Taphonomy and stratigraphy of Early Cretaceous ammonoid mass occurrences (Late Valanginian; Northern Calcareous Alps: Upper Austria)
Taphonomy and stratigraphy of Early Cretaceous ammonoid mass occurrences (Late Valanginian; Northern Calcareous Alps; Upper Austria)

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Abstract

Ammonoids of Early Cretaceous age were collected in the Kolowratshöhe section, which is located in the easternmost part of the Staufen-Höllengebirgs Nappe (Tyrolic Unit, Northern Calcareous Alps). The cephalopods, which occur in turbidite sandstones of the Rossfeld Formation, indicate a latest Late Valanginian age (Criosarasinella furcillata Zone). The ammonoid fauna (483 specimens) comprises 13 different genera, each represented by 1-2 species. Ammonitina are the most frequent components (65%, represented by Haploceras, Neocomites, Criosarasinella, Rodigieritoïdes, Olocestophanus, Jeanthieuloyites), followed by the lytoceratids (17%, Lytoceras, Leptotetragonites, Protetragonites), the phylloceratids (7%, Phylloceras, Phyllopachyceras) and the ancyloceratids (11%, Bochianites, Crioceratites, Himantoceras). The cephalopod fauna consists only of Mediterranean elements (dominated by Olocestophanus, microconchs and macroconchs, 231 specimens). The term 'Olocestophanus densicostatus abundance zone' is established for these abundance beds. The ammonoid specimens of the Kolowratshöhe are accumulated into 3 different layers within an interval of 30 centimeters of sandstone. The fauna of the Kolowratshöhe section is interpreted as a mixed assemblage, comprising allochthonous elements transported from the shallower shelf and parautochthonous pelagic elements from the open sea.

The presence of abundant glauconite indicates low sedimentation rates in the source area, whereas the final deposition of the sandstones of the Rossfeld Formation took place during conditions of relatively high sedimentation rates but under the influence of turbidites and varying bottom morphology. The allochthonous glauconite points to a shallow shelf environment as the primary source for the sandstones. This source area was interpreted as a land high and a shelf from which the sediments were delivered into basins of the Northern Calcareous Alps (e.g., Tyrolic Unit) to the north of the swell. The basin palaeogeography is interpreted as a submarine, north-directed proximal/distal slope belonging to an uplifted area situated to the south of the basin.


1. Introduction

Lower Cretaceous pelagic sediments are known to form a major element of the Staufen-Höllengebirgs Nappe of the Northern Calcareous Alps (NCA) of Austria. Valanginian to Hauterivian cephalopod-bearing deposits are represented by two different facies, the Schrambach Formation and the Rossfeld Formation. The stratigraphy of these formations and their suggested environments were recently summarized by Piller et al. (2004). Upper Valanginian to Hauterivian sediments of the
two different facies, the Schrambach Formation and the Rossfeld Formation. The stratigraphy of these formations and their suggested environments were recently summarized by Pillier et al. (2004). Upper Valanginian to Hauterivian sediments of the Schrambach Formation are mainly composed of limestones to marly limestones with rare turbiditic sandstone intercalations, whereas the Rossfeld Formation comprises turbiditic marls and sandstones (Immel, 1987).

The thickness of Lower Cretaceous sediments occurring in the northern tectonical units of the NCA decreases towards the north. Geodynamical processes occurring within the basins involved were reviewed by Faupl and Wagrreich (2000). The dominating sandstone deposits within the Tyrolic Unit (e.g., Rossfeld Formation) become less prominent within northern nappes (e.g., Bajuvaric units). Boorová et al. (1999) conducted one of the most recent and detailed lithological and biostratigraphical analyses from the Jurassic Oberalm Formation (uppermost Tithonian) up to the Upper Rossfeld Formation (Upper Valanginian) in the Gutrathbsberg Quarry (near the Rossfeld type locality).

The area around the Kolowratshöhe southeast of Bad Ischl (Upper Austria, see Fig. 1) was first mentioned by Hauer (1850; Kolowratshöhe) and later by Uhlig (1887; Pernecker Salzberg). The latter locality is most probably the same as the one reported herein. During the 1970s and 1980s, a small fauna of cephalopods was described from the surrounding area (Immel, 1978, 1987). The cephalopod fauna published by this author was collected in sandstones and marly limestones of the Rossfeld and Schrambach formations. Most of the ammonoid material that he presented is housed in private collections and was not collected by the author. Additional ammonoid faunas of surrounding areas were also described by Hauer (1847, 1848), Uhlig (1882) and Fugger (1907). Fugger’s ammonoids derive from localities of the Rossfeld, which is the type section for the Rossfeld Formation, but the localities are situated in the neighboring Markt Schellenberg (Bavaria, Germany). From the latter area, a large fauna was collected by Weber (1942) and Pichler (1963) between the Rossfeld and Markt Schellenberg.

The locality studied has been inaccessible for almost 30 years. Until now, only private persons had collected at this locality and no material could be found stored at official places like the Natural History Museum (Vienna), Institute of Palaeontology (University of Vienna), Geological Survey (Vienna) or even in smaller collections of Upper Austria or Salzburg.

New excavations (2002-2004) by the author were extremely successful and yielded a rich and diverse fauna which is presented herein. This was probably the last opportunity to collect fossils at this locality because of excavation circumstances. The collected ammonoid fauna (483 specimens) presented herein is fully integrated in the collection of the Natural History Museum (Vienna). Only a small number (18) of additional specimens is stored in private collections (e.g., collection Mahemdl, Bad Ischl).

The present study examines deposits of the Lower Cretaceous Rossfeld Formation, cropping out at the Kolowratshöhe. The aim of the present work is to detail the ammonoid fauna of the Kolowratshöhe locality, and to analyse the dynamics of the sedimentation for a better understanding of the taphonomy and sedimentology of such Cretaceous pelagic ammonoid beds.

2. Geographical setting

Outcrop. The outcrop is situated in the Staufener-Höllengebirgs Nappe in the southernmost part of Upper Austria, about 3 km southeast of Bad Ischl and 1.5 km east of Perneck (588 m, ÖK 1:50 000, sheet 96 Bad Ischl; Schäffer, 1982) (Fig. 1). The succession comprising the ammonoid-bearing beds, is located at the end of an old, overgrown forest road on the western side of the Kolowratshöhe (1109 m). The sandstone succession is running between the Rettenbach (557 m) to the north and the vicinity of the Salzberg (827 m) to the south. The poor exposure is situated on the left side of the small road. The exact position of the ammonoid site was determined by GPS: N 47°41’24” and E 13°39’24” (Fig. 2). The site can only be accessed with permission from the forest agency, over a steep forest road (approx. 10 km) which has its initial point on the main road from Bad Ischl to Bad Goisern.

3. Geological setting and biostratigraphic age

3.1 Setting

The locality is situated in the southernmost part of the Tyrolic Unit, which in this region lies under and/or adjoins the small ‘Hallstätter Scholle’. The Tyrolic Unit forms part of the ‘Traunalpen

![Figure 1: Locality map of the investigated area showing the outcrop of Lower Cretaceous sediments around the section within the Staufen-Höllengebirgs Nappe (Tyrolic Unit). Rossfeld Formation – yellow. Schrambach Formation – green. In the right upper corner map of Austria with indicated position of the Kolowratshöhe section (white square) and the type locality from the Rossfeld (black square).](image)
Scholle’, which in this region represents the westernmost part of the Staufen-Höllengebirgs Nappe (Tollmann, 1976). Lower Cretaceous sediments are represented in the area around the Kolowratshöhe section by two formations, the Rossfeld Formation (approx. 120 m, Upper Valanginian) and the Schrambach Formation (approx. 40 m, Hauterivian) (Fig. 2). The allochthonous slope-trench sediments of the Rossfeld Formation have been divided at the type locality (Decker et al., 1987) into three different depositional settings: 1) lithofacies A, which is characterized by silty grey marls (approx. 175 m); 2) lithofacies B, characterized by thin to thick bedded sandstones (approx. 120 m) and 3) lithofacies C, characterized by coarse clastics (approx. 50 m).

### 3.2 Lithology

The Kolowratshöhe section consists of essentially ochreous (weathered surface) to dark grey (fresh surface) calcareous, glauconitic sandstones of the Rossfeld Formation. The sandstones, which are assigned to the lithofacies B type of Decker et al. (1987), are well sorted and show biogenic components (e.g. foraminifera, echinids). Single grains are not well rounded, and the sediment seems to be immature. The sandstone consists mainly of quartz and calcite. Further constituents are glauconite, feldspar (albite to plagioclase), chlorite (clinochlore) and unidentified clay minerals (?illite and ?serpentine). Due to weathering, the green colour of the glauconite has changed into brown and consequently the whole sandstone becomes brownish. Glauconite occurs in two different varieties. The first is greenish, the second dark brown, the latter having probably a higher iron content. The sediment has a heavily burrow-mottled fabric owing bioturbation by abundant Chondrites and Planolites and rare Zoophycos.

Single beds are of 20-30 cm thickness and show flat lower and upper boundaries. In most cases these beds show an internal layering, displaying different compositions and a fining upward grading. The internal layers have undulating boundaries and are marked by an accumulation of phosphatic grains. Due to bioturbation, the boundaries are sometimes not clearly expressed and components are mixed and protrude into upper or lower beds. Some beds exhibit a fine, more pelitic top up to 1 cm thickness.

### 3.3 Fossil assemblage

The macroinvertebrate fauna consists of ammonoids (483), aptychi (14) and brachiopods (4, Triangope). Macrovertebrates are only represented by shark teeth (Sphenodus). The order Coniferales is represented by Brachyphyllum, which is the only identifiable plant remnant in the Kolowratshöhe section.

A small number (14) of aptychi in contrast to the very high (483) number of ammonoid specimens (compared with other Valanginian sediment successions of the NCA; Lukeneder, 2001, 2003b) is observed. Isolation of the cephalopod beaks from the ammonoid shell took place either through transport (and therefore different behaviour in the water column) or through current-induced grain differentiation during accumulation.

The abundant and generally well-preserved cephalopods are dominated by olostephanids (Fig. 3). Members of Phylloceratina, Lytoceratina, Ammonitina and Ancyloceratina are present. The very abundant Late Valanginian ammonoid assemblage consists of 13 genera: Phylloceras, Phyllopachyceras, Lytoceras,

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**Figure 2:** Exposure of the Kolowratshöhe section, which is situated in the Rossfeld Formation. 'Now and then’: Left – 1970s. Right – 2004.

**Figure 3:** Ammonoid assemblage composition from the Kolowratshöhe locality. Note the dominance of the Ammonitina and the abundance of the genus Olcostephanus.
Protetragonites, Haploceras, Olcostephanus, Neocomites, Criosarasinella, Rodighieroites, Jeanthieuloyites, Crioceratites, Himantoceras, and Bochianites were collected by the author and by Wolfgang Maherndl. The ammonoid fauna contains only descendants of the Mediterranean Province.

All the olcostephanids have been assigned to one and the same species, i.e. to Olcostephanus densicostatus. This contrasts with the idea of Immel (1987), who identified the olcostephanids from the same locality and the same level as Olcostephanus sayni (Immel, 1987: Pl. 3, Fig. 6) and Olcostephanus astierianus (Immel, 1987: Pl. 3, Fig. 8). Immel's figured material forms part of the collection of Wolfgang Maherndl (Bad Ischl), which was studied by the author. It can be concluded that the locality 'Ischler Salzberg' (Immel, 1987) is in fact the same as the studied locality of the Kolowratshöhe section. Immel's specimens are deformed and therefore morphologically different due to tectonics (different whorl-height against whorl-breadth). Therefore the morphological variation led to misidentification of this species (Fig. 4). Moreover, it has always been difficult to distinguish between juvenile micro- and macroconchs in olcostephanids. This difficulty does not exist in adult specimens (e.g., lappets or collared apertures) (Fig. 5). Finally, Olcostephanus sayni is known to occur in the Hauterivian, not in the Valanginian.

3.4 Biostratigraphy

The ammonoid association sampled in the Kolowratshöhe section indicates that the cephalopod-bearing beds of the Rossfeld Formation belong to the Criosarasinella furcillata ammonoid Zone (Criosarasinella furcillata Subzone) of the latest Late Valanginian (zonation according to Hoedemaeker et al., 2003) (Fig. 6).

The following species were identified: Phylloceras serum, Phyllopachyceras winkleri, Lytoceras subfimbriatum, Lytoceras sutile, Protetragonites sp., Haploceras (Neolissoceras) grasianum, Haploceras (Neolissoceras) desmoceratoideis, Olcostephanus densicostatus, Neocomites praediscus, Neocomites subpachydicranus, Rodighieroites sp., Jeanthieuloyites cf. quinquestriatus, Criosarasinella furcillata, Crioceratites sp., Himantoceras sp., Bochianites oosteri.

This ammonoid association and the occurrence of Criosarasinella furcillata indicate the Criosarasinella furcillata
These abundance zones ('levels', 'horizons') for certain ammonoid species in Alpine Lower Cretaceous sediments. These abundance zones are defined by the high abundance or mass-occurrence of the name-designating taxon (e.g., *Olcostephanus densicostatus* abundance zone). These marker beds apply even if the zonal index fossils are missing. They reflect the acme of such species or genera and not their stratigraphical range. In a few cases only the genus name of the abundant ammonoids could be given because the specimens were not identifiable to the species level (e.g., *Euptychoceras* abundance zone, Lukeneder, 2003b).

**4. Material, preservation and methods**

The material is in general well preserved despite the coarse sandy sediments and their normally poor casting-qualities. The preservation of the ammonoids (mostly moulds without shell) and the lithological character (mottled sandstones) of the Rossfeld Formation makes the sampling difficult. The phragmocones are mostly flattened, while the body chambers are better preserved because of early sediment infilling. The fragmentation is due to preburial transport, sediment compaction and considerable tectonic deformation. The fragmentation hampers the precise determination of most ammonoids. In most cases, faint suture lines are visible, but they are not sufficiently preserved to reproduce them.

All reported and figured specimens in the present paper were collected from the same locality, the Kolowratshöhe section. The material examined is stored in the collection of the Natural History Museum, Vienna, Austria (NHMW). All specimens in Plate 1, 2 and 3 were coated with ammonium chloride before photographing.

The author follows the classification of Cretaceous Ammonoidea by Wright et al. (1996), and the ammonoid systematics was adopted by the following authors: Reboulet (1995), Wippich (2001) and Lukeneder (2004a, b). Concerning the genus *Olcostephanus*, special attention was given to the papers by Bulot (1990, 1992, 1993), Company (1987), Cooper (1981) and Bulot and Company (1990).

In order to obtain pure glauconitic grains, samples were disaggregated with acetic acid in water. Size fractions were obtained by wet sieving with 1000 µm, 500 µm, 250 µm, 125 µm and 63 µm mesh. After ultrasonic treatment, single glauconite grains were dried at 55° C and then selected by hand-picking.

Thin sections and polished sections were made for sedimentological, mineralogical and lithological investigations. Polished surfaces were covered with hydrochloric acid to make differences in matrix visible. The sandstones were subject to X-ray diffraction analysis on a Siemens D5000 X-ray diffractometer. Quantitative chemical analyses were carried out on a JEOL JSM-6400 scanning electron microscope equipped with a KEVEX energy-dispersive system. All the analyses were carried out in the laboratories of the Department of Geology and Palaeontology at the Natural History Museum (Vienna).

**5. Discussion**

**5.1 Taphonomy**

The taphonomic investigations of cephalopod assemblages provide insight not only into the autecology of these organisms,
but also into their palaeoenvironment and palaeocommunity structure (Bottjer et al., 1995; Brett and Baird, 1986). Taphonomical results based on data obtained from the marine fossil record have been extensively reviewed by Allison and Briggs (1991).

The Lower Cretaceous sediments of the Rossfeld Formation (Staufen-Höllengebirgs Nappe) do not represent the best conditions for excellent preservation of entire ammonoids because of their depositional history (turbidites) and the sandy, rather coarse composition. Interestingly, the ammonoids from the Kolowratshöhë section are well preserved and most of them are entire (approx. 70%) what hints to no or moderate, non-destructive transport mechanisms and therefore favors a more autochthonous nature of the latter specimens. Judging from the internal structures of the sandstones, we are dealing turbidite beds of a medial position between a proximal (near-source) and a distal depositional history. Hence, transportation of at least some bio-clasts is presumed.

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The fragmentatio of at least 30% of the ammonoids provides evidence for post-mortem transport, breakage on the sea floor through current effects, and/or consequences of predation (Lukeneder, 2004a, b). In most cases, breakage probably resulted from the impact of shells with other bioclasts within the turbidity currents, or the shells were ruptured by current-induced transport before embedding. Accumulated small ammonoids and shell fragments in body chambers of adjacent large ammonoids, in combination with cephalopod alignment in single layers suggest also current-effects on deposition (Fig. 9). This applies both to straight shells (e.g., Bochianites) as well as coiled shells (e.g., Lytoceras, Haploceras, Olcostephanus). This points to regulation by bottom currents. Erosional features on the upper side of large ammonoids (e.g., macroconchs of Olcostephanus) suggest erosion of uncovered shell parts after embedding. The shell transport took place during phases of turbidity flows, as is reflected by their occurrence in several separated ammonoid-layers (up to 10 cm thickness).

The accumulation of the shells which show horizontal alignment in thin, separated layers, is probably due to reworking and current-induced removal of sediment (Figs. 7, 8). The latter specimens were most probably secondarily re-orientated and so aligned after a first taphidic sedimentation phase. In contrast, ammonoids are extremely rare or even missing in the sandstone beds between the ammonoid beds (I, II, and III; Figs. 7, 8). Encrustation by serpulids on larger smooth shell fragments hint at a longer depositional history for the latter ammonoids. Either they were encrusted during a drifting stage or were colonised while laying on the sea floor long enough for the polychaetes to settle on these special hard substrates or secondary ‘hardgrounds’ (see Lukeneder and Harzhauser, 2003). Encrustation is missing on ribbed ammonoid shells. Densely ribbed shells of the olcostephanid group are less fragmented than those of the lytoceratids (e.g., Lytoceras), phylloceratids (e.g., Phylloceras), ammonitids (e.g., Haploceras, Neocomites and Criocerasina) and ancyloceratids (e.g., Bochianites and Criocerasina). Because of the fragile, juvenile phragmocone morphology of heteromorphic ammonoids, Bochianites, Criocerasina and Himantoceras are generally fragmented; in most cases, only smaller, fractured parts are present. This may reflect different living habitats and therefore different post-mortem histories. It may also reflect the more stable shells of the more ‘spheroidal’ and involute olcostephanids are more resistant to damage than compared other ammonid shell morphologies.

In accumulated mixed assemblages, such as at the Kolowratshöhë section, the KB1-A outcrop (Lukeneder, 2004b) and the Eibeck section (Lukeneder, 2004a), macroconchs and microconchs are found together. Mixed assemblages are defined by the latter author by comprising allochthonous elements transported from the shallower shelf and autochthonous benthic and parautochthonous pelagic elements (e.g., olcostephanids) from the open sea. Assuming an analogous situation for the Kolowratshöhë section as for the Eibeck section, this would mean that the presence of undamaged macroconchs accompanied by intact microconchs (with lappets) within the same bed points to a similar derivation of the ammonoids from the same source, in this case the pelagic fauna of the sea above.

This interpretation is contrasted by the occurrence of some lytoceratid specimens showing different sediment-infillings of the phragmocones (fine, light-grey material) as compared to the body chambers ‘normal’ sandstone). Reasons for these differences in sediment infilling remain still unclear. Probably it’s due to infilling processes, which separates fine from coarse sediment particles. However the former aspect is evidence that at least a small contingent of ammonoids was allochthonous, i.e. transported from shallow to deeper regions, from shelf to slope.
The cephalopods of the Kolowratshöhe section thus constitute a mixed allochthonous/parautochthonous fauna. This effect is enhanced by the fact that turbidity currents and other submarine mass-flows may already contain a mixed shelf and slope assemblage by picking up bioclasts from different bathymetric zones along their way (Einsele and Seilacher, 1991). The term ‘mixed assemblage is used in the sense of Kidwell and Bosence (1991). The latter described a mixed assemblage as the addition of shells of one assemblage to the members of another assemblage. For classification and reviews on taphonomical processes of marine shelly faunas see also Norris (1986), Kidwell et al. (1986), Kidwell (1991), Kidwell and Bosence (1991), and Speyer and Brett (1991).

5.2 Sedimentological and lithological implications

The described fauna was deposited within sediments formed by turbidity currents on the slope (Decker et al., 1987). The sediments were probably reworked and transported in suspension some distance to the north. Originally, the sediments had been deposited on the shelf south of the later embedding place of the ammonoid fauna (Fig. 10). In this southern area, unstable marine sediment accumulations form the prerequisite for the turbidity currents (Einsele, 1991) that built up the Rossfeld Formation. The position of the source area was determined by the work of the present author and others including Faupl (1979), Faupl and Tollmann (1979), Decker et al. (1983), Decker et al.
Glauconite is not stable during surface weathering. It tends to oxidize ochre in sandstones and, during surface alteration, to form kaolinite and iron oxide.

6. Conclusions

The final deposition of the sandstones from the Kolowratshöhe took place during conditions of relatively high sedimentation rates. The sandstones of the Rossfeld Formation in this area consist mainly of turbidites. The source area was a subaerial high and a shelf from which the sediments were delivered into northern basins of the Northern Calcareous Alps. The high has been shown to extend above the sea-level as confirmed by findings of the land plant Brachyphyllum. On the whole, the presence of glauconite indicates a low deposition rate in the source area. The lithological and mineralogical diagnostic findings point to an amalgamation of single turbidite beds after a decline or cessation of sedimentation. A cessation is strongly supported by the accumulation of glauconitic grains in single layers that separate single beds of glauconitic sandstones.

The macrofauna of the Kolowratshöhe section is represented especially by ammonoids. The whole section yielded 483 ammonoids. Based on the presence of the index fossil Criosarasinella furcillata, the fauna can be assigned to the Criosarasinella furcillata ammonoid Zone (Criosarasinella furcillata Subzone). The ammonoid fauna contains only descendants of the Mediterranean Province.
The invertebrate fauna (e.g., ammonoids and brachiopods) are accumulated in isolated single-layers. The shells are aligned concentrated in particular levels and some show current-induced orientation. This applies both to straight shells (e.g., Bochianites) as well as coiled shells (e.g., Lytoceras, Haploceras, Olcostephanus). This points to orientation by currents. Additionally, accumulated small ammonoids and shell fragments in the body chambers of somewhat larger ammonoids supports the assumed effect of agglomeration and scavenging by currents. The accumulation of ammonoid layers indicates either deposition on site at short, favourable ‘time-intervals’, or to reworked accumulation-layers after turbiditic transport.

At least some of the abundant ammonoid specimens seem to have been redeposited from shallower shelf regions into a slope environment. The encrustation of larger smooth shell fragments by serpulids indicates a somewhat longer depositional history for such shells. This is interpreted as a sign for overgrowth of such secondary ‘hardgrounds’ uncovered by sediments, by the benthic organisms during lengthier exposure. Most probably the encrustation took place already at the primary depositional area on the shelf.

The very small number (14) of aptychi contrasts the very high (483) number of ammonoid specimens. Isolation took place either through transport (and therefore different behaviour in the water column) or through current-induced grain differentiation during accumulation. The latter scenario leads to different places of deposition for these two cephalopod elements of the same animal.

Based on all these data, the fauna of the Kolowratshöhe section is interpreted as a mixed assemblage, comprising transported elements from the shallower shelf (allochthonous) along with more parautochthonous pelagic elements (olcostephanids) from the open sea.

**Acknowledgements**

Thanks are due to the Austrian Science Fund (FWF) for financial support (project P16100-N06). I am grateful to Miguel
Company (Granada), Jaap Klein (Leiden), Luc Bulot (Marseille) and Stephane Reboulet (Lyon) for important discussions on some of the ammonoid specimens. I am particularly grateful to Robert Seemann (Vienna) and Franz Brandstätter (Vienna), who helped me with geochemical analysis. Many thanks go to Wolfgang Peter Maherndl (Bad Ischl) for provide access to his collection. Very special thanks go to Miguel Company (Granada) and Philip J. Hoedemaeker (Leiden) for their careful reading and reviewing the manuscript. Photographs were taken by Alice Schumacher (Vienna).

References


Received: 4. April 2005
Accepted: 8. November 2005

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Plate 1:
Figure A: *Phylloceras serum* (Oppel), x 0.5, 2005z0233/0001.
Figure B: *Phylloceras serum* (Oppel), x 0.5, 2005z0233/0002.
Figure C: *Lytoceras subfimbriatum* (d'Orbigny), x 0.5, 2005z0233/0003.
Figure D: *Lytoceras sutile* Oppel, x 0.5, 2005z0233/0004.
Figure E: *Lytoceras sutile* Oppel, x 0.5, 2005z0233/0005.
Figure F: *Phyllopachyceras winkleri* (Uhlig), x 0.5, 2005z0233/0006.
Figure G: *Protetragonites cf. quadrisulcatus* (d'Orbigny), x 0.5, 2005z0233/0007.
Figure H: *Phyllopachyceras cf. rogersi* (Kitchin), x 0.5, 2005z0233/0008.
Figure I: *Phyllopachyceras cf. rogersi* (Kitchin), x 0.5, 2005z0233/0009.
Figure J: *Phyllopachyceras cf. rogersi* (Kitchin), x 0.5, 2005z0233/0010.
Figure K: *Phyllopachyceras cf. rogersi* (Kitchin), x 0.5, 2005z0233/0011.
Figure L: *Haploceras desmoceratoide* Wiedmann, x 0.5, 2005z0233/0012.
Figure M: *Haploceras grasianum* (d'Orbigny), x 0.5, 2005z0233/0013.
Figure N: *Haploceras grasianum* (d'Orbigny), x 0.5, 2005z0233/0014.
Figure O: *Olcostephanus densicostatus* (Wegner), M, x 0.5, 2005z0233/0015.
Figure P: *Olcostephanus densicostatus* (Wegner), M, x 0.5, 2005z0233/0016.
Figure Q: *Olcostephanus densicostatus* (Wegner), M, x 0.5, 2005z0233/0017.
Figure R: *Olcostephanus densicostatus* (Wegner), M, x 0.5, 2005z0233/0018.
Figure S: *Olcostephanus densicostatus* (Wegner), m, x 0.5, 2005z0233/0019.
Figure T: *Olcostephanus densicostatus* (Wegner), M, x 0.5, 2005z0233/0020.
Figure U: *Olcostephanus densicostatus* (Wegner), m, x 0.5, 2005z0233/0021.
Figure V: *Olcostephanus densicostatus* (Wegner), M and m, x 0.5, 2005z0233/0022.
Plate 2:

**Figure A:** Jeanthieuloyites cf. quinquestriatus (Besairie), x 0.5, 2005z0233/0023.

**Figure B:** Jeanthieuloyites cf. quinquestriatus (Besairie), x 0.5, 2005z0233/0024.

**Figure C:** Jeanthieuloyites cf. quinquestriatus (Besairie), x 0.5, 2005z0233/0025.

**Figure D:** Jeanthieuloyites cf. quinquestriatus (Besairie), x 0.5, 2005z0233/0026.

**Figure E:** Criosarasinella furcillata Thieuloy, x 0.5, 2005z0233/0027.

**Figure F:** Criosarasinella furcillata Thieuloy, x 0.5, 2005z0233/0028.

**Figure G:** Criosarasinella furcillata Thieuloy, body chamber, x 0.5, 2005z0233/0029.

**Figure H:** Criosarasinella furcillata Thieuloy, body chamber, x 0.5, 2005z0233/0030.

**Figure I:** Criosarasinella furcillata Thieuloy, body chamber, x 0.5, 2005z0233/0031.

**Figure J:** Neocomites subpachydicranus Reboulet, x 0.5, 2005z0233/0032.

**Figure K:** Neocomites subpachydicranus Reboulet, x 0.5, 2005z0233/0033.

**Figure L:** Neocomites praediscus Reboulet, x 0.5, 2005z0233/0034.

**Figure M:** Neocomites praediscus Reboulet, x 0.5, 2005z0233/0035.

**Figure N:** ?Rodighieroites sp., x 0.5, 2005z0233/0036.

**Figure O:** Himantoceras sp., x 0.5, 2005z0233/0037.

**Figure P:** Crioceratites sp., x 0.5, 2005z0233/0038.

**Figure Q:** Crioceratites sp., x 0.5, 2005z0233/0039.

**Figure R:** Crioceratites sp., x 0.5, 2005z0233/0040.

**Figure S:** Bochianites oosteri (d’Orbigny), x 0.5, 2005z0233/0041.

**Figure T:** Lamellaptychus sp., x 0.5, 2005z0233/0042.

**Figure U:** Lamellaptychus sp., x 0.5, 2005z0233/0043.

**Figure V:** Zoophycos, x 1, 2005z0233/0044.

**Figure W:** Triangope sp., x 1, 2005z0233/0045.

**Figure X:** Sphenodus sp., shark tooth, x 1, 2005z0233/0046.

**Figure Y:** Brachyphyllum sp., Coniferales, x 1, 2005z0233/0047.

**Figure Z:** Accumulated ammonoids on a bedding plane, Olcostephanus, Protetragonites, Neocomites. x 1, 2005z0233/0048.
Plate 3:

**Figure A:** Current-directed ammonoid shells (*Olcostephanus, Protetragonites, Haploceras, Bochianites*) on a bon a bedding plane (65 specimens). For explanation see Figure 9. x 0.5, 2005z0233/0049.