

# A Late Valanginian Mediterranean ammonoid fauna from the Lunz Nappe (Northern Calcareous Alps; Lower Austria)

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## Abstract

Early Cretaceous ammonoids were collected from the Northern Calcareous Alps in the southeasternmost part of the Lunz Nappe (Perchtoldsdorf Syncline) near Vienna. The cephalopod assemblage, the easternmost Early Cretaceous assemblage from the Northern Calcareous Alps, derives from the Rossfeld Formation, indicating a mid Late Valanginian age (*Neocomites peregrinus* Zone). The deposition of the sandy limestones and marly limestones in this interval occurred during unstable environmental conditions which led to a preserved autochthonous fauna comprising additional transported allochthonous ammonoid specimens. The ammonoid fauna yields 6 different genera, each apparently represented by 1-2 species. Ammonitina are the most frequent components (*Haploceras*, *Neocomites*, *Jeanthieuloyites*), followed by the lytoceratids (*Lytoceras*), the phylloceratids (*Phylloceras*), and ancyloceratids (*Himantoceras*). The cephalopod fauna consists of Mediterranean elements dominated by neocomitids.

Unterkreide-Ammonoideen der Nördlichen Kalkalpen werden aus dem südöstlichsten Teil der Lunzer Decke (Perchtoldsdorf Mulde) beschrieben. Die Cephalopoden Fauna der Rossfeld-Formation zeigt unteres Ober-Valanginium an (*Neocomites peregrinus* Zone). Die sandigen und mergeligen Kalke dieses Abschnitts lagerten sich während instabiler Umweltbedingungen ab, welche zu einer autochthonen Fauna mit teilweise transportierten allochthonen Ammoniten führten. Die Ammonoideen-Fauna zeigt 6 unterschiedliche Gattungen, von welchen jede durch 1-2 Arten vertreten ist. Ammonitina stellen das häufigste Faunenelement dar (*Haploceras*, *Neocomites*, *Jeanthieuloyites*), gefolgt von der Gruppe der Lytoceratina (*Lytoceras*), den Phylloceratina (*Phylloceras*) und den Ancyloceratina (*Himantoceras*). Die Cephalopodenfauna setzt sich aus zahlreichen mediterranen Elementen, dominiert durch *Neocomites* zusammen.

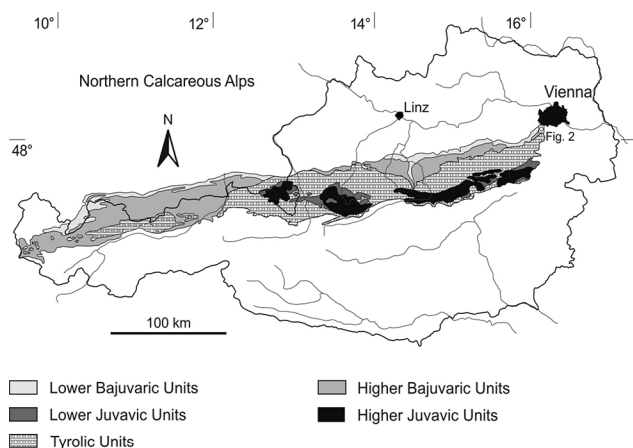
## 1. Introduction

Lower Cretaceous pelagic sediments are known to form a significant element of the northernmost tectonic units of the Northern Calcareous Alps (NCA) (e.g. Ternberg-, Reichraming-, Frankenfels-, and Lunz-nappes; Lukeneder 2003, 2004 a, b, 2005a, b, c; Figure 1). In the Lunz Nappe comprising the Schirgengraben locality, Valanginian cephalopod-bearing deposits are recorded in two different facies, the Schrambach and the Rossfeld formations. Upper Valanginian sediments of the Schrambach Formation are composed of limestones with turbiditic sandstone intercalations (lower parts), whereas the Rossfeld Formation comprises turbiditic marls and sandstones (Vašíček and Faupl 1996, 1998; Boorová et al. 1999; Lukeneder 2003, 2004a, b, 2005a, b, c). Typically, sediments are much coarser (breccias and coarse sandstones) and thicker in the proximal south (Perchtoldsdorf Syncline at the southern Lunz Nappe) than to the distal north of the Flössel Syncline (northern Lunz Nappe) where the turbidites interfinger with fine sandstone layers within the Schrambach Formation (Lukeneder 2003, see for comparison Vašíček and Faupl 1996, 1998). The stratigraphy of the Lower Cretaceous sediments in the investigated area is based on rare ammonoids and microfossil data (Spitz 1910; Plöckinger 1963; Plöckinger and Prey 1964, 1993; Egger and Faupl 1999; Lukeneder and Smrecková 2006; Egger and van Husen 2011; Egger and Wessely 2014).

The presented cephalopod fauna was collected in sandy and marly limestones of the Rossfeld Formation from the eastern Lunz Nappe in Lower Austria, the easternmost locality comprising Lower Cretaceous deposits in the NCA.

Lukeneder (2004a) documented Late Valanginian (*Saynoceras verrucosum* Zone) ammonoids as Mediterranean and Boreal elements from the Rossfeld Formation in Upper Austria (Ebenforst Syncline, Bajuvaric Unit). The sea-level controlled migration for the described *Dichotomites* (*Prodichotomites*) provided the first evidence of Boreal ammonoids within NCA during the Valanginian and, moreover, the southernmost occurrence of this genus so far (see also Lukeneder, 2005c).

The taphonomy and stratigraphy of a Late Valanginian (*Criosarasinella furcillata* Zone) ammonoid mass occurrences within the Northern Calcareous Alps and the source area of the Rossfeld Formation were investigated by Lukeneder (2005a). The fauna from the Upper Austrian Kolowratshöhe section was interpreted as a mixed assemblage, comprising allochthonous elements transported from the shallower shelf and parautochthonous pelagic elements from the open sea. The source area of this turbidite sandstones was interpreted as emerged areas and shelf from which the sediments were delivered into basins of the NCA (e.g. Tyrolic Unit) to the north of the high (Lukeneder 2005a). The basin palaeogeo-



**Figure 1.** Locality map of Austria showing the extension of the Northern Calcareous Alps with the tectonical Bajuvaric, Tyrolic and Juvavic units. The Upper Austroalpine Northern Calcareous Alps extend from the Austrian western border to the city area of Vienna. Indicated is the position of the Schirgenwald locality and area of Figure 3.

graphy is interpreted as a submarine, north-directed proximal-distal slope belonging to an uplifted area situated to the south of the basin.

An additional Early Valanginian ammonoid association from the Rossfeld Formation of Upper Austria (Bajuvaric Unit, Northern Calcareous Alps, Lukeneder, 2005b) was documented from the Hochkogel section in the Ebenforst Syncline (Reichraming Nappe), deposited from a southern source area during unstable environmental conditions with gravitational transport of marls and sandstones with fragmented ammonoid specimens. The cephalopod layers consist only of Mediterranean ammonoid genera and species. The chronostratigraphic significance from the limestone parts of the Rossfeld Formation of the Hochkogel section was precised by an observed calpionellid association indicating an Early Valanginian age (Lukeneder and Reháková, 2007). According to Reháková and Michalík (1997) the standard *Calpionellites* Zone (with *Calpionellites darderi* and *Calpionellites major* subzones) coincides with the Early Valanginian ammonoid zones of *Karakaschiceras inostranzewi*, *Neocomites neocomiensiformis* and "*Thurmanniceras*" *pertransiens*.

Vašíček and Faupl (1996) reported Late Valanginian (*S. verrucosum*, *Neocomites peregrinus* and *C. furcillata* Zone) ammonoid assemblages from the Rossfeld Formation of the Reichraming Nappe (NCA). Only ammonoids belonging to the Mediterranean faunal province deposited in synorogenic clastic deep-water sediments of the Rossfeld Formation were detected. The cephalopod fauna shows similarities to localities in France, Spain or Romania and in contrast severe differences with the geographical direct neighbourhood and its equivalent pelagic deposits from the Western Carpathians. Lateron, Vašíček and Faupl (1998) showed Late Valanginian cephalopods in relation to the palaeogeographic position of the Rossfeld and Schrambach Formation of the Reichraming Nappe. Ammonoids were found in the southern part of the nappe within the synorogenic Rossfeld Formation. Ammonoids were only from the Mediterranean

faunal province. Differences in the faunal composition of Rossfeld Formation versus Schrambach Formation to the north was explained by sorting processes during the turbiditic transport (i.e. mass flows) of the sediment from the southern source area (Vašíček and Faupl 1998). In conclusion, Mediterranean ammonoids clearly dominate the Austrian Early Cretaceous cephalopod fauna.



**Figure 2.** Exposure of the investigated locality and position of the outcrop Schirgenwald, which is situated in the Rossfeld Formation.

## 2. Geographical setting

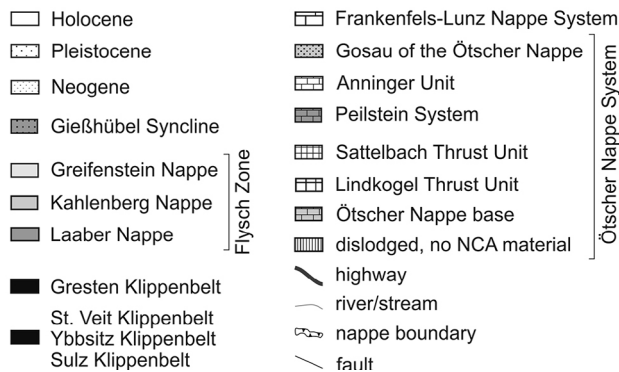
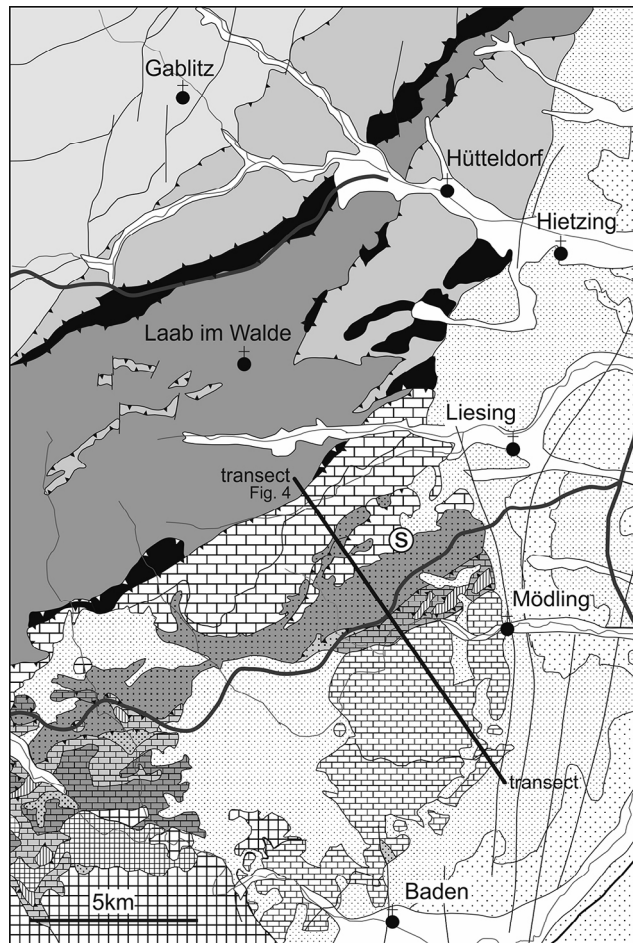
**Outcrop.** The outcrop Schirgenwald (370 m above sea level) is situated in the Lunz Nappe in Lower Austria (Figure 1, about 2.5 km southwest of Vienna and 1 km north of Gießhübl, 416 m; ÖK 1:25 000, sheet 58 Baden 1996; Austromap Online 2015). The outcrop is located at the eastern end of a narrow artificial ravine in the Schirgenwald in the vicinity of the Tirolerhofsiedlung directly to the south (Egger and Wessely 2014; Figure 2). The ravine crosses the easternmost part of the northeast-southwest striking Perchtoldsdorf Syncline in east-west direction (Toula 1905; Plöckinger 1963, 1980; Schnabel et al. 1997; Wessely 2006). The Perchtoldsdorf Syncline is running between Perchtoldsdorf (260 m) in the northeast to the southwest of Gießhübl (416 m; Figure 3). The syncline is part of the Frankenfels-Lunz Nappe System (Föhrenberg-Wasserspreng Unit) in Lower Austria, about 2.5 km southwest of Vienna and 1 km north of Gießhübl (Figure 4).

The succession, comprising the ammonoid-bearing beds, is located 300 m to the south of the Schirgenwald and is badly exposed on the left side of the ravine (GPS – global positioning system coordinates: N 48°06'28", E 16°14'22").

## 3. Geological setting and dating

**Setting.** The Upper Valanginian succession of southeastern Lower Austria was deposited in an unstable shelf setting characterized by thick pelagic limestones punctuated by tectonic events, as represented by the deposition of conglomerates and sandstones (see Faupl 1979). The terrigenous, proximal, deep-water turbiditic Rossfeld Formation (Piller et al. 2004) of the Lunz Nappe represents a synorogenic development

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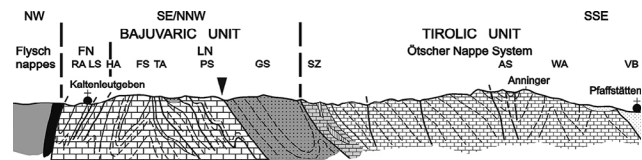
**Figure 3.** Geography and geology of the investigated area with indicated position of the section Schirgengraben (S in circle) in the easternmost part of the Northern Calcareous Alps (Lower Austria). Transect (bold black line) through the nappes of the Northern Calcareous Alps is shown in Figure 4, the map is modified after Schnabel et al. (1997).

(Vašíček and Faupl 1998).

The locality, with dipping of layers to southeast and east-northeast striking shear surfaces paralleling the main fractures of the western Vienna Basin margin, is 50–100 m to the south-east of the excursion point 25b of Egger and Wessely (2014), where stratigraphically older deposits from Tithonian to Berriasian comprising coarser breccia occur. By which extant and dimensions the Lunz Nappe (southern Bajuvaric Unit, Northern Calcareous Alps) reaches below the Upper Cretaceous sedi-

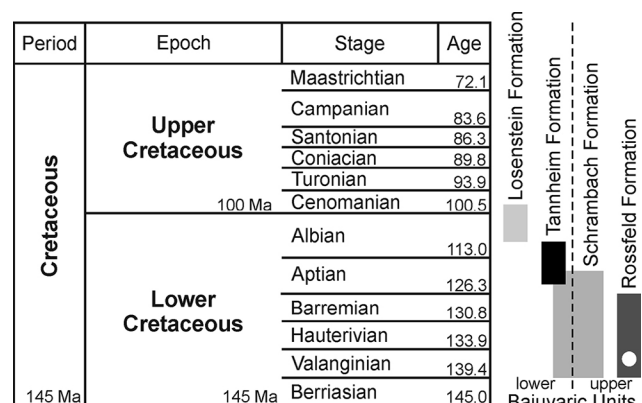
ments of the southern Gießhübl Syncline (Schnabel et al. 1997; Egger and Wessely 2014) is not fully understood. Lower Cretaceous sediments are represented at the Schirgengraben section by two formations, the Schrambach Formation (approx. 20 m, Berriasian-Valanginian) and the Rossfeld Formation (approx. 30 m, Upper Valanginian; Figure 5).

**Lithology.** The Schirgengraben section consists of essentially ochreous (weathered) to grey (fresh surface) calcareous silty marlstones and sandstones of the Rossfeld Formation. The



**Figure 4.** Transect (marked in Figure 3) through the nappes of the Northern Calcareous Alps with the locality (marked by a black arrow) situated in the southernmost Lunz Nappe (higher Bajuvaric Unit). FN Frankenfels Nappe, LN Lunz Nappe, FS Flössel Syncline, RA Rand-Anticline, LS Liesing Syncline, HA Höllenstein Anticline, TA Teufelstein Anticline, PS Perchtoldsdorf Syncline, GS Gießhübl Syncline, SZ ,Schürflingszone', AS Anninger Syncline, WA Wetterkreuz Anticline (redrawn after Plöching and Prey 1993, Lukeneder 2003). Legend as in Figure 3.

calcareous sandstones (wackestone to packstone) comprise various microfossils such as foraminifera, ostracods, radiolaria and abundant sponge spiculae. The radiolarian-spiculite microfacies is dominated by sponge spiculae over radiolaria. Macrofossils (ammonoids, aptychi, echinoids) exhibit the coarse components of the sandstone deposits. Biogenic voids are filled by secondary chalcedony and calcite. Sandstones are well sorted and assigned to the lithofacies B type of Decker et al. (1987). The sandstones consists mainly of calcite and quartz grains. Numerous bioclasts are phosphatized. Further constituents are glauconite, muscovite, unidentified clay minerals and abundant framboidal pyrite. The fabric of the sediment is heavily burrow-mottled (rock samples and thin sections) owing to bioturbation by abundant *Chondrites* and *Planolites*.



**Figure 5.** The stratigraphic position within the studied Upper Valanginian Schirgengraben fauna (white dot) in the Perchtoldsdorf Syncline. Table after Lukeneder (2014, with modifications).



No bedding planes are observable in the massiv sandstone body, hence no internal layering and grading is visible in the outcrop.

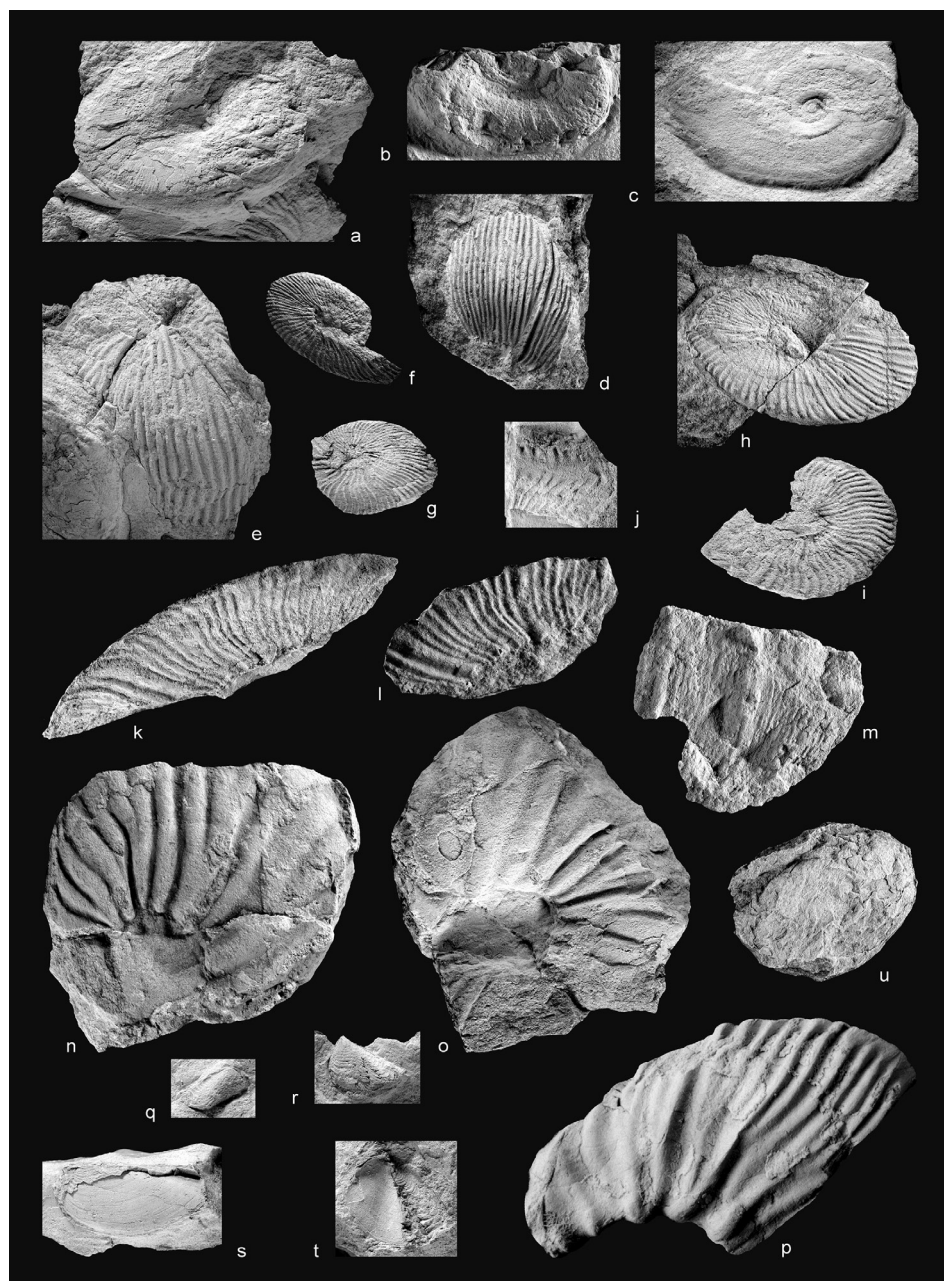
**Fauna.** The invertebrate fauna consists of ammonoids (abundant,  $n = 65$ ), aptychi (rare,  $n = 9$ ), echinoderms (rare echinoids,  $n = 2$ ), bivalves (abundant in matrix), sponges (abundant spiculae), benthic and planktonic foraminifera (abundant) and radiolarian (abundant). The only benthic macrofossils observed in the ammonoid beds are rare echinoids and the remains of heavily fragmented bivalves. The abundant cephalopods (crushed, flattened and fragmented) are dominated by ammonoids. The fairly fossiliferous part of the section shows remarkably abundant neocomitids (Figure 6). Existing plant remnants (debris) are not only identifiable.

Members of Phylloceratina (1%), Lytoceratina (6%), Ammonitina (91%) and Ancyloceratina (2%) are present. The Late Valanginian ammonoids assemblage consists only of 6 genera: *Phylloceras* (*Hypophylloceras*), *Lytoceras*, *Haploceras*, *Neocomites*, *Jeanthieuloyites* and *Himantoceras*.

The mixing of allochthonous and autochthonous faunal elements in the deposits of the Schirgengraben section is based on specimens derived from the local community and preserved as an 'in place assemblage' as well as of fossils that were transported from other habitats.

The cephalopod fauna consists of Mediterranean elements dominated by neocomitids (49%).

**Biostratigraphy.** The association indicates that the cephalopod-bearing deposits of the Rossfeld Formation belong



**Figure 6.** Ammonoid fauna from the Late Valanginian (*Neocomites peregrinus* Zone) Schirgengraben section. Figure 6p is refigured from the Eibeckgraben section (Upper Austria, NCA) of Lukeneder (2004). **a)** *Phylloceras* (*Hypophylloceras*) *tethys* (d'Orbigny), lateral view, NHMW2016/0051/0001. **b)** *Lytoceras subfimbriatum* (d'Orbigny), lateral view, NHMW2016/0051/0002. **c)** *Haploceras grasiacum* (d'Orbigny), lateral view, NHMW2016/0051/0003. **d)** *Jeanthieuloyites* cf. *quinquestriatus* (Besairie), lateral view, NHMW2016/0051/0004. **e)** *Jeanthieuloyites* cf. *quinquestriatus* (Besairie), oblique view, NHMW2016/0051/0005. **f)** *Neocomites* (*Varlheideites*) *peregrinus* (Rawson and Kemper), microconch, lateral view, NHMW2016/0051/0006. **g)** *Neocomites* (*Varlheideites*) *peregrinus* (Rawson and Kemper), microconch, lateral view, NHMW2016/0051/0007. **h)** *Neocomites* (*Varlheideites*) *peregrinus* (Rawson and Kemper), microconch, lateral view, NHMW2016/0051/0008. **i)** *Neocomites* (*Varlheideites*) *peregrinus* (Rawson and Kemper), microconch, lateral view, NHMW2016/0051/0009. **j)** *Neocomites* (*Varlheideites*) *peregrinus* (Rawson and Kemper), microconch, external view, NHMW2016/0051/0010. **k)** *Neocomites* (*Varlheideites*) *peregrinus* (Rawson and Kemper), macroconch, 3 main three-tuberculated ribs, lateral view, NHMW2016/0051/0011a. **l)** *Neocomites* (*Varlheideites*) *peregrinus* (Rawson and Kemper), cast of the negative of k, macroconch, note 3 main three-tuberculated ribs and adoral constrictions, lateral view, NHMW2016/0051/0011b. **m)** *Himantoceras* cf. *trinodosum* Thieuloy, 3 main tuberculated ribs, lateral view, NHMW2016/0051/0012. **n)** *Jeanthieuloyites* sp., lateral view, NHMW2016/0051/0013. **o)** *Jeanthieuloyites* sp., opposite side, lateral view, NHMW2016/0051/0013. **p)** *Dichotomites* (*Prodichotomites*) sp., adult specimen, Eibeck section, NHMW2003z0080/0016. **q)** *Lamellaptychus* sp., lateral view, NHMW2016/0051/0014. **r)** *Lamellaptychus* sp., lateral view, NHMW2016/0051/0015. **s)** *Lamellaptychus* sp., lateral view, NHMW2016/0051/0016. **t)** *Lamellaptychus* sp., lateral view, NHMW2016/0051/0017. **u)** sea urchin sp., aboral view, NHMW2016/0051/0018. Genus *Varlheideites* sensu Rawson and Kemper (1978), All figures x 1.

to the *Neocomites peregrinus* ammonoid Zone (upper part of the *N. peregrinus* Subzone and/or lower part of the *H. trinodosum* Subzone = *Olcostephanus* (*Olcostephanus*) *nicklesi* Subzone; Klein and Hoedemaeker 1999; Reboulet et al. 2014) of the early Late Valanginian (according to the Lower Cretaceous Ammonite Working Group of the IUGS; 'Kilian Group'; 2014).

The following ammonoids were observed: *Phylloceras* (*Hypophylloceras*) *tethys* (n = 1), *Lytoceras subfimbriatum* (n = 4), *Haploceras grasianum* (n = 24), *Jeanthieuloyites* cf. *quinquestriatus* (n = 3), *Neocomites* (*Varlheideites*) *peregrinus* (n = 32), *Himantoceras* cf. *trinodosum* (n = 1). *Neocomites* (*Varlheideites*) *peregrinus* (for the zone and subzone) and the typical ammonoid association (Figure 6) hint towards the *N. peregrinus* Zone (Reboulet et al. 2014). As noted by Hoedemaeker et al. (2003) the zonal index ammonoid *N. (V.) peregrinus* is easily recognizable, occurs throughout in the Mediterranean Province (e.g. Spain, France, Austria), and has an inter-realm distribution (in Boreal of north Germany).

#### 4. Material

During the course of this study (collecting 2004 and 2015), 65 ammonoids and 9 lamellaptychi were examined. Additional ammonoids (n = 10) were collected by Benno Plöschinger (Geological Survey of Austria, GSA and Museum Mödling, MUMÖ) and private collectors in the early 1960s, 1970s and

1980s and have been reinvestigated by the author.

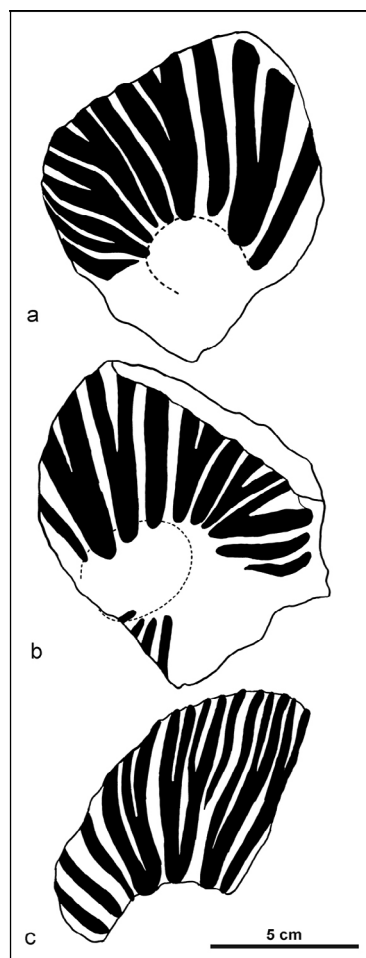
In general the material is moderately well preserved (n = number of specimens). Ammonoids show no remnants of primary (aragonite) or altered shell (calcite). Only calcitic lamellaptychi (n = 9) are preserved in original composition. The phragmocones and body chambers are mostly flattened. Relics of suture lines are only visible in few specimens. The fragmentation of ammonoids is due to preburial transport, sediment compaction and considerable tectonic deformation, which hampers the precise determination of most cephalopods with chambered hard-parts (e.g. ammonoids).

Thin sections were carried out in the laboratories of the Natural History Museum Vienna. Macrofossils were prepared by the author by the use of mechanical vibro tools. Ammonoids, aptychi and echinoids were coated with ammonium chloride before photographing. The basic classification of Cretaceous Ammonoidea by Avram and Gr dinaru (1993), Wright et al. (1996), Klein (2005, 2006), Klein et al. (2009) has been followed. The detailed ammonite systematics and taxonomy were adopted and correlated with papers by numerous authors cited in introduction and Discussion above and below. The material examined is deposited in the palaeontological collection of the Natural History Museum, Vienna (NHMW) and at the Museum Mödling, Lower Austria (MUMÖ).

#### 5. Discussion

##### *Late Valanginian stratigraphy of the Schirgengraben section*

The age of the sandy to calcareous marls from the artificial ravine in the Schirgenwald was given by Egger and Wessely (2014) as early Early Cretaceous (based on primary determination of ammonoids by A. Lukeneder). Underlying breccia layers of excursion point 25b in Egger and Wessely (2014) were determined to be of Tithonian to Berriasian age. The breccia sediments were deposited by gravitational transport and slumpings (see Figure 8) in the Late Jurassic and Early Cretaceous, resulting in brecciated accumulation layers with components from the NCA (Beck-Mannagetta 1947; Egger and Wessely 2014). Plöschinger (1963) noted a "Neocomian" age and up to 10 m thickness for the breccia and a Berriasian to Valanginian age and approx. 30 m thickness for the overlying sandy, marly limestones. The author noted also the occurrence of hoplitids and lamellaptychi in the sandy parts. The sandy layers were described as equivalent to the Lower Cretaceous deposits which occurred at the *Acanthiscus*-quarry (= "*Acanthiscus*steinbruch" in Toulou 1907a, b, Plöschinger 1963; Plöschinger and Karanitsch 2002; excursion point 25a in Egger and Wessely 2014). Toulou (1907a) noted from that outcrop the Lower Cretaceous ammonoids "*Hoplites* (*Neocomites*) aff. *campylotoxus*" (= *Busnardoites campylotoxus*, see Klein 2005), "*Hoplites* sp." (= *Neocomites*, see Klein 2005) and the ammonoid jaws of "*Aptychus* cf. *didayi*". This cephalopod assemblage extended by the findings recorded by Plöschinger (1963) and Plöschinger and Karanitsch (2002) with "*Partschiceras winkleri*" (= *Phyllopachyceras winkleri winkleri*, see Klein et al. 2009), *Lamellaptychus beyerichi* and *Lamellaptychus lamellosus*. An



**Figure 7.** Drawings of a special morphotype of *Jeanthieuloyites* sp. figured in Figure 6n and Figure 6o from the Schirgengraben locality. **a)** *Jeanthieuloyites* sp., NHMW2016/0051/0013, lateral view. **b)** Opposite side of the same specimen. **c)** Drawing of a refigured *Dichotomites* (*Prodictomites*) sp. specimen from the Eibeckgraben in Upper Austria (*Saynoceras verrucosum* Zone, *Karakaschiceras pronecostatum* Subzone, Lukeneder 2004a) NHMW2003z0080/0016, lateral view. Scale bar 5cm.



additional fauna from the sandy and marly limestones from the "Acanthisussteinbruch" was reported by Plöschinger (1963) with "*Holcostephanus*" (= *Olcostephanus*), *Lamellaptychus* cf. *mortilleti*, *Lamellaptychus* cf. "*exavatus*" (corr. *excavatus*) and *Lamellaptychus* sp. accompanied by a single belemnite (collected by G. Wessely and determined by F. Trauth). From equivalent sandy deposits at the northeast edge of the "Vösendorfer Wald" (Vösendorf woods) additional *Lamellaptychus seranonis* and "*Hoplites* sp." (= *Neocomites*) were described by Plöschinger (1963). From a modern point of taxonomic view most of the determinations are not correct and highly speculative. Most of the historical material is lost and cannot be reinvestigated, hence not used for detailed biostratigraphy.

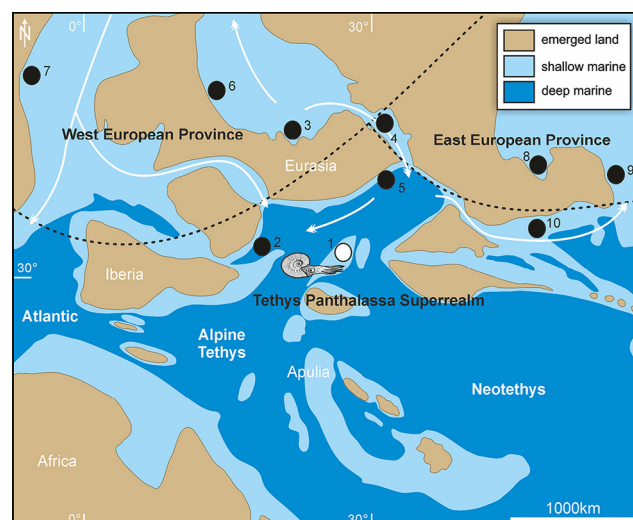
The more recently collected ammonoid fauna from the Schirgengraben and the additional specimens (same locality) in the Plöschinger collection (MUMÖ) appears with 6 different genera (noted above) accompanied by ammonoid beaks (i.e. lower jaws) from the group *Lamellaptychus*. The ammonoid assemblage (compared to other Mediterranean occurrences, see discussion below) hint to a middle Late Valanginian age (upper part of the *N. peregrinus* Subzone and/or lower part of the *H. trinodosum* Subzone).

During the Valanginian, the NCA were situated at the eastern border of the Alpine-Carpathian block, which was located at the western margin of the Tethys (e.g. Cecca 1997, 1998; Vašíček and Michalik 1999; Stampfli and Mosar 1999; Lukeneder 2003). The Upper Austrian Eibeck ammonoid locality differs from the Lower Austrian Schirgengraben assemblage by the abundance and dominance of the genus *Olcostephanus* (*Olcostephanus guehardi* with 46 % versus 0 %). This might be explained by the significant biostratigraphic shift from the *S. verrucosum* (*K. pronecostatum* Subzone) at the Eibeck section to the *Neocomites peregrinus* Zone (*N. peregrinus* Subzone) at the Schirgengraben section.

As noted by Vašíček et al. (1994) and Vašíček and Faupl (1998, 1999) and shown by Lukeneder (1997, 1998, 2001, 2003, 2004b, 2005a, b, c) in numerous papers on the Lower Cretaceous deposits of Austria, so far Mediterranean ammonoids dominate the Lower Cretaceous of the NCA (Lukeneder 2004a).

#### Taphonomic implications

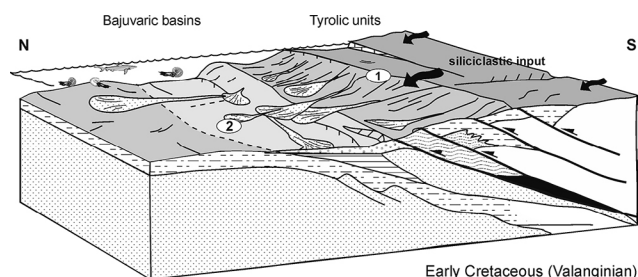
Taphonomic investigations among invertebrate-assemblages (e.g. ammonoids) provide insight not only into the auto-



**Figure 9.** Paleogeographic map of the Mediterranean area during the Late Valanginian to Late Hauterivian based on Kotetishvili (1988), Wiedmann (1988), Dercourt et al. (1993), Kiessling et al. (2003), Scotese (2001), Barrier and Vrielynck (2008) and Lukeneder and Grunert (2013). Numbers indicate well known Lower Cretaceous localities from literature: 1) Northern Calcareous Alps, Austria 2) Vocontian Basin, France 3) North German Basin, Germany, 4) Polish Through, Poland, 5) Western Carpathians, Czech Republic, 6) East Midlands Shelf, England, 7) Western North-Atlantic Shelf, Greenland, 8) Russian Platform, Russia, 9) Mangyshlak Peninsula, Kazakhstan, 10) Crimean Platform, Republic Crimea. Generalized marine molluscan environments (adapted after Zakharov and Rogov 2003). Dashed line marks the boundaries between the Southern Tethys-Panthalassa Superrealm and the northern Boreal Atlantic Realm with the West-European and East-European provinces.

cology of these organisms, but also into their palaeoenvironment and palaeocommunity structure (Brett and Baird 1986, Bottjer et al. 1995). The tectonically strongly deformed Lower Cretaceous sediments of the Perchtoldsdorf Syncline (Lunz Nappe, eastern NCA) do not represent the best conditions for excellent preservation of entire ammonoids. This issue reflects the depositional history (turbidites, Figure 8)) and the sandy, rather coarse composition of the Valanginian deposits of the Rossfeld Formation. The fragmentation of numerous ammonoid shells points to at least a minimal transportation. In most cases they resulted from the impact of shells with other bioclasts during episodes of current transport before embedding.

The described specimens were deposited in sediments of the outer shelf to slope (see Faupl, 1979; Decker et al., 1987; Faupl and Wagreich, 1992). The sediments were probably reworked and transported in suspension some distance to the north (Figure 8). Originally, the sediments had been deposited south of the later embedding place of the ammonoid fauna. In this southern area, unstable marine sediment accumulations form the prerequisite for the turbidity currents (Einsele 1991; Einsele et al. 1991; Einsele and Seilacher 1991) that built up the deposits of the Rossfeld Formation. The source area for the siliciclastics was a tectonically active land high (compare Faupl and Wagreich, 1992; Vašíček and Faupl, 1996, 1998) from which the sediments were delivered into northern basins of the NCA (e.g., Tyrolic Unit).



**Figure 8.** Model for the palaeogeographic transect and sedimentary origin of the sandy turbidite beds of the Rossfeld Formation at Giesshübl during the Late Valanginian. 1) source area of sediments and ammonoids. 2) final deposition after transport.

This reconstruction allows a tentative interpretation of the original habitat of the ammonoids investigated. They probably dwelled in more shallow waters than those in which they were ultimately deposited. Based on its abundance, the dominating genera *Neocomites* (49 %) and *Haploceras* (37 %) are the most valuable constituents of the described fauna for palaeogeographic and taphonomic interpretation. The interpretation of the faunal origin is strengthened by the suggested palaeogeographic position of the studied section. Therefore, the author assumes that the Schirgengraben cephalopods constitute a mixture of autochthonous (bivalves, echinoids) and allochthonous (ammonoids, belemnoids) faunal elements. 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.

The fragmented ammonoid specimens lack any encrustation, indicating rapid sinking of the animal without any transport on the sea-surface or lying for quite a long time on the sea-floor (compare Lukeneder, 2004a, 2005a). The shell transport took place after the embedding in the sediment as ‘mudflows’, as is reflected in the different alignments of the ammonoid shells and fragments within the sediment. Judging from the internal structures (bad sorting, no gradation) of the sandstones, we are dealing turbidite beds of a medial position between a proximal (near-source) and a distal depositional development (Einsele, 1991). Hence, transportation of at least some bio-clasts is presumed. Note that caution should be exercised when applying the terms autochthonous and allochthonous in cephalopods (e.g. ammonoids, belemnoids, aptychi).

## 6. Conclusions

The macrofauna reported for the first time of the Schirgengraben section (Perchtoldsdorf Syncline, Lunz Nappe, Northern Calcareous Alps) is represented especially by ammonoids, aptychi, and echinoids. The whole section has yielded 65 ammonoids, 9 aptychi and 2 echinoids. The ammonoid assemblage is the easternmost Early Cretaceous fauna described from the Northern Calcareous Alps so far.

The fauna can be assigned to the upper part of the *N. peregrinus* Subzone and/or lower part of the *H. trinodosum* Subzone (sensu Reboulet et al. 2014). Ammonoids were observed with *Phylloceras* (*Hypophylloceras*) *tethys*, *Lytoceras subfimbriatum*, *Haploceras grasianum*, *Jeanthieuloyites* cf. *quinquestriatus*, *Neocomites peregrinus*, and *Himantoceras* cf. *trinodosum*.

The ammonoid fauna contains only descendants of the Mediterranean Province.

The deposition of the sandstone of the Rossfeld Formation took place during conditions of relatively stable water masses and high sedimentation rates but under unstable sedimentological (e.g. turbidites, bottom morphology) conditions. The

shells were transported within ‘mass flows’ following embedment in the sediment. The invertebrate fauna (e.g., ammonoids, aptychi, echinoids) are dispersed in the matrix of the sandstones and not accumulated in isolated single-layers. No ammonoid shell alignment or concentration occurs.

The abundant ammonoids specimens (phylloceratids, lytoceratids, neocomitids, haloploceratids, holcodiscids, ancyloceratids) seem to have been redeposited from a southern source area with subaerial highs, shallower shelves and upper slopes (Tyrolic units) into deeper shelf environments to the north (Bajuvaric units). The fauna of the Schirgengraben section is therefore interpreted as a mixed assemblage, comprising transported elements from the shallower shelf and autochthonous benthic and parautochthonous pelagic elements from the open sea.

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