Leptotetragonites* sp., *\*Phylloceras thetys* (d'ORBIGNY), *Phylloceras* sp., *\*Phyllopachyceras winkleri* (d'ORBIGNY), *Phyllopachyceras infundibulum* (d'ORBIGNY), *Oosterella* ex gr. *gaudryi* (d'ORBIGNY), *Oosterella kitteli* (d'ORBIGNY), *Olcostephanus* (*Olcostephanus*) *astierianus* (d'ORBIGNY), *\*Olcostephanus* (*Olcostephanus*) *sayni* (KILIAN), *\*Olcostephanus* (*Olcostephanus*) *densicostatus* (WEGNER), *\*Olcostephanus* (*Jeannoticeras*) *jeannoti* (d'ORBIGNY), *Olcostephanus* (*Olcostephanus*) *bal-estrai* (RODIGHERO), *\*Olcostephanus* sp., *\*Haploceras grasianum* (d'ORBIGNY), *\*Haploceras* sp., *?Kilianella* sp., *Thurmanniceras* sp., *\*Eleniceras* ex gr. *tchecchitevi* BRESKOVSKI, *Eleniceras* sp., *\*Spitidiscus* cf. *meneghinii* (ZIGNO in RODIGHIERO), *\*Acanthodiscus radia-tus* (BRUGUIÈRE), *\*Leopoldia* sp., *\*Neocomites* (*Neocomites*) cf. *neocomiensis* (d'ORBIGNY), *\*Neocomites* (*Teschenites*) *neocomiensiformis* (HOHENEGGER), *\*Neocomites* (*Teschenites*) sp., *\*Barremites* sp., *\*Pulchellia* sp., *\*Himantoceras trinodosum* (THIEULOY), *\*Himantoceras* sp., *\*Crioceratites* (*Crioceratites*) cf. *quenstedti* (OOSTER), *Crioceratites* (*Crioceratites*) *majoricensis* (NOLAN), *Crioceratites mortilleti* (PICTET & LORIOU), *\*Crioceratites krenkeli* (SARKAR), *\*Crioceratites loryi* (SARKAR), *\*Bochianites neocomiensis* (d'ORBIGNY), *\*Bochianites oosteri* (SARASIN & SCHÖNDELMAYR), *\*Karsteniceras* sp., *\*Euptychoceras* sp., *\*?Hamulina* sp., *\*?Anahamulina* sp., *\*Lamellaptychus seranonis seranonis* (COQUAND), *\*Lamellaptychus* sp., and belemnites.

Other macrofossils and trace fossils: brachiopods, *Zoophycos*, *Planolites* and *Chondrites*.

#### 4. 'AMMONOID-BEDS': ABUNDANCE ZONE

An abundance zone is a stratum or 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 are made 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 the change of frequency of its members (see SALVADOR, 1994; STEININGER & PILLER, 1999). The latter authors recommended the term biohorizon to be used instead of the terms 'surface', 'level', 'marker' and 'datum planes'. Such biohorizons are of great importance for lateral correlation.

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. Most probably ammonoid mass-occurrences reflect transgressive phases (see also HOEDEMAEKER, 1994; AGUIRRE-URRETA & RAWSON, 1998, 1999). The *Crioceratites krenkeli*-beds, which are also recognized at the Kaltenleutgeben section, were formed during a transgressive sea-level highstand (highest of the whole Hauterivian) in the latest Hauterivian (HOEDEMAEKER, 1994).

Patterns which lead to beds with a notable abundance of ammonoid shells have been called inter-regional mass-occurrences in the former case, and stray occurrences in the latter (KEMPER et al., 1981). These abundance zones are of exceptional value for the interregional correlation in the Lower Cretaceous (e.g., *Olcostephanus*, *Crioceratites*, *Pseudothurmannia*, *Neocomites*, *Karakaschiceras*, *Neohoploceras*).

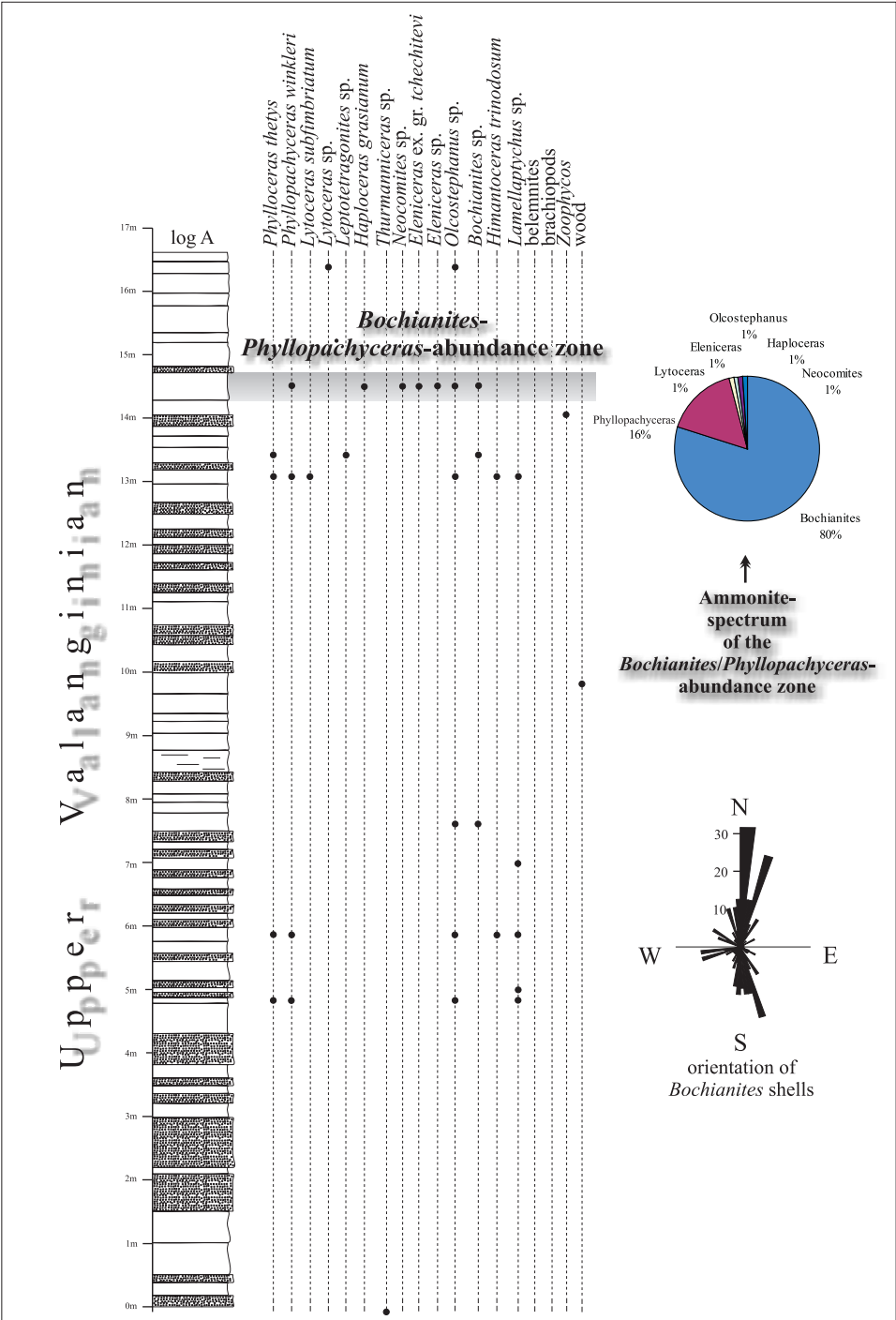
Such Lower Cretaceous 'uniformity-beds' formed by a monotonous ammonoid assemblage over at least a single bed up to a few metres thickness were reported for example by RAWSON ('*guebhardi* chronocline' and '*densicostatus* chronocline', Upper Valanginian; 1993), AUTRAN (equivalent of the '*Astieria* Schichten', Upper Valanginian; 1993), KEMPER et al. ('*Astieren* Schichten', Upper Valanginian; 1987), HOEDEMAEKER ('*Pseudothurmannia* beds', Upper Hauterivian; 1994), VAŠÍČEK & MICHALÍK ('*Pseudothurmannia* beds', Upper Hauterivian; 1988), VAŠÍČEK et al. ('*Euptychoceras* beds' and '*Pseudothurmannia* beds', Upper Hauterivian; 1994), VAŠÍČEK (rich associations of *Bochianites*, Upper Valanginian; 1997), BULOT et al. (*Crioceratites loryi* and *O. (O.) jeannoti* biohorizons; 1992), LUKENEDER (mass occurrences of *Olcostephanus guebhardi* and *Karsteniceras ternbergense*; 1998, 2001) and many others.

At the investigated Kaltenleutgeben section the following ammonoid abundance zones (characterized by abundance or mass-occurrence of ammonoids) could be detected for the first time. The names of the separated beds were given following the dominating genus or species (Figs. 5, 9).

- *Bochianites/Phyllopachyceras*-abundance zone (Upper Valanginian), at metre 12, 0.5 m thickness, dark grey marly limestones, log A, dipping 280/60°  
Dominated by the occurrence of *Bochianites oosteri* and *Phyllopachyceras winkleri* (Fig. 6).

Note the orientation of the *Bochianites* shells, which is interpreted as being related to bottom currents.

Fig. 6: Log A with indicated position of the *Bochianites/Phyllopachyceras*-abundance zone (grey) and its ammonoid spectrum. Notice the orientation of the *Bochianites* shells indicated on the right side of the figure. →



- *Bochianites*-abundance zone (Hauterivian), at metre 90, 0.3 m thickness, light grey marly limestones, log C, dipping 290/55°  
Dominated by the occurrence of *Bochianites oosteri* (Fig. 7; layer 21).
- *Olcostephanus* (*J.*) *jeannoti*-abundance zone (Hauterivian), at metre 140, 0.4 m thickness, dark grey marly limestones, log D, dipping 260/45°  
Dominated by the occurrence of *Olcostephanus* (*J.*) *jeannoti* (Fig. 8).
- *Euptychoceras*-abundance zone (Hauterivian), at metre 225, 0.3 m thickness, light grey marly limestones, log E, dipping 230/40°  
Dominated by the occurrence of *Euptychoceras* sp. (Fig. 8).
- *Crioceratites krenkeli*-abundance zone (uppermost Hauterivian), at metre 275, 0.6 m thickness, light grey marly limestones, log F, dipping 230/35°  
Dominated by the occurrence of *Crioceratites krenkeli* (Fig. 8).

## 5. RESULTS AND DISCUSSION

The Upper Valanginian to Upper Hauterivian beds in the Kaltenleutgeben succession are very rich in ammonoids. About 120 specimens have been collected during the last years. The frequency of the ammonoids and the richness of the fauna makes this section especially suited for an accurate study of the vertical ammonoid distribution.

The result of the stratigraphic study revealed that the Kaltenleutgeben section comprises Upper Valanginian to Upper Hauterivian (Fig. 10). Whether the Lower Barremian, and thus the Hauterivian/Barremian boundary, is represented at the Kaltenleutgeben section remains unclear due to the bad outcrop situation at the top of the sequence. At the investigated site Barremian fossils are only found in loose blocks. SCHWINGHAMMER (1975) and IMMEL (1987) still considered the Lower Cretaceous of the Flössel Syncline to range from the Upper Valanginian to the Lower Barremian. This conclusion required *Crioceratites* (*P.*) *mortilleti* to be a representative of the Lower Barremian. More recently, HOEDEMAEKER (1994) and COMPANY et al. (1994) regarded *Crioceratites* (*P.*) *mortilleti* as an Upper Hauterivian form (see VASÍČEK et al., 1994).

Ammonoids limited to the Barremian are missing, although some of the species mentioned by SCHWINGHAMMER (1975) occur also in the Barremian (VASÍČEK et al., 1994).

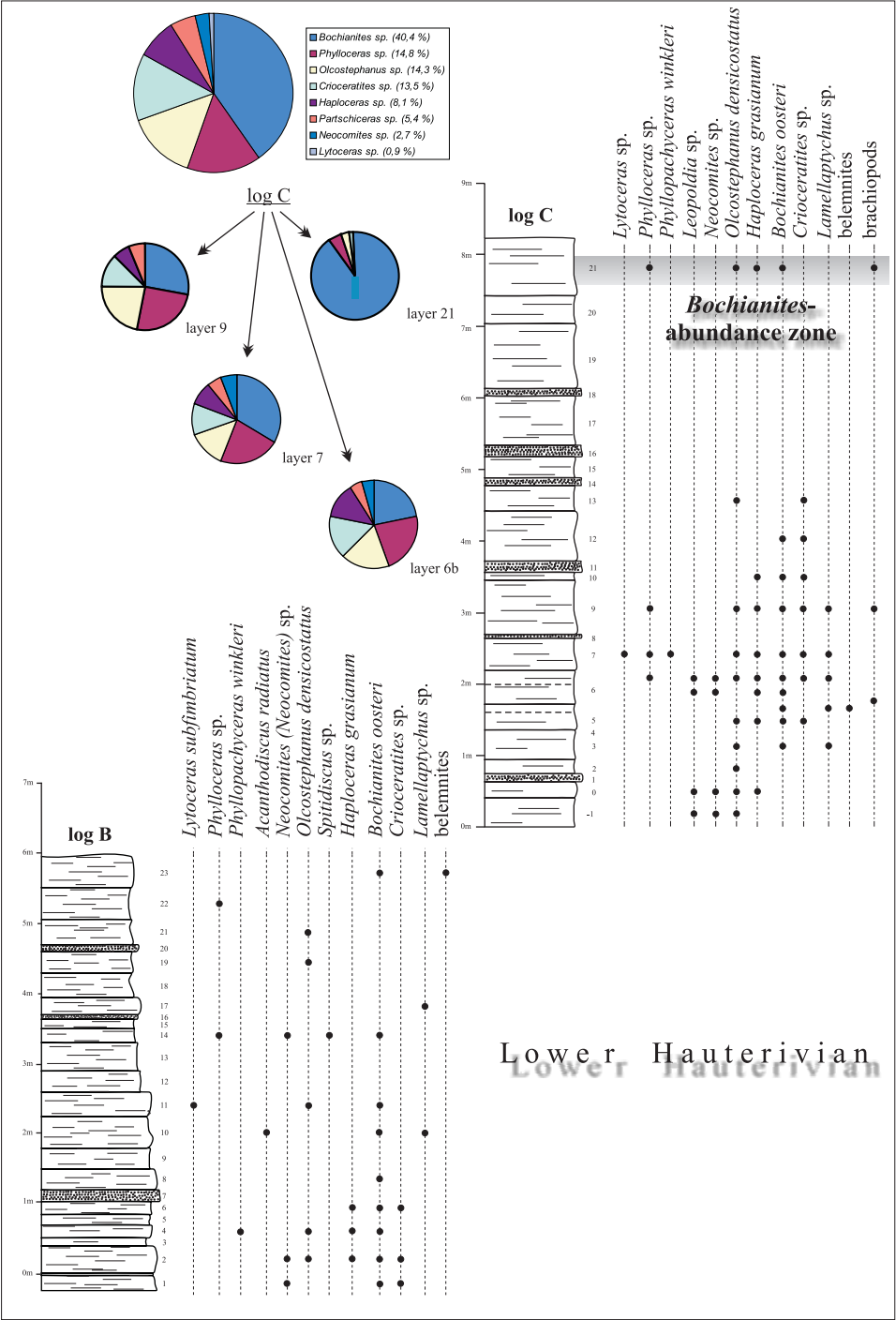
The stratigraphy within this paper follows the compiled reference stratigraphy papers by HOEDEMAEKER (1994), BULOT (1995), RAWSON et al. (1999), REBOULET & ATROPS (1999), and HOEDEMAEKER & RAWSON (2000).

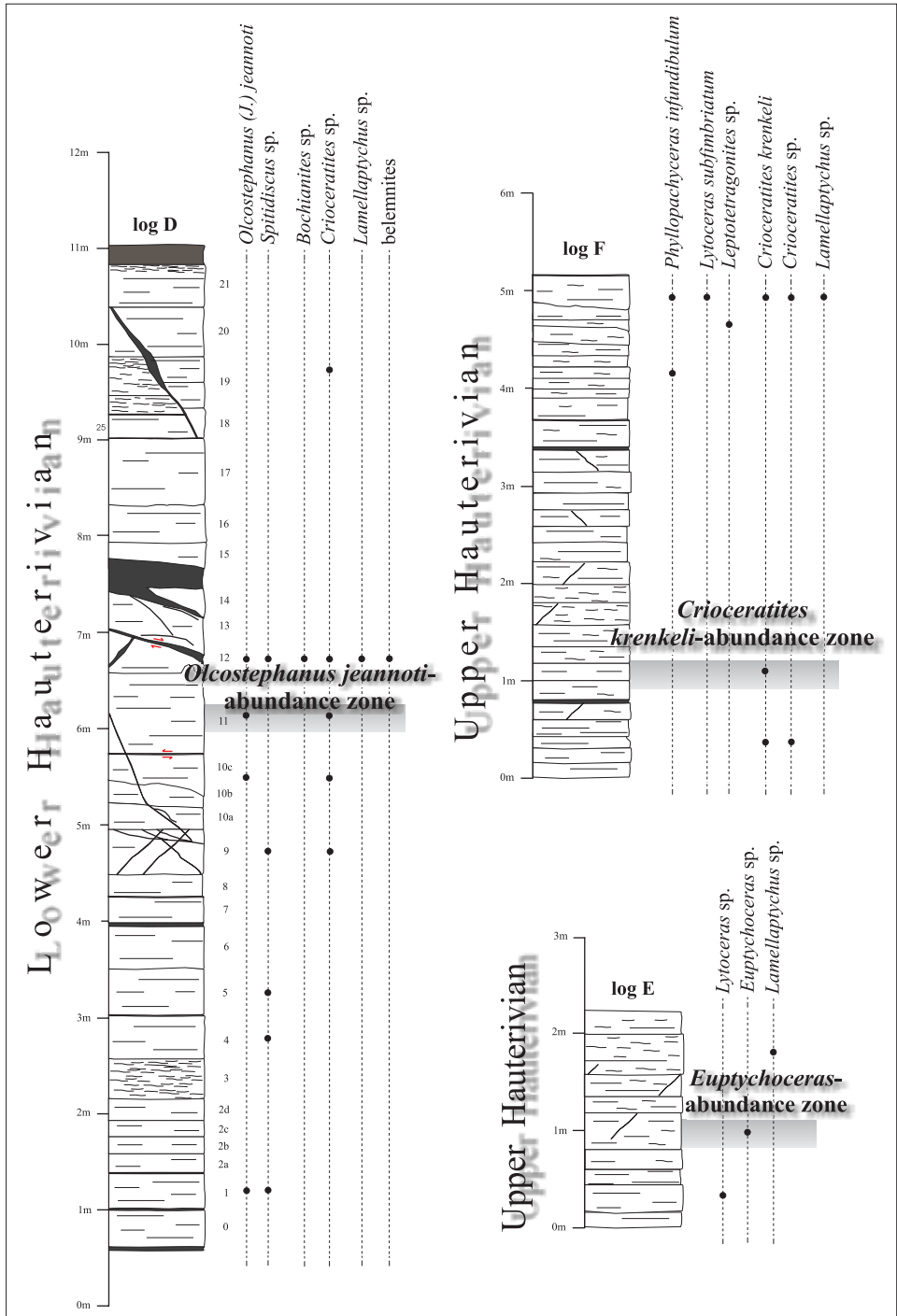
The fossil list presented above yields a stratigraphic framework of the excavation site from the Upper Valanginian up to the Lower Barremian.

**Upper Valanginian (log A):** The Valanginian ammonoid association of the Kaltenleutgeben section is dominated by *Bochianites* and *Phyllopachyceras*.

The Upper Valanginian fauna comprises the following ammonoids: *Phylloceras thetys* (d'ORBIGNY), *Phylloceras* sp., *Lytoceras subfimbriatum* (d'ORBIGNY), *Lytoceras* sp., *Lep-*

Fig. 7: Logs B and C. Log C with indicated position of the *Bochianites*-abundance zone (grey) and ammonoid spectra of Log C and selected single beds. →





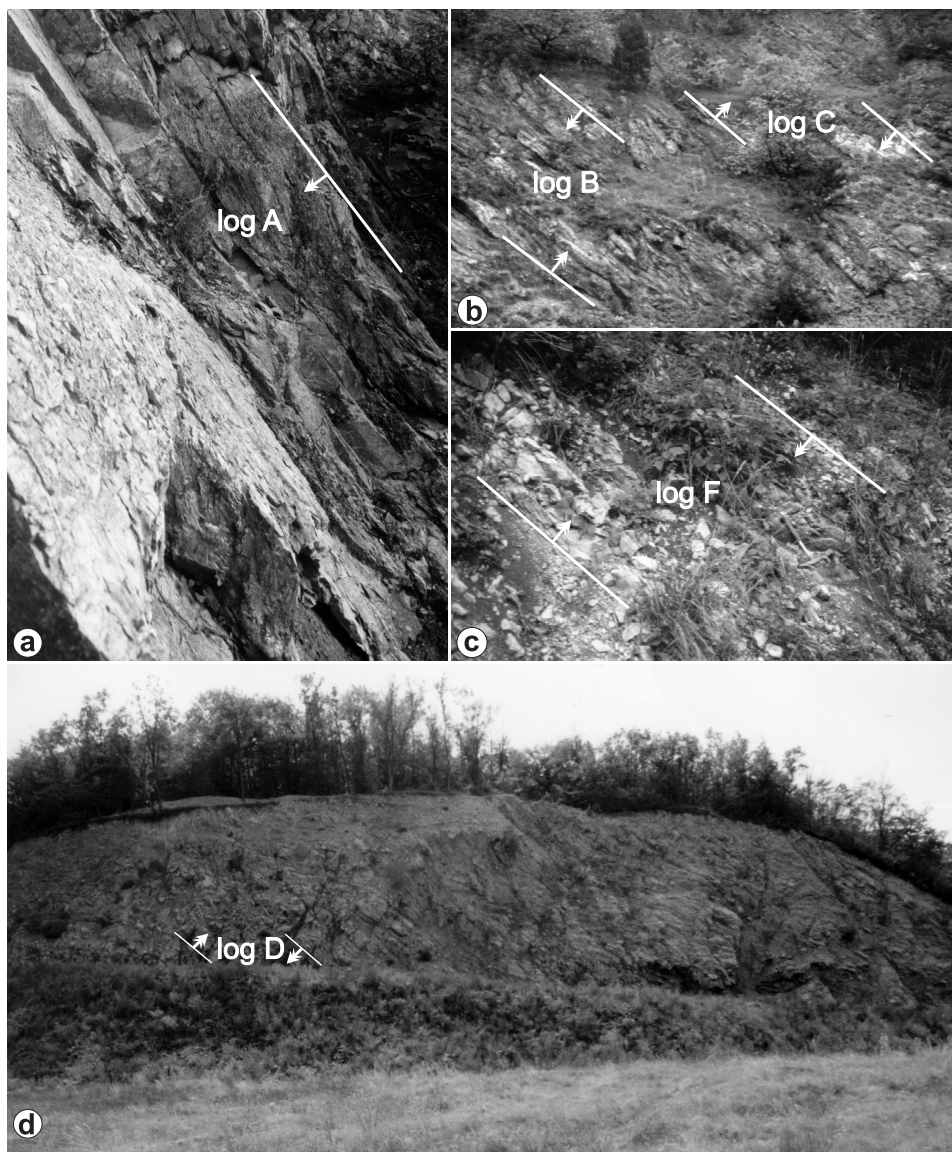


Fig. 9: Exposures of the investigated detailed logs and ammonoid-abundance zones. a- *Bochianites/Phyllopachyceras*-abundance zone, b- logs B and C with *Bochianites*-abundance zone, c- *Crioceratites krenkeli*-abundance zone, d- Hauterivian part of the sequence with indicated position of log D and the *Olcostephanus (J.) jeannoti*-abundance zone.

← Fig. 8: Logs D, E and F. Log D with indicated position of the *Olcostephanus (J.) jeannoti*-abundance zone, log E with indicated position of the *Euptychoceras*-abundance zone, and log F with indicated *Crioceratites krenkeli*- abundance zone (abundance zones in grey).

*totetragonites* sp., *Haploceras grasianum* (d'ORBIGNY), *Thurmanniceras* sp., *Neocomites* (*Neocomites*) sp., *Eleniceras* ex gr. *tchechitevi* BRESKOVSKI, *Eleniceras* sp., *Olcostephanus* sp., *Bochianites oosteri* (SARASIN & SCHÖNDELMAYR), *Bochianites* sp., and *Himantoceras trinodosum* (THIEULOY).

*Himantoceras trinodosum* represents the index ammonoid of the *trinodosum* Zone (middle Upper Valanginian).

**Lower Hauterivian (log B, C, and D):** The Lower Hauterivian ammonoid association of the Kaltenleutgeben section is dominated by *Olcostephanus* and *Crioceratites*. The fossil record of the Hauterivian ammonoid succession in the Kaltenleutgeben section is mainly poor, except within a few ammonoid-levels. The ammonoid fauna comprises: *Phyllocer-*

| Stages                 |                    | Zones                               | Subzones                                            |
|------------------------|--------------------|-------------------------------------|-----------------------------------------------------|
| HAUTERIVIAN            | Upper              | <i>P. angulicostata</i><br>auctorum | <i>P. catulloi</i><br><i>P. angulicostata</i> auct. |
|                        |                    | <i>B. balearis</i>                  |                                                     |
|                        |                    | <i>P. ligatus</i>                   |                                                     |
|                        |                    | <i>S. sayni</i>                     |                                                     |
|                        | Lower              | <i>L. nodosoplicatum</i>            |                                                     |
|                        |                    | <i>C. loryi</i>                     | <i>O. (J.) jeannoti</i>                             |
|                        |                    |                                     | <i>C. loryi</i>                                     |
|                        | <i>A. radiatus</i> |                                     |                                                     |
| VALANGINIAN            | Upper              | <i>T. callidiscus</i>               |                                                     |
|                        |                    | <i>H. trinodosum</i>                | <i>C. furcillata</i>                                |
|                        |                    |                                     | <i>O. (O.) nicklesi</i>                             |
|                        |                    | <i>S. verrucosum</i>                | <i>V. peregrinus</i>                                |
|                        |                    |                                     | <i>K. pronecostatum</i>                             |
|                        |                    |                                     | <i>S. verrucosum</i>                                |
|                        | Lower              | <i>B. campylotoxus</i>              |                                                     |
|                        |                    | <i>T. pertransiens</i>              |                                                     |
|                        |                    | <i>T. otopeta</i>                   |                                                     |
|                        | BERRIASIAN         | Upper                               | <i>F. boissieri</i>                                 |
| <i>B. picteti</i>      |                    |                                     |                                                     |
| <i>M. paramimounum</i> |                    |                                     |                                                     |
| Middle                 |                    | <i>T. occitanica</i>                | <i>D. dalmasi</i>                                   |
|                        |                    |                                     | <i>B. privasensis</i>                               |
|                        |                    |                                     | <i>T. subalpina</i>                                 |
| Lower                  | <i>B. jacobi</i>   |                                     |                                                     |

Fig. 10:  
The stratigraphic range of the Schrambach Formation (in grey) in the Flössel Syncline. Table after HOEDEMAEKER & RAWSON (2000; with modifications)

as sp., *Phyllopachyceras winkleri* (d'ORBIGNY), *Lytoceras subfimbriatum* (d'ORBIGNY), *Lytoceras* sp., *Leopoldia* sp., ?*Acanthodiscus radiatus* (BRUGUIÈRE), *Neocomites* sp., *Olcostephanus (Jeannoticeras) jeannoti* (d'ORBIGNY), *Olcostephanus (Olcostephanus) densicostatus* (WEGNER), *Spitidiscus* cf. *meneghinii* (ZIGNO in RODIGHIERO), *Spitidiscus* sp., *Haploceras grasianum* (d'ORBIGNY), *Bochianites oosteri* (SARASIN & SCHÖNDELMAYER), *Bochianites* sp., *Crioceratites loryi* (SARKAR), and *Crioceratites* sp.

?*Acanthodiscus radiatus* (BRUGUIÈRE) represents the index fossil of the lowermost zone of the Hauterivian, the *radiatus* Zone. *Olcostephanus (J.) jeannoti* is the index fossil of the *jeannoti* Subzone within the *loryi* Zone (middle Lower Hauterivian). *Crioceratites loryi* (SARKAR), the index ammonoid for the *loryi* Zone and for the *loryi* Subzone, was also detected.

**Upper Hauterivian (log E and F):** The Upper Hauterivian ammonoid association of the Kaltenleutgeben section is dominated by *Crioceratites*. The *angulicostata* auctorum Zone (*angulicostata* auct. Subzone after HOEDEMAEKER & RAWSON, 2000) forms the top of the Hauterivian. Upper Hauterivian species of the poor ammonoid-fauna (except the ammonoid-levels) are as follows: *Phyllopachyceras infundibulum* (d'ORBIGNY), *Lytoceras subfimbriatum* (d'ORBIGNY), *Lytoceras* sp., *Leptotetragonites* sp., *Crioceratites krenkeli* (SARKAR), *Crioceratites* sp., and *Euptychoceras* sp.

**Barremian:** Despite a few findings of *Karsteniceras*, *Hamulina*, *Barremites*, *Pulchellia*, ?*Moutoniceras*, and *Anahamulina* in loose blocks from the top of the sequence, which is not exposed at the moment, the Barremian is postulated for the top of the Kaltenleutgeben section. The reported genera are Barremian, but more investigations on the top of the sequence are needed.

## 6. CONCLUSIONS

The macrofauna, as already stated, is represented especially by ammonoids, belemnites, aptychi, brachiopods, and echinoderms. In the whole section about 120 ammonoids have been found. Due to the bad preservation (limonitic steinkerns) of the ammonoids and the lithologic character of the Schrambach Formation they are difficult to collect. Nevertheless the ammonoid zones defined by HOEDEMAEKER & RAWSON (2000) can be recognized, at least for some subzones.

The stratigraphic investigation of the ammonoid fauna revealed that the Kaltenleutgeben section comprises Upper Valanginian to Upper Hauterivian sediments. The Barremian ammonoids could only be recognized in loose blocks.

The presented paper is a first step of correlating abundance zones (layers of ammonoid mass-occurrences) in Lower Cretaceous sediments within the Northern Calcareous Alps. It appears that most of the ammonoids found at the Kaltenleutgeben section were abundant or accumulated in the following few beds over the whole sequence: *Bochianites/Phyllopachyceras*-abundance zone (Upper Valanginian), *Bochianites*-abundance zone (Hauterivian), *Olcostephanus jeannoti*-abundance zone (Hauterivian), *Euptychoceras*-abundance zone (Hauterivian), and *Crioceratites krenkeli*-abundance zone (uppermost Hauterivian). Some of the presented ammonoid abundance zones (e.g., *Bochianites*-abundance zone) seem to be related to bottom currents, what is indicated through the orientation of the straight *Bochianites* shells.

Only ammonoid species of Mediterranean character were observed at the Kaltenleutgeben section. The limonitic ammonoid moulds (except the body chamber) are restricted to the limestone- and marl-beds. No ammonoids were found within the sandstone layers. The latter have been formed by turbidity currents, show gradation and, on their top, plant debris.

Main investigation-topics of future work concerning these ammonoid abundance zones and biohorizons within the above described framework will be the palaeoecological, palaeobiogeographical and biostratigraphical development of Lower Cretaceous ammonoid-beds within the Northern Calcareous Alps. Further topics of investigation are the original position and environmental conditions of the sedimentation area. This leads consequently to the question, if the ammonoid abundance zone are autochthonous or allochthonous. Expected answers are essential for geodynamical, palaeoceanographical and palaeobiological conclusions. This leads furthermore to the question of the original water depths during the formation of ammonoid mass-occurrences.

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## Plate 1

Fig. 1: *Phyllopachyceras winkleri* (d'ORBIGNY), log A – x 1, 2002z0070/0041.

Fig. 2: *Olcostephanus* (J.) *jeannoti* (d'ORBIGNY), log D – x 1, 2002z0070/0017.

Fig. 3: *Olcostephanus* (O.) *balestrai* (RODIGHERO), log A – x 1, 2002z0070/0018.

Fig. 4: *Olcostephanus* (O.) *densicostatus* (WEGNER), log C – x 1, 2002z0070/0019.

Fig. 5: *Thurmanniceras* sp., log A – x 0.5, 2002z0070/0037.

Fig. 6: *Eleniceras* ex. gr. *tchecchitevi* BRESKOVSKI, log A – x 1, 2002z0070/0038.

Fig. 7: *Spitidiscus* cf. *meneghinii* (ZIGNO in RODIGHIERO), log B – x 1, 2002z0070/0039.

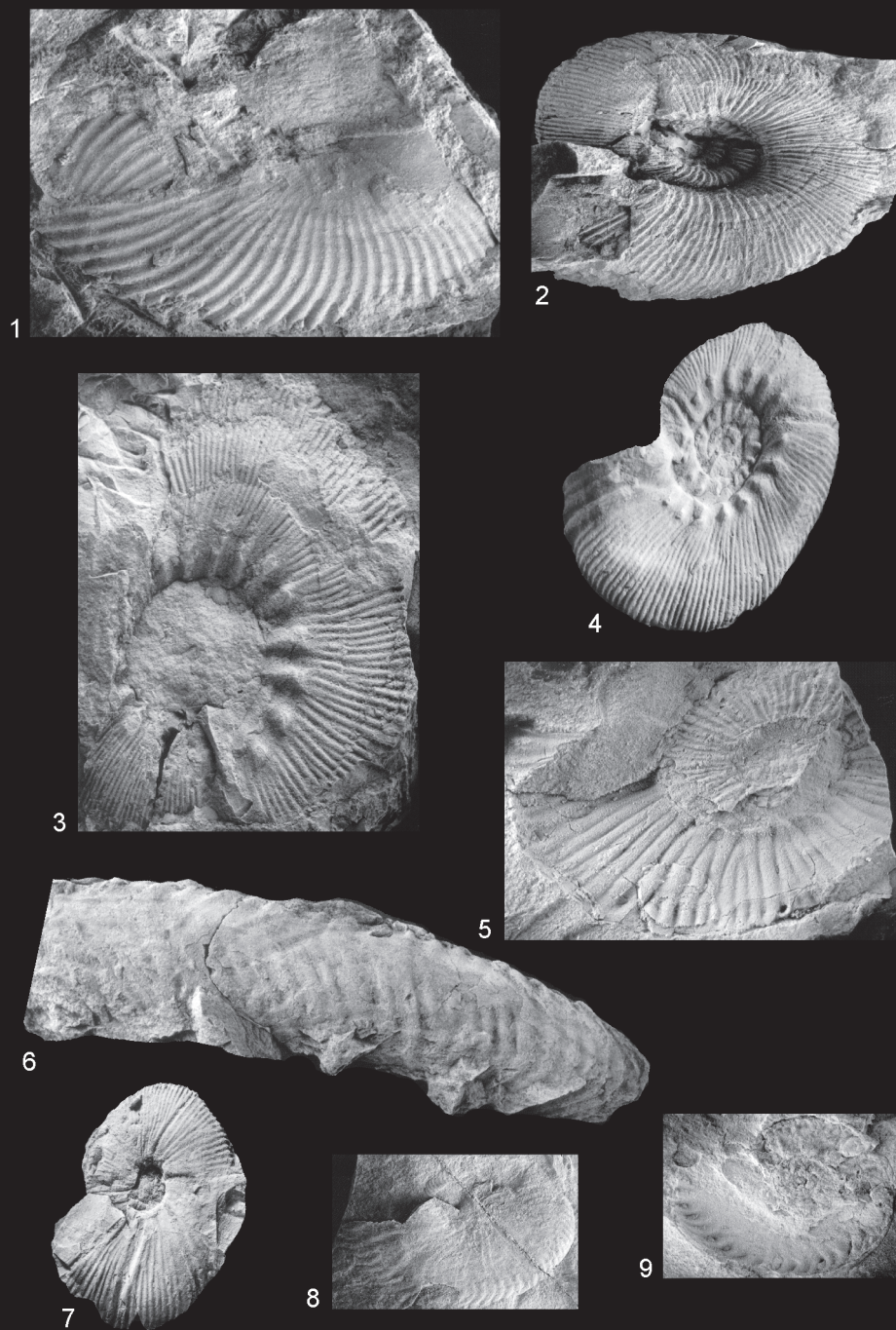
Fig. 8: ?*Acanthodiscus radiatus* (BRUGUIÉRE), log B – x 1, 2002z0070/0040.

Fig. 9: *Leopoldia* sp., log C – x 1, 2002z0070/0032.

All specimens were collected at the Flösselberg quarry.

All specimens were coated with ammonium chloride before photographing.

All specimens are stored at the Museum of Natural History (Vienna, Burgring 7, A-1014, Vienna).



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## Plate 2

Fig. 1: *Neocomites (Neocomites)* sp., log A – x 1, 2002z0070/0042.

Fig. 2: *Neocomites* sp., log A – x 1, 2002z0070/0043.

Fig. 3: ?*Kilianella* sp., log A – x 1, 2002z0070/0033.

Fig. 4: *Neocomites (Neocomites)* sp., log A – x 1, 2002z0070/0044.

Fig. 5: *Himantoceras trinodosum* (THIEULOY), log A – x 1, 2002z0070/0020.

Fig. 6: *Himantoceras trinodosum* (THIEULOY), log A – x 1, 2002z0070/0021.

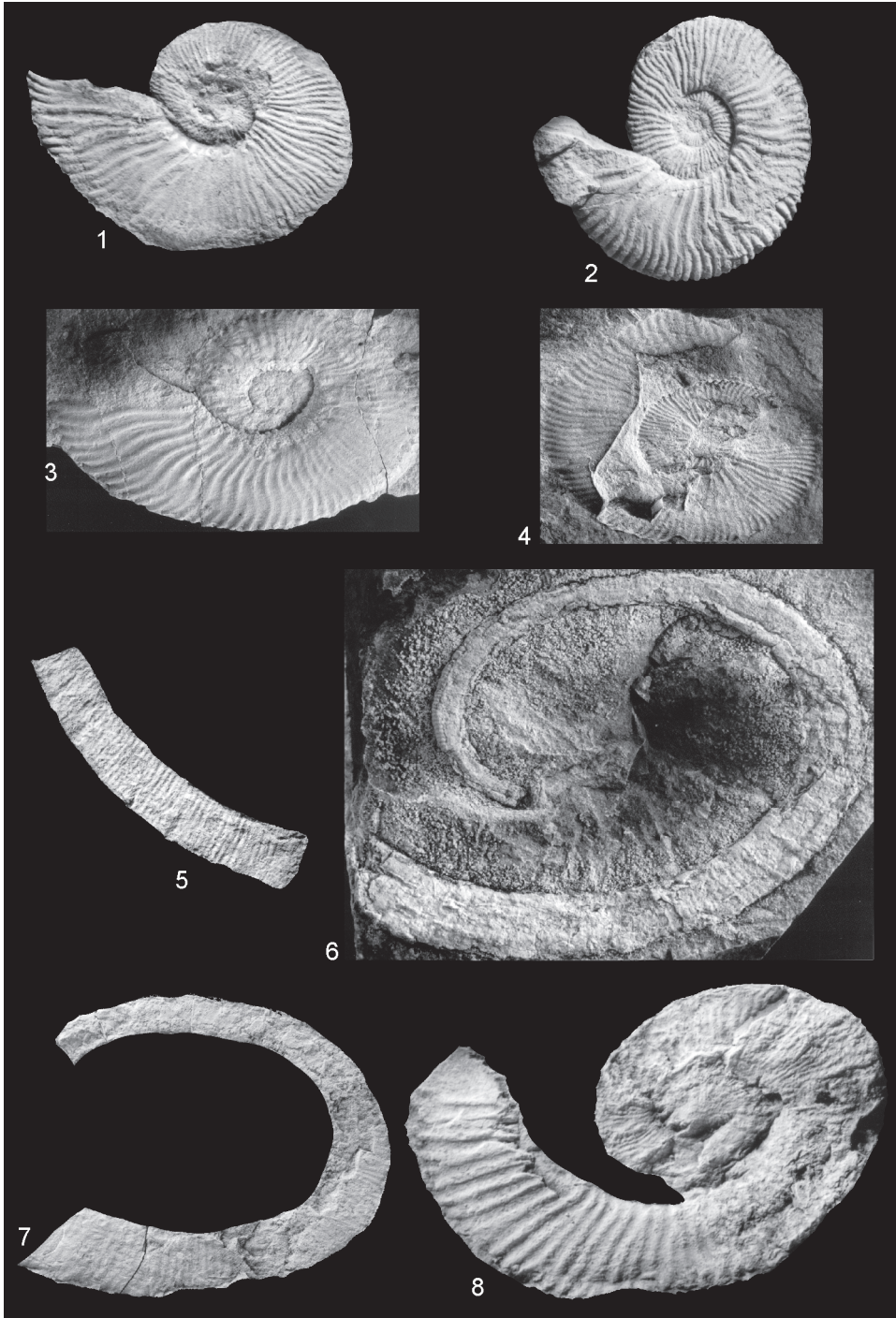
Fig. 7: *Himantoceras trinodosum* (THIEULOY), log A – x 1, 2002z0070/0022.

Fig. 8: *Crioceratites (C.) majoricensis* (NOLAN), log ? – x 1, 2002z0070/0023.

All specimens were collected at the Flösselberg quarry.

All specimens were coated with ammonium chloride before photographing.

All specimens are stored at the Museum of Natural History (Vienna, Burgring 7, A-1014, Vienna).



### Plate 3

Fig. 1: *Crioceratites loryi* (SARKAR), log D – x 1, 2002z0070/0024.

Fig. 2: *Crioceratites* (*Crioceratites*) sp., log ? – x 1, 2002z0070/0025.

Fig. 3: *Crioceratites* (*Crioceratites*) sp., log ? – x 1, 2002z0070/0027.

Fig. 4: *Crioceratites* (*Crioceratites*) cf. *quenstedti* (OOSTER), log ? – x 1, 2002z0070/0026.

Fig. 5: *Ptychoceras* sp., log ? – x 1, 2002z0070/0035.

All specimens were collected at the Flösselberg quarry.

All specimens were coated with ammonium chloride before photographing.

All specimens are stored at the Museum of Natural History (Vienna, Burgring 7, A-1014, Vienna).



#### Plate 4

Fig. 1: *Bochianites oosteri* (SARASIN & SCHÖNDELMAYER), log A – x 1, 2002z0070/0031.

Fig. 2: *Euptychoceras* sp., log E – x 1, 2002z0070/0036.

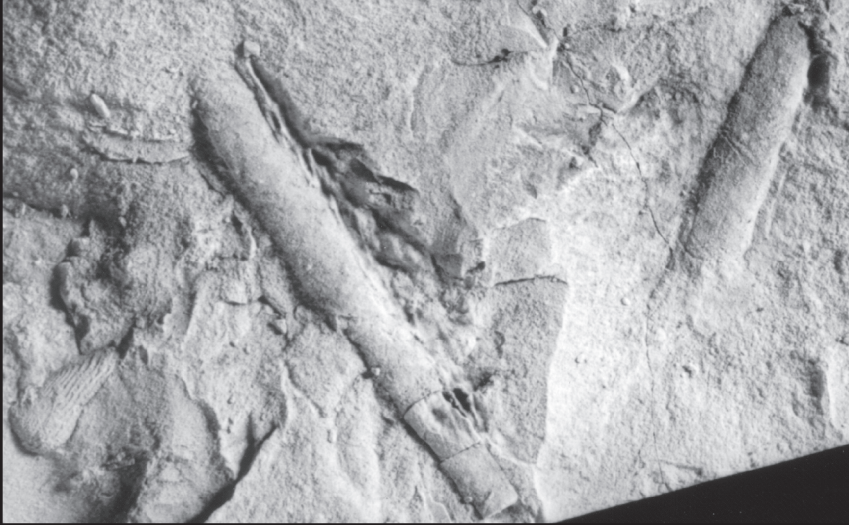
Fig. 3: *Crioceratites krenkeli* (SARKAR), log F – x 1, 2002z0070/0028.

Fig. 4: *Crioceratites krenkeli* (SARKAR), log F – x 1, 2002z0070/0029.

All specimens were collected at the Flösselberg quarry.

All specimens were coated with ammonium chloride before photographing.

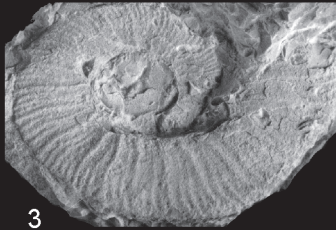
All specimens are stored at the Museum of Natural History (Vienna, Burgring 7, A-1014, Vienna).



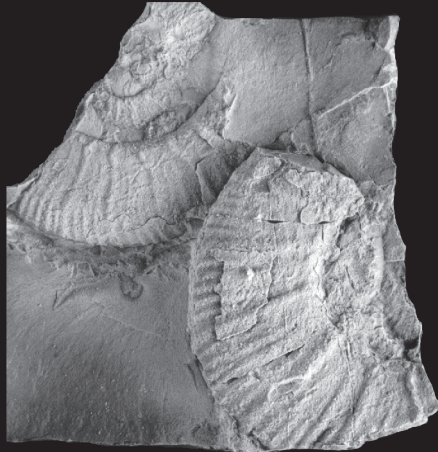
1



2



3



4

