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

Alexander LUKENEDER
Geological-Palaeontological Department, Natural History Museum, Burgring 7, A-1010 Wien, Austria; alexander.lukeneder@nhm-wien.ac.at

KEYWORDS Tethyal ammonoid assemblage; Early Cretaceous (Late Valanginian); Perchtoldsorf Syncline; Lunz Nappe; Northern Calcareous Alps

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 zeigte unteres Ober-Valanginium an (Neocomites peregrinus Zone).

The sandigen und mergeligen Kalke dieses Abschnitts lagerten sich während instabiler Umweltbedingungen ab, welche zu einer autochthonen Fauna 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 Schirngengraben 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 (Vašiček 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 Vašiček 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; Plöchinger 1963; Plöchinger 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 palaeogeog-
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.

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

(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 southeast 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 sediments of the southern Gießhübl Syncline (Schnabel et al. 1997; Egger and Wessely 2014) is not fully understood. Lower Cretaceous sediments are represented at the Schirngengraben 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 Schirngengraben section consists of essentially oechrous (weathered) to grey (fresh surface) calcareous silty marlstones and sandstones of the Rossfeld Formation. The calcareous sandstones (wackestone to packstone) comprise various microfossils such as foraminifera, ostracods, radiolarians and abundant sponge spiculae. The radiolarian-spiculite microfacies is dominated by sponge spiculae over radiolarians. 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 bioturbated by abundant Chondrites and Planolites.

Figure 3. Geography and geology of the investigated area with indicated position of the section Schirngengraben (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).

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 southermost Lunz Nappe (higher Bajuvaric Unit). FN Frankenfels Nappe, LN Lunz Nappe, FS Flössel Syncline, RA Rand-Anticline, LS Liesing Syncline, HA Hollenstein Anticline, TA Teufelstein Anticline, PS Perchtoldsdorf Syncline, GS Gießhübl Syncline, SZ „Schürflingszone”, AS Anninger Syncline, WA Wetterkreuz Anticline (redrawn after Plöchinger and Prey 1993, Lukeneder 2003). Legend as in Figure 3.

Figure 5. The stratigraphic position within the studied Upper Valanginian Schirgenwald 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), aptchyi (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 refuged from the Eibeckgraben section (Upper Austria, NCA) of Lukeneder (2004). a) Phylloceras (Hypophylloceras) tethys (d’Orbigny), lateral view, NHMW2016/0051/0001. b) Lytoceras subimbriatum (d’Orbigny), lateral view, NHMW2016/0051/0002. c) Haploceras gracium (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 (Varheiideites) peregrinus (Rawson and Kemper), microconch, lateral view, NHMW2016/0051/0006. g) Neocomites (Varheiideites) peregrinus (Rawson and Kemper), microconch, lateral view, NHMW2016/0051/0007. h) Neocomites (Varheiideites) peregrinus (Rawson and Kemper), microconch, lateral view, NHMW2016/0051/0008. i) Neocomites (Varheiideites) peregrinus (Rawson and Kemper), microconch, lateral view, NHMW2016/0051/0009. j) Neocomites (Varheiideites) peregrinus (Rawson and Kemper), microconch, lateral view, NHMW2016/0051/0010. k) Neocomites (Varheiideites) peregrinus (Rawson and Kemper), macroconch, 3 main three-tuberculated ribs, lateral view, NHMW2016/0051/0011a. l) Neocomites (Varheiideites) 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, NHMW2016/0051/0014. p) Dichotomites (Prodichotomites) sp., adult specimen, Eibeck section, NHMW2003/2008/0016. 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 Varheiideites 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 = Olocastephanus (Olocastephanus) nicklesi Subzone; Klein and Hoedemaeker 1999; Rebulot 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 Plöchinger (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 phragmocoones 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 Gröndinur (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). Plöchinger (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 Acanthicus-quarry (= “Acanthicussteinbruch” in Toula 1907a, b, Plöchinger 1963; Plöchinger and Karanitsch 2002; excursion point 25a in Egger and Wessely 2014). Toula (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 Plöchinger (1963) and Plöchinger and Karanitsch (2002) with “Partschiceras winkleri” (= Phyllopachyceras winkleri winkleri, see Klein et al. 2009), Lamellaptychus bayerichi and Lamellaptychus lamellosus. An
additional fauna from the sandy and marly limestones from the “Acanthicussteinbruch” was reported by Plochinger (1963) with “Holocostephanus” (= Olocostephanus). 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 equidistant sandy deposits at the northeast edge of the “Vösendorf Wald” (Vösendorf woods) additional Lamellaptychus seranonis and “Hoplitid sp.” (= Neocomites) were described by Plochinger (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 Plochinger 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 Michalík 1999; Stampfl and Mosar 1999; Lückeneder 2003). The Upper Austrian Eibeck ammonoid locality differs from the Lower Austrian Schirgengraben assemblage by the abundance and dominance of the genus Olocostephanus (Olocostephanus guebhardi 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 (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 autecology 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 palaeoecographic 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, aptchi).

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 earliest 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 Rebourlet et al. 2014). Ammonoids were observed with Phylloceras (Hyphophylloceras) tethys, Lytoceras subfimbriatum, Haploceras grasiarum, Jeantieuloyrites 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 redepsoited from a southern source area with subaerial highs, shallow 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.

Acknowledgements

The author would like to thank Godfrid Wessely (Vienna) who made me aware of the Schirgengraben area and guided me to the Cretaceous outcrops. I am particularly grateful to Peter Alsen (Copenhagen), Miguel Company (Granada), Zdenek Vašíček (Ostrava-Poruba), and Evgenij Baraboshkin (Moscow) for the discussion on ammonoid taxonomy. Thanks go to Daniela Reháková (Bratislava) for the evaluation of a thin section. The manuscript greatly benefited from reviews by István Fózy (Budapest), and two anonymous reviewer and the editor in chief Michael Wagreich (Vienna). Monika Chromy (Museum Mödling) is acknowledged for providing access to the specimens in the exhibition and collection of the Museum Mödling (Lower Austria). Thin sections were carried by Anton Englert (Vienna). Photographs were taken by Alice Schumacher (Vienna).

References

Austromap Online 2015. Bundesamt für Eich- und Vermessungswesen, Wien. http://www.austriamap.at/amap/index.php?SKN=1&XPX=637&YPX=492, accessed 6 October 2015.

Avram, E. and Grădinaru, E., 1993. A peculiar Upper Valanginian cephalopod fauna from the Carpathian Bend (Codlea Town area, Romania): biostatigraphic and paleobiogeographic implications. Jahrbuch der Geologischen Bundesanstalt, 136, 665-700.

Barrier, E. and Vrielynck, B. 2008. Palaeotectonic maps of the Middle East, CCGM, 14 maps.

Beck-Mannagetta, P., 1947. Geologische Beobachtungen in der Gießhübler Mulde bei Mödling. Anzeiger der Österreichischen Akademie der Wissenschaften, mathematisch-naturwissenschaftliche Klasse, 89, 59-66.

Boorová, D., Lobitzer, H., Skupien, P., Vašíček, Z., 1999. Biostatigraphy and facies of Upper Jurassic-Lower Cretaceous pelagic carbonate sediments (Oberalm-, Schrambach- and Rolf-Mödling-Fauna) in the Northern Calcareous Alps, South of Salzburg. Abhandlungen der Geologischen Bundesan-
stalt, 56/2, 273-318.

Bottjer, D.J., Campbell, K.A., Schubert, J.K. and Droser, M.L., 1995. Palaeoecological models, non-uniformitarianism, and tracking the changing ecology of the past. In: D. W. J. Bosence and P. A. Allison (Editors): Marine palaeoenvironmental analysis from fossils. Geological Society London Special Publication, 83, 7-26.

Brett, C.E. and Baird G.C., 1986. Comparative taphonomy: a key to palaeoenvironmental interpretation based on fossil preservation. Palaios, 1, 207-227.

Cecca, F., 1997. Late Jurassic and Early Cretaceous uncoiled ammonites: trophism-related evolutionary processes. Comptes Rendus Académie des Sciences Paris, série II, 325, 629-634.

Cecca, F., 1998. Early Cretaceous (pre-Aptian) ammonites of the Mediterranean Tethys: Palaeoecology and palaeobiogeography. Palaeoecogeography, Palaeoclimatology, Palaeoecology, 138, 305-323. http://dx.doi.org/10.1016/S0031-0182(97)00126-0

Decker, K., Faupl, P. and Müller, A., 1987. Synorogenetic Sedimentation on the Northern Calcareous Alps during the Early Cretaceous. In: Flügel H.W. and Faupl P. (eds), Geodynamics of the Eastern Alps, 126-141.

Dercourt, J., Ricou, L.E. and Vrielynck, B., 1993. Atlas Tethys Palaeoenvironmental Maps. p. 307, Gauthier-Villars, Paris, (with 14 maps).

Egger, H. and Faupl, P., 1999. 69 Grossraming. Geologische Karte der Republik Österreich 1:50 000. Geologische Bundesanstalt, Wien.

Egger, H. and van Hunen, D. 2011. Erläuterungen zu Blatt 69 Großraming. Geologische Karte der Republik Österreich 1:50 000. Geologische Bundesanstalt, Wien, 119 pp.

Egger, H. and Wessely, G., 2014. Wienerwald. Sammlung geologischer Führer. Band 59, Gebrüder Borntraeger, Stuttgart, 203 pp.

Einsele, G., 1991. Submarine Mass Flow Deposits and Turbidites. In: Einsele, G., Ricken, W. and Seilacher, A. (eds), Cycles and Events in Stratigraphy. Springer Verlag, Berlin-Heidelberg, pp. 313-339.

Einsele, G. and Seilacher, A., 1991. Distinction of tempestites and Turbidites. In: Einsele, G., Ricken, W. and Seilacher, A. (eds), Cycles and Events in Stratigraphy. Springer Verlag, Berlin-Heidelberg, pp. 377-382.

Einsele, G., Ricken, W. and Seilacher, A. (eds), 1991. Cycles and Events in Stratigraphy. Springer Verlag, Berlin-Heidelberg, 955 pp.

Faupl, P., 1979. Turbidite series within the Cretaceous sequence of the Austroalpine unit and their palaeogeographical significance. In: J. Wiedmann (Editor): Aspekte der Kreide Europa. IUGS Series, A 6, 403-411.

Faupl, P. and Wagreich, M., 1992. Cretaceous flysch and pelagic sequences of the Eastern Alps: correlations, heavy minerals and palaeogeographic implications. Cretaceous Research, 13, 387-403. http://dx.doi.org/10.1016/0195-6671(92)90006-C

Hoedemaeker, P., Reboulet, S., Aguirre-Urreta, M.B., Alsen, P., Aoutem, M., Atrops, F., Barragan, R., Company, M., González, C., Klein, J., Lukeneder, A., Ploch, I., Raisossadat, N., Rawson, P.F., Ropolo, P., Vašicek, Z., Vermeulen, J., Wippich, M.G.E., 2003. Report on the 1st International Workshop of the IUGS Lower Cretaceous Ammonite Working Group, the ‘Kilian Group’ (Lyon, 11 July 2002). Cretaceous Research, 24, 89-94. http://dx.doi.org/10.1016/S0195-6671(03)00018-1

Kidwell, S.M. and Bosence, D.W.J., 1991. Taphonomy and Time-Averaging of Marine Shelly Faunas. In: Allison, P.A. and Briggs, D.E.G. (eds), Taphonomy: Releasing the Data Locked in the Fossil Record. Topics in Geobiology Volume 9, Plenum Press, New York, pp. 115-209.

Kissling, W., Flügel, E. and Golonka, J., 2003. Patterns of Phanerozoic carbonate platform sedimentation. Lethaia, 36, 195-226. http://dx.doi.org/10.1080/00241160310004648

Klein, J., 2005. Lower Cretaceous Ammonites I. Perispinctacea 1: Himalayitidae, Olcostephanidae, Holcocidica, Neocomitidae, Oosterellidae. In: Riegfr, W. (ed.), Fossilium Catalogus I: Animalia. Blackhuys, Leiden, Vol. 139, 484 pp.

Klein, J., 2006. Lower Cretaceous Ammonites II. Perispinctacea 2: Polypcytitidae. In: Riegfr, W. (ed.), Fossilium Catalogus I: Animalia. Blackhuys, Leiden, Volume 141, 2-186.

Klein, J. and Hoedemaeker, P.J. 1999. Ammonite stratigraphy of the Valanginian to Barremian for the Mediterranean region. Scripta Geologica, Special Issue, 3, 97-127.

Klein, J., Hoffmann, R., Joly, B., Shigeta, Y., Vašicek, Z., 2009. Boreophylloceratoidea, Phylloceratoidea, Lycteroidea, Tetragonitoidea, Haploceratoidea including the Upper Cretaceous representatives. In: Riegfr, W. (ed.), Fossilium Catalogus IV: Animalia. Blackhuys, Leiden and Margraff, Weikersheim, Vol. 146, 416 pp.

Kotetishvili, E.V., 1988. Distribution globale des Ammonites éocretacés du Caucase. In: Wiedmann, J. and Kullman, J. (eds), Cephalopods – Present and Past, 453-468.

Lukeneder, A., 1997. Bericht 1996 über stratigraphische Untersuchungen in den Schrambachschichten auf Blatt 69 Großraming. Jahrbuch der Geologischen Bundesanstalt, 140/3, 370-372.

Lukeneder, A., 1998. Zur Bistrafigraphie der Schrambach Formation in the Ternberger Decke (O.-Valanginium bis Aptium des Tiefbajuvarikums-Oberösterreich). Geologisch Paläontologische Mitteilungen Innsbruck, 23 (5. Jahrestagung der ÖPG, Lunz 1998), 127-128.

Lukeneder, A., 2001. Palaeoecological and palaeoeoceanographical significance of two ammonite mass-occurrences in the Alpine Lower Cretaceous. PhD Thesis, University of Vienna, Vienna, 316 pp.

Lukeneder, A., 2003. Ammonoid stratigraphy of Lower Cretaceous successions within the Vienna Woods (Kaltenleutgeben section, Lunz Nappe, Northern Calcareous Alps, Lower Austria). In: W.E. Piller (Editor): Stratigraphia Austriaca. Österreichische Akademie der Wissenschaften, Schriftenreihe der Erdwissenschaftlichen Kommissionen, 16, 165-191.

Lukeneder, A., 2004a. Late Valanginian ammonoids: Mediterranean and Boreal elements – implications on sea-level con-
trolled migration (Ebenforst Syncline, Northern Calcareous Alps, Upper Austria). Austrian Journal of Earth Sciences, 95/96, 46-59.

Lukeneder, A., 2004b. Stratigraphische Erkenntnisse aus einem neuen Vorkommen von Unterkreide-Ammonioideaen in der Losensteiner Mulde (Temberger Decke, Nördliche Kalkalpen). Jahrbuch der Geologischen Bundesanstalt, 144, 173-189.

Lukeneder, A., 2005a. Taphonomy and stratigraphy of Early Cretaceous ammonoid mass occurrences (Late Valanginian, Northern Calcareous Alps; Upper Austria). Austrian Journal of Earth Sciences, 98, 34-51.

Lukeneder, A., 2005b. An Early Cretaceous Ammonoid Association from Upper Austria (Late Valanginian, Northern Calcareous Alps). Beiträge zur Paläontologie, 29, 1-13.

Lukeneder, A., 2005c. First nearly complete skeleton of the Cretaceous duvaliid belemnite Conobelus. Acta Geologica Polonica, 55/2, 147-162.

Lukeneder, A., 2014. Cretaceous ammonites from Upper Austria. In: Berning, B. and Lukeneder, A. (eds), Studies on Fossil and Recent Cephalopods. Denisia, 32, 59-79.

Lukeneder A. and Grunert P., 2013. Palaeoenvironmental evolution of the Southern Alps across the Faraoni Level equivalent: new data from the Trento Plateau (Upper Hauterivian, Dolomites, N. Italy). Acta Geologica Polonica, 63, 89-104.

Lukeneder, A. and Reháková, D., 2007. Chronostatigraphic significance of an early Valanginian (Cretaceous) calpionellid association (Hochkogel section, Upper Austria, Northern calcareous Alps). Geological Quarterly, 51/1, 27-38.

Lukeneder, A. and Smrecková, M., 2006. An Early Cretaceous radiolarian assemblage: palaeoenvironmental and palaeoecological implications for the Northern Calcareous Alps (Barremian, Lunz Nappe, Lower Austria). Annalen des Naturhistorischen Museums Wien, 107A, 23-57.

ÖK 1:25 000, 1996. 58 Baden. Österreichische Karte 1:25 000. Bundesamt für Eich- und Vermessungswesen, Wien.

Piller, W.E., Egger, H., Erhart, C.W., Gross, M., Harzhauser, M., Hubmann, B., van Husen, D., Krenmayr, H.-G., Krystyn, L., Lein, R., Lukeneder, A., Mandl, G., Rögl, F., Roetzel, R., Rupp, C., Schnabel, W., Schönlaub, H.P., Summesberger, H. and Wagreich, M., 2004. Die Stratigraphische Tabelle von Österreich 2004 (sedimentäre Schichtfolgen). Kommission für die Paläontologische und stratigraphische Erforschung Österreichs. Österreichische Akademie der Wissenschaften und Österreichische Stratigraphische Kommission, Wien.

Plöchinger, B., 1963. Die Kreide-Paläozänablagerungen in der Gießhübler Mulde, zwischen Perchtoldsdorf und Sittendorf (N.-O.). Mitteilungen der Geologischen Gesellschaft in Wien, 56, 469-501.

Plöchinger, B., 1980. Die Nördlichen Kalkalpen. In: Oberhauser, R., ed. 1980. Der geologische Aufbau Österreichs. Geologische Bundesanstalt, Springer Verlag, Wien, 218-264.

Plöchinger, B. and Karanitsch, P. 2002. Faszination Erdgeschichte mit Brennpunkt Mödling am Alpenostrand. Heimat Verlag, Schwarzhach, 238 pp.

Plöchinger, B. and Prey., S., 1964. Exkursion II/5: Wienerwald, Flysch, Kalkalpen, Gosau. Mitteilungen der Geologischen Gesellschaft in Wien, 57, 181-192.

Plöchinger, B. and Prey., S., 1993. Der Wienerwald. Gebrüder Borntraeger, Berlin-Stuttgart, Sammlung Geologischer Führer, 59, 168 pp.

Rawson, P.F. and Kemper, E., 1978. Varilheidites, n. gen. (Ammonoidea, Neocomitinae) aus dem Obervalangin NW-Deutschlands. Geologisches Jahrbuch, A 45, 163-181.

Reboulet, S., Szives O., Aguirre-Uretra, B., Barragán, R., Company, M., Idakieva, V., Ivanov, M., Kakabadze, M.V., Moreno-Bedmar, J.A., Sandoval, J., Baraboshkin E., Çaglar M.K., Fözy, I., González-Areola, C., Kenjo, S., Lukeneder, A., Raissossadat, S.N., Rawson, P.F., Tavera, J.M. 2014. Report on the 5th International Meeting of the IUGS Lower Cretaceous Ammonite Working Group, the Kilian Group (Ankara, Turkey, 31st August 2013). Cretaceous Research, 50, 126-137. http://dx.doi.org/10.1016/j.cretres.2014.04.001

Reháková, D. and Michalik, J., 1997. Evolution and distribution of calpionellids – the most characteristic constituents of Lower Cretaceous Tethyan microplankton. Cretaceous Research, 18, 493-504.

Schnabel, W., Brix, F., Fuchs, R., Plöchinger, B., Prey, S., Wessely, G., Hofmann, T., Nowotny, A., Plachy, H. Schedl, A., Vecer, B., 1997. Geologische Karte der Republik Österreich 1:50 000, 58 Baden. Geologische Bundesanstalt, Wien.

Scotese, C.R., 2001. Atlas of Earth History, Paleomap project, Arlington, 52 pp, Texas.

Spitz, A., 1910. Der Höhlensteinzug bei Wien. Mitteilungen der Geologischen Gesellschaft, 3, 351-433.

Stampfl i, G. and Mosar, J., 1999. The making and becoming of Apulia. Memorie di Scienze Géologiche (University of Padova). Special volume, 3rd Workshop on Alpine Geology, 51/1, 141-154.

Toula, F., 1905. Geologische Exkursionen im Gebiete des Liesing- und des Mödlingbaches. Jahrbuch der kaiserlich-königlichen geologischen Reichsanstalt, 55, 243-326.

Toula, F., 1907a. Die Acanthicus-Schichten im Randgebirge der Wiener Bucht bei Gießhübl (Mödling WWN). Verhandlungen der k. k. geologischen Reichsanstalt, 13, 299-305.

Toula, F., 1907b. Die Acanthicus-Schichten im Randgebirge der Wiener Bucht bei Gießhübl (Mödling WWN). Abhandlungen der k. k. geologischen Reichsanstalt, 16/2, 1-120.

Vašíček, Z. and Faupl, P., 1996. Die Cephalopoden aus den Roselfeldschichten der Reichraminger Decke (Obervalangini-um; oberösterreichische Kalkalpen). Jahrbuch der Geologischen Bundesanstalt, 139, 101-125.

Vašíček, Z. and Faupl, P., 1998. Late Valanginian cephalopods in relation to the palaeogeographic position of the Rossfeld and Schrambach Formation of the Reichraming Nappe (Northern Calcareous Alps, Upper Austria). Centralblatt für Geologie und Paläontologie, Teil 1, 27-38.

Vašíček, Z. and Faupl, P., 1999. Zur Biostratigraphie der Schrambachschichten in der Reichraminger Decke (Unterkreide, oberösterreichische Kalkalpen). Abhandlungen der Geologischen Bundesanstalt, 56/2, 593-624.
Vašíček, Z. and Michalík, J., 1999. Early Cretaceous ammonoid paleobiogeography of the West Carpathian part of the Paleoeuropean shelf margin. Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, 212, 241-262.
Vašíček, Z., Michalík, J., Reháková, D. and Faupl, P., 1994. Stratigraphische Daten zur Unterkreide der Lunzer und Reichraminger Decke (Östliche Kalkalpen, Ober- und Niederösterreich). Jahrbuch der Geologischen Bundesanstalt, 137, 407-412.
Wessely, G., 2006. Niederösterreich. Geologie der Österreichischen Bundesländer. Geologische Bundesanstalt Wien, 415 pp.
Wiedmann, J., 1988. Plate tectonics, sea level changes, climate and the relationship to ammonite evolution, provincialism, and mode of life. In: Wiedmann, J. and Kullmann, J. (eds.), Cephalopods – Present and Past, pp. 735-765.
Wright, C.W., Callman, J.H. and Howarth, M.K., 1996. Treatise on invertebrate paleontology, Part L, Mollusca 4 revised (Cretaceous Ammonoidea), Geological Society of America, Boulder and University of Kansas Press, Lawrence, 362 pp.
Zakharov, V.A. and Rogov, M.A. 2003. Boreal-Tethyan Mollusk Migrations at the Jurassic-Cretaceous Boundary Time and Biogeographic Ecotone Position in the Northern Hemisphere. Stratigraphy and Geological Correlation, 11, 2003, 152-171.

Received: 13. November 2015
Accepted: 4 July 2016