Sinemurian biostratigraphy of the Tannscharten section near Reichraming (Lower Jurassic, Schneeberg Syncline, Northern Calcareous Alps)

Petra LUKENEDER1) & Alexander LUKENEDER1)

1) Museum of Natural History Vienna, Burgring 7, 1010 Vienna, Austria;

* Corresponding author: petra.lukeneder@gmx.at

Abstract

Lower Jurassic ammonites were collected from deep-water limestones of the Tannscharten section, southwest of Reichraming (Northern Calcareous Alps, Upper Austria). The outcrop provides a rich Upper Sinemurian (Lower Jurassic) ammonite fauna of the Allgäu Formation. The area is situated in the westernmost part of the Schneeberg Syncline in the north of the Reichraming Nappe (High Bajuvaric Unit). The ammonite fauna consists of seven different genera, each apparently represented by 1–2 species. Echioceratids are the most frequent components (Echioceras, Leptechioceras, Paltechioceras), followed by the phylloceratids (Juraphyllites, Partschioceras) and oxynoticeratids (Gleviceras, Paroxynoticeras). Juraphyllites libertus, Partschioceras striatocostatum, Gleviceras panicum, Echioceras quenstedti, Echioceras raricostatoideus, Paltechioceras boehmi, Leptechoiceras meigeni, Leptechoiceras macdonnelli and Paltechioceras oosteri are new for the Schneeberg Syncline and allow for the first time a detailed biostratigraphy of the Echioceras raricostatum zone. The assemblage is correlated with other faunas from Austria, Germany, United Kingdom, France, Switzerland and Romania. The cephalopod fauna consists of a mix of elements from the Northwest European Province and the Mediterranean Province. The detailed biostratigraphy based on ammonites is presented here.

1. Introduction

Lower Jurassic pelagic to hemipelagic sediments are known to form a significant element of the northernmost tectonic units of the Northern Calcareous Alps (e.g. Ternberg-, Reichraming-, Frankenfeld-, and Lunz- nappes; Tollmann, 1976, 1985; Egger, 1988; Egger and Faupl, 1999; Vašíček and Faupl, 1999; Egger and van Husen, 2011; see also Piller et al., 2004). In the Reichraming Nappe comprising the Lower Jurassic Tannscharten locality, Liassic cephalopod-bearing deposits are recorded in a deep-water limestone facies, the Allgäu Formation (= Lias Fleckenmergel). Sinemurian sediments of the Allgäu Formation are composed of grey, intensely burrow-mottled limestones with intercalated marls and frequent allogenic crinoid limestone layers (Müller, 1987; Egger, 1988; Egger and van Husen, 2011). Deposits of the Allgäu Formation are formed in deeper basins from deep neritic environments (Jacobshagen, 1963, 1965) to bathyal regions (Bernoulli and Jenkyns, 1970).

Lower Jurassic (i.e. Sinemurian) ammonite faunas are rare in the Northern Calcareous Alps. Ammonite occurrences were described from various regions of Austria and Germany. Meister and Friebe (2003) published on Liassic ammonites from Adnet limestones and Allgäu Formation in the Northern Calcareous Alps of Vorarlberg. Jacobshagen (1965) described ammonites from the Allgäu Formation (= “Jura-Fleckenmergel”) of the Wettersteingebirge. Blau and Grün (1995) and Blau (1998) described extensive faunas from the Allgäu Formation of the Upper Austroalpine (Lienz Dolomites, Eastern Tyrol, Carinthia, Austria). Schröder (1925, 1927) and Schlegelmilch (1976) figured and described both assemblages from similar ammonite faunas of southern Germany (e.g. Bavarian Alps).

The presented cephalopod fauna (ammonites, belemnites) was collected from marly limestones and limestones of the Allgäu Formation from the Northern Reichraming Nappe in Upper Austria. Fossiliferous Sinemurian outcrops are scarce; hence, well-preserved ammonites are rare from that time slice in the Northern Calcareous Alps. The new fauna increases the knowledge on Sinemurian ammonite assemblages from the Northern Calcareous Alps. No Liassic ammonites were described or figured until now from the Allgäu Formation of the Reichraming Nappe.

The present ammonite occurrence is clearly linked to a facies change in the Upper Triassic carbonate platform of the Reichraming Nappe. Shallow-water deposits (Rhaetian oolites and limestones) are overlain by a deepening sequence of red, condensed Adnet limestones and
deep-water deposits of the Allgäu Formation. Ammonites were collected from numerous layers in the Lower Jurassic of the Allgäu Formation. A detailed ammonite biozonation of the Lower Jurassic (i.e. late Sinemurian) in the Northern Calcareous Alps is presented. The aim of this study was to better understand the Lower Jurassic environments and facies zonation in the Reichraming Nappe.

The ammonite data were the first step in a detailed biostratigraphic survey of the westernmost part of the Schneeberg Syncline, a tectonical key area in the Reichraming Nappe (Northern Calcareous Alps). More investigations on this important occurrence of the Allgäu Formation will take place within a planned project on Jurassic and Lower Cretaceous climate. The present work forms the base for additional ammonite collections (bed by bed) that will be carried out to precise the exact position of zone, subzone and biohorizon boundaries.

2. Geographical setting
The outcrop Tannscharten (1211 m above sea level) is located 3.5 km west of Reichraming within the Reichraming Nappe in Upper Austria (ÖK 1:50,000, sheet 69 Großraming; Austromap Online 2017; Fig. 1). The succession, comprising the ammonite-bearing beds, is located 50 m south of the Tannscharten and 500 m north of the Schneeberg (1244 m). It is exposed on the left side (mountain side) by a forest road construction (private road Kautsch). The exact position of the ammonite occurrences was determined by global positioning system (GPS): N 47°52’33.80” and E 14°24’53.40”. The site can only be accessed with permission of the owner Maximilian Kautsch.

3. Geological background
The Lower Jurassic Tannscharten section is located in the westernmost part of the Schneeberg Syncline (Egger and Faupl, 1999, Geological map 1:50,000, sheet 69 Großraming; Egger and van Husen, 2011; Fig. 1). The Schneeberg Syncline is the northernmost Jurassic/Cretaceous Syncline of the Reichraming Nappe, followed by the Anzenbach Syncline and the Ebenforst Syncline to the south (Fig. 2). The Reichraming Nappe (High Bajuvaric Unit of the Northern Calcareous Alps) is bordered to the north by the Ternberg Nappe, to the east by the Frankenfels Nappe and to the south by the Tyrolic units. The Tannscharten area is situated in a relatively small part along the westernmost border of the Schneeberg Syncline. It appears tectonically isolated from the main area of the Schneeberg Syncline starting 3 km to the west at Dimbach. The Schneeberg Syncline (Fig. 2) is typically formed by deposits of the Upper Triassic Kössen Formation (Rhaetian), oolites and limestones (both Rhaetian), the Lower Jurassic Adnet limestone (Liassic) and Allgäu Formation (Liassic), the Middle Jurassic Chiengau Formation (Dogger) and Vils limestone (Dogger), red Upper Jurassic to Lower Cretaceous limestone (Tithonian–Berriasian) and in the core of the syncline by the Lower Cretaceous Schrambach Formation (Valanginian-Barremian; Egger, 1988; Egger and Faupl, 1999; see also Piller et al., 2004). Important work on regional geology was done by Jacobshagen (1963, 1965), Egger (1988), Böhm (1992), Egger and Faupl (1999) and Vašíček and Faupl (1999).

The outcrop is exposed over a length of 80–100 m. It consists of about 50 m cherty limestones and burrow-mottled limestones ("Fleckenmergel"; Tollmann, 1976, 1985; Figs. 3, 4) of the Allgäu Formation, intercalated by numerous crinoid-bearing layers (i.e. allodapic limestones). The multiple occurrence of the crinoidal limestone beds are probably caused by intense folding of the Lower Jurassic succession. According to Jacobshagen (1963, 1964), the characteristic feature of the Allgäu Formation is intense burrow-mottled, dark-grey limestones with intercalated marls. Based on the definition by the latter author, the Tannscharten section is part of the lower Allgäu Formation (= Ältere Allgäu-Schichten; Jacobshagen, 1963, 1965), ranging from the Hettangian to the Pliensbachian. Blau (1998) interpreted the Allgäu Formation as Lower Jurassic deep-water basin facies. Deposits of the Allgäu Formation overlay fossiliferous (ammonites, foraminifers, crinoids) red limestones (10 m) of the Sinemurian Adnet Formation (Adnet Group). Rhaetian yellowish to grey foraminiferl limestone are underlain by Rhaetian shallow-water oolites (20 m) (Figs. 3, 4).

4. Material and methods

4.1 Fossil material
The fossils originate from the Lower Jurassic Allgäu Formation at the Tannscharten. 46 ammonite specimens were collected bed by bed, prepared and photographed. The ammonite material is well preserved, though partly fragmented and flattened. Moulds were coated with ammonium chloride before photographing. Original (primary aragonite) shell material was absent. Suture lines were only fragmentary preserved in a few specimens. Additionally, four belemnite specimens and two brachiopods were collected. The material was
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The ammonite assemblage consists of 7 late Sinemurian genera. Echioceratids (*Echioceras*, *Leptechioceras*, *Echinosoceras*) stored at the Natural History Museum in Vienna (NHMW 2017/0139/0001-0046). Additional 10 ammonite specimens from the Fahrenberg section were collected by the private collectors Berthold Lumplecker (n = 10, collection BL in Großraming) and Fabian Rabl (n = 12, collection FR in Bad Kreuzen).

The ammonite assemblage consists of 7 late Sinemurian genera. Echioceratids (*Echioceras*, *Leptechioceras*, *Echinosoceras*)

Figure 2: Geological map of the investigated area with position of the sections Tannscharten (star 1) and Fahrenberg (star 2) in the northernmost part of the Northern Calcareous Alps (Upper Austria). Tectonic map shows the regional extent of the Schneeberg Syncline (SS) and Anzenbach Syncline (AS).
Figure 3: Lower and middle parts of the Tannscharten log with beds 68–185 of the lower Allgäu Formation (at 43–60 m). Rhaetian oolites and limestones are overlain by red limestones of the Jurassic Adnet Formation.
Figure 4: Middle and upper parts of the Tannscharten log with beds 1–67 of the lower Allgäu Formation (at 60–70 m; a, b, c). The marly, silicious and burrow-mottled (d) limestones of the lower Allgäu Formation with indicated beds 4, 34 and 127 are overlain by cherty limestones (e) of the upper Allgäu Formation.
Paltechioceras) are the most frequent components, followed by the phylloceratids (Juraphyllites, Parachiceras), and oxynoticeratids (Gleviceras, Paroxynticeras). The cephalopod fauna consists of Euroboreal and Tethyan elements.

### 4.2 Morphological parameters

All morphological parameters (Fig. 5) were measured whorl by whorl on each ammonite specimen to obtain comparable results. For species determination, the number of ribs was counted and parameters such as maximum diameter \(d\), aperture height \(ah\), whorl height \(h\), umbilical width \(u\), whorl breadth \(w\) and average distance of each ammonite specimen were measured or, if necessary, extrapolated.

The degree of involution \(h/u\), whorl compression \(h/w\), whorl expansion rate (WER) and proportional height \(h/d\) were calculated. Additionally, presence and shape of a keel and grooves aside, as well as shape and direction of ribs and other characteristic traits, were taken into account for determination.

**Abbreviations.** \(d\), maximum diameter; \(h\), whorl height; \(h/d\), proportional height; \(h/u\), degree of involution; \(h/w\), whorl compression; \(n\), number of ribs; \(u\), umbilical width; \(u/d\), proportional umbilical width; \(w\), whorl breadth; \(w/d\), proportional whorl breadth; \(r^2\), coefficient of determination; OD, original designation; NCA, Northern Calcareous Alps; NHMW, Natural History Museum Vienna. WER = \([d/(d - ah)]^2\) for subdivision of ammonite coiling (after Korn (2000), Klug (2001)). WER standard (Korn 2000): low < 1.60, moderate 1.61–2.0, moderately high 2.01–2.40, high 2.41–2.80 and very high > 2.80. Average rib distance was calculated from mean of three values.

### 4.3 Biostratigraphical background

The Upper Sinemurian ammonite biozonation with zonal index species is partly shown in Figure 6. According to Page (2003) and Ogg and Hinno (2012), the Sinemurian stage is subdivided into the following chronozones (named after the ammonite index species, Fig. 6). From the topmost: Upper Sinemurian *Echioceras raricostatum*, *Oxynoticeras oxynotum* and *Asteroceras obtusum* zones; Lower Sinemurian *Caenisites turneri* and *Arnioceras semicostatum* zones and Lowermost Sinemurian *Arietites bucklandi* zone. Zonation is quite varying in the Northwest European Province (United Kingdom, Ireland, France, Northern Germany, Switzerland and others) and the Mediterranean Province (Austria, Southern Germany and Italy; Page 2003). We did not follow the statement of Page (2003, p. 36) that *Echioceras raricostatoides* is a junior synonym of *E. raricostatum*.

*Figure 5:* Measured morphological parameters in evolute and involute. \(d\), maximum diameter; \(ah\), aperture height; \(h\), whorl height; \(u\), umbilical width.

*Figure 6:* Ranges of the ammonite taxa occurring in the Tannscharten section with indicated biostratigraphic ammonite zonation from the Lower Jurassic (Upper Sinemurian). Occurrence of black range bars of ammonite taxa in the section. Paltechioceras oosteri derives from the Fahrenberg locality of the same syncline. Assumed biohorizons (Gleviceras paniceum, Echioceras quenstedti, Echioceras raricostatoides, Paltechioceras boehmi, Leptechioceras meigeni, Leptechioceras macdonnelli) are highlighted in grey.

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The chronozones are subdivided into subzones and biohorizons (see Blau, 1998; Fig. 6). The *E. raricostatum* zone is divided into subzones from the bottom to top as follows: Crucilobiceras *densinodulum*, *E. raricostatum*, *Leptachioceras macdonnelli* and *Paltechioceras aplanatum*. The *O. oxynotum* zone starts with the lower *Oxynoticeras simpsoni* subzone and the upper *O. oxynotum* subzone. Blau and Meister (2000) proposed further 41 horizons for the Upper Sinemurian. More sampling and additional material would be needed to adopt these detailed subdivisions to the fauna from the Tannscharten locality.

For a concise international correlation, ammonite bio-geographical provinces have to be considered. According to Schlegelmilch (1976), the *C. densinodulum* subzone and the *E. raricostatum* subzone are not distinguishable in Southern Germany. This might be also the case in the High Bajuvaric Units of the Northern Calcareous Alps. Page (2003) listed all zones and horizons detected so far in the Mediterranean province. The lower Allgäu Formation consisting of bioturbated limestones and intercalated marls embraces both the *O. oxynotum* zone and the *E. raricostatum* zone (Jacobshagen, 1965).

5. Systematic Palaeontology

All collected specimens belong to the suborders Phylloceratina and Ammonitina (class Cephalopoda, subclass Ammonoidea). For the ammonite determination, publications of Schlegelmilch (1976), Blau (1998) and Meister and Friebe (2003) were used. The ammonite systematics and taxonomy were adopted and compared with those in papers by the latter authors. In the following, except one specimen of *Paroxynoticeras*, only specimens that are identified on a species level, and thus of biostratigraphical importance, are described and figured (Figs. 7, 8):

Class Cephalopoda Cuvier, 1797
Order Ammonoidea Zittel, 1884
Suborder Phylloceratina Arkell, 1950
Family Phylloceratidae Zittel, 1884
Genus *Partschiceras* Fucini, 1923

Type of species: *Ammonites Partschi* Stur, 1851 (nomen nudum); = *Partschiceras striatocostatum* (Meneghini, 1853)

*Partschiceras striatocostatum* (Meneghini, 1853)

Fig. 7a, b; Tab. 1

1851 *Ammonites partschi* – Stur, p. 26 (nomen nudum)
*1853 *Ammonites striatocostatus* – Meneghini, p. 28
1927 *Phylloceras Partschi* Stur – Schröder, p. 122
1991 *P. striatocostatum* (Meneghini, 1853) – Blau, p. 177, pl. 2, figs., 2, 3
1998 *P. striatocostatum* (Meneghini, 1853) – Blau, p. 196, pl. 1, figs. 8, 9, 14 (cum. syn.)
1999 *P. striatocostatum* (Meneghini, 1853) – Rakús, p. 348, text-fig. 8, pl. 1, figs. 9–11

2000 *P. striatocostatum* (Meneghini, 1853) – Joly, p. 35, text-figs. 56, 57; pl. 4, fig. 5
2003 *P. gr. striatocostatum* (Meneghini, 1853) – Meister and Friebe, p. 23, pl. 1, figs. 8, 13; pl. 2, figs. 4, 7 (cum. syn.)

Number of specimens: One specimen from the Tannscharten section (NHMW 2017/0139/0001)

Description: One half of a specimen is preserved. The involute specimen exhibits an oval, elongated whorl section with a well-rounded venter and subrounded flanks. Strong, primary prosiradial ribs start at the mid flanks and cross the venter without interruption. Very fine, fibrous ribs are overprinting the primary ribs. The umbilicus is narrow with a steep wall. About 33 primary ribs were counted on the last half whorl. The average rib distance is 2.64 mm. The high WER value of 2.52 reflects the fast whorl height growth. The specimen represents a phragmocone with the suture line visible throughout. According to Blau (1998), the flanks are slightly arched and the maximal width can be observed near the centre of the flanks. For a more detailed description, see Wiedenmayer (1977) and Braga and Rivas (1987). Meister and Friebe (2003) stated that *P. striatocostatum* is easily to distinguish from similar species such as *Partschiceras proclive* (Rosenberg), *Partschiceras sturi* (Stur) and *Partschiceras anonymum* (Haas) by their rursiradial ribbing. The related species *Partschiceras tenuistriatum* (Meneghini) shows much finer ribbing. *P. sturi* and *P. anonymum* are often treated to be synonymous with *P. striatocostatum* and *P. tenuistriatum* (see Braga and Rivas, 1987; Blau, 1998).

Measurements:

<table>
<thead>
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<th>Type/Inv. Nr.</th>
<th>d</th>
<th>h</th>
<th>w</th>
<th>u</th>
<th>ah</th>
<th>h/w</th>
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<td>20.55</td>
<td>5.92</td>
<td>27.53</td>
<td>2.11</td>
<td>0.58</td>
<td>7.32</td>
<td>0.08</td>
<td>0.28</td>
<td>2.52</td>
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Occurrence and stratigraphic range: At the Tannscharten section, *P. striatocostatum* appears in bed 26, part of the *E. raricostatum* zone. The species occurs in the entire Tethyan realm and southern North-west European Province (Caucasus Basin; Meister and Friebe, 2003). According to Blau (1998), this species has a stratigraphic range from the early Sinemurian (*A. semicostatum* zone) to the early Toarcian *Dactylioceras tenuicostatum* zone. Blau and Meister (1991) reported *P. striatocostatum* from the late Pliensbachian *Amaltheus margaritatus* zone (*Amaltheus stokesi* – *A. margaritatus* and *Amaltheus subnodosus* subzones). Meister and Friebe (2003) mentioned a Sinemurian to Pliensbachian age for *P. striatocostatum*. The lectotype specimen described by Rakús (1999) from Hirlatz Mountain is from the *O. oxynotum* zone.

Family Juraphyllitidae Arkell, 1950
Genus *Juraphyllites* Müller, 1939
**Type of species:** *Phylloceras diopsis* Gemmellaro (1884); OD

*Juraphyllites libertus* (Gemmellaro, 1884)

Fig. 7c, d; Tab. 2

*1884 Phylloceras libertum* – Gemmellaro, p. 168, pl. 2, figs. 1–5
1927 *Rhacophyllites libertus* (Gemmellaro) – Schröder, p. 143, pl. 8, figs. a, b
1998 *J. libertus* (Gemmellaro, 1884) – Blau, p. 200, text-figs. 18, 19; p. 255, pl. 1, figs. 4, 11, 18 (cum. syn.)

2000 *J. libertus* (Gemmellaro, 1884) – Joly, p. 29
2003 *J. libertus* (Gemmellaro, 1884) – Meister and Friebe, p. 25, pl. 2, fig. 6 (cum. syn.)

**Number of specimens:** Two specimens, one from the Tannscharten section (NHMW 2017/0139/0001) and the other from the Fahrenberg section (BL 2017/0001)

**Description:** The semi-involute and discoidal specimen appears with almost flat to subrounded flanks and a rounded venter. The last whorl encompasses the previous one down to one half. The early whorls seem to be smooth, whereas the sculpture of the last, third whorl
Figure 8: Ammonite fauna from the late Sinemurian Tannscharten and Fahrenberg sections. a, b Echioceras raricostatoides Vadász, lateral and ventral views, NHMW 2017/0139/0006. c Echioceras quenstedti (Schafhäutl), lateral view, NHMW 2017/0139/0011. d Leptechioceras meigeni (Hug), lateral view, NHMW 2017/0139/0014. e, f L. meigeni (Hug), lateral and ventral views, NHMW 2017/0139/0015. g L. meigeni (Hug), lateral view, BL 2017/0002. h, i, j Leptechioceras gr. macdonnelli (Portlock), lateral view, NHMW 2017/0139/0024-0026. k Paltechioceras boehmi (Hug, 1899), lateral view, NHMW 2017/0139/0030. l, m Paltechioceras oosteri (Dumortier), lateral and ventral views, BL 2017/0010. White scale bars represent 1 cm.
shows two major elements. Fine, prorsiradiate ribbing sets in from mid-flank and crosses the venter slightly projected without interruption. Three straight and strongly prorsiradiate constrictions are visible on the final whorl half. The constrictions start from the steep umbilical wall, pass the venter and form an angle (approximately 10°–20°) with the finally stronger external ribbing. The first constriction marks the beginning of the body chamber, which is also marked by the last visible suture line. An average rib distance of 1.58 mm was measured on a specimen (NHMW 2017/0139/0002; Fig. 7d) with a diameter of 44.9 mm. The specimen appears with a WER value of 2.53, hence doubling the whorl height within the last whorl. The presence of constrictions is the main difference to the similar Juraphyllites diopsis (Gemmellaro). The stronger ribbing in the related species Juraphyllites nardii (Meneghini) starts below the mid-flank in contrast to J. libertus.

Measurements:

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Occurrence and stratigraphic range: At the Tannscharten, Paroxynoticeras sp. occurs in bed 26, a part of the E. raricostatum zone. Pia (1914) proposed a Lias number 3 of late Pliensbachian (Sinemurian) age for P. salisburgense. Many specimens of Paroxynoticeras (i.e. P. salisburgense) are known from the O. oxynotum zone (i.e. O. oxynotum subzone) of the late Sinemurian in the Tethyan realm (Blau, 1998; Rakús, 1999).

Genus Gleviceras Buckman, 1918

Type of species: Gleviceras glevense Buckman, 1918; OD Gleviceras paniceum (Quenstedt, 1884) Fig. 7f, g, h; Tab. 4

*1885 Ammonites paniceus – Quenstedt, p. 163, pl. 21, figs. 27–29
1906 Oxynoticeras paniceum – Pompeckj, p. 266, number 3
1914 O. paniceum Quenst. spec. – Pia, p. 33, pl. 6, fig. 3
1976 G. paniceum (Quenstedt, 1884) – Schlegelmilch, p. 60, pl. 23, fig. 2 (cum. syn.)

Number of specimens: Two specimens (NHMW 2017/0139/0004-5)

Description: The involute shell is sub-oxycone (see Meister, 2006). The umbilical wall is steep and short. Specimens show strong primary ribs that start at umbilical seem. Approximately 60 ribs appear on the last whorl of the larger specimen, with an average rib distance of 4.72 mm. The ribbing style typically changes during ontogeny in both specimens. Ribbing starts with strong, sharp and bifurcating ribs on the inner whorls and changes to single ribs in the adult stages. Ribs are slightly rursiradiate, changing in adults to prorsiradiate directions. Bifurcation is at the lower third side of the flanks and ends at the ventral side with a strong projection at a smooth band on both sides of the accented keel. The species shows maximum diameters of up to 208 mm, which is in accordance with the observations made by Schlegelmilch (1976). The suture line is partly visible, as the smaller specimen (Fig. 7h) exhibits almost an entire
phragmocone, whereas the last half whorl of the large specimen (Fig. 7f, g) is formed by the body chamber. The smaller specimen shows a WER value of 2.97, whereas the larger specimen shows a decreased WER value of 2.07, hence a decreasing trend of whorl height growth within the last whorl. Both specimens, the large (NHMW 2017/0139/0004) and the small (NHMW 2017/0139/0005; Fig. 7h), show a partly preserved, distinct and sharp keel up to 3 mm high. According to Meister and Friebe (2003) and Blau (1998) (see both authors also for other species descriptions), *G. paniceum* exhibits a well-expressed ornamentation that distinguishes it from other related species such as *Glevicas lotharingium* (Reynes) and *Gleviceras boucaultianum* (Dumortier).

**Measurements:**

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<td>3.17</td>
<td>0.16</td>
<td>0.23</td>
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**Occurrence and stratigraphic range:** At the Tannscharten, *G. paniceum* (Quenstedt) occurs in beds 100 and 105, which are part of the *O. oxynotum* zone. According to Schlegelmilch (1976), *G. paniceum* appears in the *O. oxynotum* zone, whereas Pia (1914) mentioned that this species occurs earlier in the late Sinemurian *Asteroceras obtusum* zone.

Family Echioceratidae Buckman, 1913

**Genus Echioceras Bayle, 1878**

**Type of species:** *A. raricostatus* Zieten, 1831

*Echioceras raricostatoides* Vadász, 1908

Fig. 8a, b; Tab. 5

1907 *Arietites raricostatoides* nov. sp. – Vadász, p. 358

* 1908 *A. raricostatoides*, nov. sp. – Vadász, p. 373, fig. 26

1973 *E. raricostatoides* (Vadász) – Getty, p. 13, pl. 1, fig. 12

1976 *E. raricostatoides* (Vadász, 1908) – Schlegelmilch, p. 51, pl. 21, fig. 11

1998 *E. raricostatoides* (Vadász, 1908) – Blau, p. 206, pl. 4, figs. 3–8 (cum. syn.)

2002 *Echioceras* sp. – Plöchinger and Karanitsch, p. 87, fig. 152

2005 *E. raricostatoides* (Vadász, 1908) – Tubelec, p. 485, pl. 3, fig. 2

2007 *E.? raricostatoides* (Vadász, 1908) – Tomas and Pálfy, p. 247, fig. 5g–h, j–k

**Number of specimens:** Five specimens (NHMW 2017/0139/0006-10)

**Description:** The evolute specimens show a fastigiate and rounded whorl section. The string like keel occurs throughout ontogeny, without grooves aside. Smooth areas accompany the keel throughout. The primary ribs are strong and slightly prorsiradiate and raricostate, thickening ventrolaterally. On the adult body chamber, the ribs appear with almost a ventral swelling.Spacing of ribs changes from narrow to wide at approximately 10–12 mm diameter. According to Blau (1998), the transition to a wide-spaced ribbing stage is around 5 mm diameter. The difference may be the result of the diagenetic compression of the inner whorls in the figured specimen (Fig. 8a, b). No suture line is visible. *E. raricostatoides* is similar to *Echioceras quenstedti* (Schafhättl), but ribs end up in swellings. Less primary ribs at comparable same diameter occur in *E. raricostatoides* with 20 on the last whorl and 27 in *E. quenstedti*. The average rib distance is 3–5 mm in *E. raricostatoides* on the final whorl and 2–3 mm in *E. quenstedti*. The whorl section in the related *E. raricostatum* (Zieten) is rectangular (flat venter) and not rounded as in *E. raricostatoides* (Schlegelmilch, 1976), but sometimes it is hard to distinguish.

**Measurements:**

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<td>0.70</td>
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**Occurrence and stratigraphic range:** At the Tannscharten, *E. raricostatoides* Vadász, 1908 occurs in beds 32–52, which are part of the *E. raricostatum* zone. This species appears in the entire Tethyan realm and is restricted to a short stratigraphic range in the late Sinemurian *E. raricostatum* zone (*E. raricostatum* subzone; Blau, 1998; Blau and Meister, 2000; Tubelec, 2005). Blau (1998) mentioned an even more restricted occurrence from the Lienz Dolomites (Upper Austroalpine, Austria) as *E. raricostatoides* horizon in the lower *E. raricostatum* subzone.

*Echioceras quenstedti* (Schafhättl, 1847)

Fig. 8c; Tab. 6

*1847 Ammonites quenstedti* m. – Schafhättl, p. 810, pl. 8, fig. 1; pl. 15, fig. 9

1973 *E. quenstedti* (Schafhättl) – Getty, p. 20, pl. 2, fig. 7

1989 *E. quenstedti* (Schafhättl) – Dommergues and Meister, p. 464, pl. 1, figs. 4–17

1998 *E. quenstedti* (Schafhättl, 1847) – Blau, p. 205, pl. 4, figs. 1, 2 (cum. syn.)

2003 *Echioceras* gr. *quenstedti* (Schafhättl, 1847) – Meister and Friebe, p. 36, pl. 10, figs. 6–8; pl. 11, figs. 1, 2
Number of specimens: Three specimens (NHMW 2017/0139/0011–13)

Description: The evolute specimens show a fastigiate and rounded whorl section (subcircular after Meister and Friebe, 2003). The string-like keel (feeble keel) occurs throughout ontogeny, without grooves or sulci aside. Smooth areas accompany the keel throughout. The primary ribs are strong, sharp and radiate to slightly prossiradiate and raricostate. In contrast to E. raricostatoides, the ribs are equal in thickness from the rounded umbilical edge up to the venter. Ventral endings of primary ribs do not end up in swellings. Ribbing is not as strong as in E. raricostatoides. On the adult body chamber, very fine ribbing (may be growth lines), almost not visible, intercalates the primary ribs. Spacing of ribs changes from narrow to wide at approximately 15 mm diameter (see also Dommergues and Meister, 1989). The entire specimen (NHMW 2017/139/0011) shows a low WER value of 1.42 mirroring the slow increasing trend of whorl height growth within the last whorl. No suture line is visible. A total of 27 primary ribs occur in E. quenstedti compared to E. raricostatoides with 20 ribs on the last whorl at the same diameter. The average rib distance appears in E. quenstedti with 2–3 mm and in E. raricostatoides on the final whorl, slightly increased to 3–5 mm. The whorl section in the related E. raricostatum (Zieten) is rectangular (flat venter) and not rounded as in E. quenstedti (Schaßhäutl, 1847), sometimes hard to distinguish. Numerous additional species such as Echioceras aeneum Truman and Williams, Pleurochioceras typicum Buckman and Echioceras rhodanicum Buckman were synonymized with E. quenstedti (Schaßhäutl, 1847) by Blau (1998) and earlier. Getty (1972) placed Echioceras laevidomus (Quenstedt), Echioceras parvum Truman and Williams, Echioceras concinnum Truman and Williams and Echioceras declivis Truman and Williams in the synonymy of E. quenstedti Schaßhäutl (1847).

Measurements:

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Occurrence and stratigraphic range: At the Tannscharten, E. quenstedti (Schaßhäutl, 1847) occurs in beds 59–69, which are part of the E. raricostatum zone. According to Dommergues and Meister (1989), Blau (1998) and Meister and Friebe (2003), E. quenstedti has a short stratigraphic range at the base of the late Sinemurian E. raricostatum zone (E. raricostatum subzone) within the lowermost E. quenstedti biohorizon. According to Meister and Friebe (2003), E. quenstedti is mostly known from the Alps (Subbrianconnaiss and Upper Austroalpine Units).

Genus Leptechioceras Buckman, 1923

Type species: Ammonites macdonnelli Portlock, 1843

Leptechioceras meigeni (Hug, 1899)

Fig. 8d–g; Tab. 7

*1899 Ammonites meigeni – Hug, p. 18, pl. 11, figs. 2, 2a, 3, 3a
1987 L. meigeni (Hug 1899) – Schlatter, p. 1122, text-figs. 1, b, c; pl. 1, fig. 4a, b
1989 L. meigeni (Hug 1899) – Dommergues and Meister, p. 465, pl. 3, figs. 3–4
1998 L. meigeni (Hug, 1899) – Blau, p. 219, pl. 6, figs. 3, 5–15; pl. 7, figs. 1–11; pl. 8, figs. 1–8 (cum. syn.)
2000 L. meigeni (Hug) – Blau et al., p. 268, figs. 5.2, 6.2, 6.4
2003 L. meigeni (Hug) – Edmunds et al., p. 69, figs. 3.1, 3.2, 3.3
2003 L. gr. meigeni (Hug, 1899) – Meister and Friebe, p. 38, pl. 11, figs. 5, 9 (cum. syn.)
2005 L. meigeni (Hug, 1899) – Tibuleac, p. 485, pl. 3, fig. 5

Number of specimens: Fourteen specimens (NHMW 2017/0139/0014–23; BL 2017/0002–0005)

Description: The very evolute specimens exhibit a fastigiate, elliptic and slightly compressed whorl section; the keel is sharp and appears throughout ontogeny. Smooth areas (not sulci) run on both sides of the keel. The primary ribs are strong and sharp, more radiate on inner whorls and slightly to strongly prorsiradiate in adult stages. The ribs are equal in thickness from the rounded umbilical edge over the rounded flanks up to the smooth area on the venter. Specimens reach a maximum diameter of approximately 77 mm. On the most complete specimen (Fig. 8e, f), approximately 42 ribs were counted on juvenile whorls (5th whorl) at a diameter of 20 mm. On the final whorl, 37 ribs were counted at a diameter of 77 mm. Specimen Fig. 8d shows approximately 46 ribs on juvenile whorls (4th whorl) at a diameter of 15 mm. On the penultimate half whorl, 26 ribs were counted at a diameter of 48 mm. The number of ribs decreases slowly but steadily. Both specimens (NHMW 2017/0139/0014 and 0015; 8d and 8e) show a very low WER value of 1.43 and 1.45, mirroring the slow increasing trend of whorl height growth on the final whorl. No suture line is visible. Our specimens are quite similar to those shown in Blau (1998) from the Lienz Dolomites. Blau (1998) reported them as quite variable in ribbing, from 15 to 22 primary ribs at the same diameter. L. meigeni from the Tannscharten section shows a high variability in number and development of the ribs (straight to slightly curved; specimen 8d has 56 ribs on the last whorl with an average rib distance of 3.41 mm, while specimen 8g has 44 ribs on the last whorl with a rib distance of 4.13 mm). The related Leptechioceras hugi (Buckman) has finer and radially oriented ribs throughout the ontogeny (Schlatter, 1991). Blau (1998) concluded that L. meigeni shows...
highly variable intraspecific ribbing values in quantity and thickness and subsequently synonymized L. hugi with L. meigeni.

**Measurements:**

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<td>0.61</td>
<td>0.16</td>
<td>1.52</td>
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**Occurrence and stratigraphic range:** At the Tannscharten, L. meigeni (Hug) occurs in beds 6–11, which are part of the E. raricostatum zone. L. meigeni occurs in the Tethyan realm and Euroboreal realm in the late Sinemurian E. raricostatum zone (L. macdonnelli subzone; Schlatter, 1987; Blau, 1998; Meister and Friebe, 2003; Tibuleac, 2005).

**Leptechioceras gr. macdonnelli** (Portlock, 1843)

Fig. 8h, i, j; Tab. 8

*1843 Ammonites macdonnelli – Portlock, p. 134, pl. 29A, fig. 12
1927 Vermiceras Macdonelli Portl. – Schröder, p. 183, pl. 9, figs. 13a, b, c
1976 L. macdonnelli (Portlock, 1843) – Schlegelmilch, p. 51, pl. 21, fig. 13
1986 L. macdonnelli (Portlock) – Reid and Bancroft, p. 46, fig. 2J, K
1998 L. macdonnelli (Portlock, 1843) – Blau, p. 217, pl. 8, figs. 9–10; p. 271, pl. 9, figs. 1–5, 7, 9–18; p. 281, pl. 14, fig. 5
1998 L. cf. macdonnelli (Portlock, 1843) – Blau, p. 219, pl. 9, figs. 6, 8
2000 L. macdonnelli (Portlock, 1843) – Blau et al., p. 267, figs. 6.3, 10.1, 10.4
2003 L. macdonnelli (Portlock) – Edmunds et al., p. 68

**Number of specimens:** Six specimens (NHMW 2017/0139/00024-29)

**Description:** The very evolute specimens show a fastigiate and subrounded whorl section. The string-like keel (feeble keel) occurs throughout ontogeny, without grooves or sulci aside. Smooth areas accompany the keel throughout. The primary ribs are strong and sharp and radiate to slightly prorsiradiate. The ribs are equal in thickness from the rounded umbilical edge up to the smooth area on the venter. Specimens reach a maximum diameter of approximately 90 mm (diagnostically flattened). On the large specimen (Fig. 8h), approximately 22 ribs can be counted on the last half whorl. The penultimate whorl appears with 17 ribs on half whorl. One specimen (Fig. 8i) appears with 19 ribs per half whorl at a diameter of 47 mm with 22 per half whorl at a diameter of 29 mm. The innermost whorl on specimen Fig. 8j shows 24 ribs per half whorl at a diameter of 14 mm. The ribbing increases slowly but steadily. Rib spacing is 3–4 mm comparably wide on the final whorl. Both specimens (NHMW 2017/139/0024 and 0025; 8h and 8i) show a very low WER value of 1.47, mirroring the slow increasing trend of whorl height growth within the final whorl. No suture line is visible. Our specimens are quite similar to the assemblage shown by Blau (1998) from the Austrian Lienz Dolomites. Blau (1998) reported three ontogenetical ribbing styles in his L. cf. macdonnelli: fine ribbed inner whorls, followed by a stage with very fine and weak rib and ending with prominent regular bounding again. Blau (1998) interprets his L. cf. macdonnelli as a transitional form of L. meigeni (Hug) and “real” L. macdonnelli. L. cf. macdonnelli Blau (1998) might have a variation in ribboning, therefore not be a different species. Therefore, we take it into synonymy.

**Measurements:**

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**Occurrence and stratigraphic range:** At the Tannscharten, L. gr. macdonnelli (Portlock, 1843) appears in beds 4–6, which are part of the E. raricostatum zone. L. macdonnelli occurs in the Tethyan realm in the late Sinemurian E. raricostatum zone (L. macdonnelli subzone; Schlegelmilch, 1976; Blau, 1998).

**Genus Paltechioceras** Buckman, 1924

**Type of species:** Paltechioceras elicitum Buckman, 1924; OD

**Paltechioceras boehmi** (Hug, 1899)

Fig 8k; Tab. 9

*1899 Arietites Boehmi n. sp. – Hug, p. 16, pl. 12, figs. 8, 8a, b
1958 P. boehmi (Hug) – Donovan, p. 26, pl. 2, figs. 6a, b
1998 P. boehmi (Hug, 1899) – Blau, p. 208, pl. 4, fig. 9-20, pl. 5, fig. 21
2003 P? boehmi (Hug, 1899) – Edmunds et al., p. 70, fig. 4.1
2005 P. boehmi (Hug, 1899) – Tibuleac, p. 485, pl. 3, fig. 9

**Number of specimens:** Five specimens (NHMW 2017/0139/0030; BL 2017/0006-09)
**Description:** The very evolute specimens show a fastigiate and rounded to subrounded early whorl section; later in ontogeny, elliptic and slightly compressed whorl section is seen. Keel is sharp and appears throughout ontogeny. Smooth areas (not sulci) run on both sides of the keel throughout. The densely primary ribs are strong, sharp and slightly curved and prorsiradiate in adult stages. The ribs are equal in thickness from the rounded umbilical edge, over the rounded flanks up to the smooth area on the venter. One specimen (NHMW 2017/0139/0030; 8k) shows a low WER value of 1.46 mirroring the slow increasing trend of whorl height growth within the final whorl. Our specimens are quite similar to the ones from the Lienz Dolomites shown by Blau (1998), whose whorl growth is very slow. The juvenile specimen (NHMW 2017/0139/0030, Fig. 8k) shows 54 ribs on the last whorl (5th whorl). The average rib distance on the last whorl is 1.12 mm. The final whorl depicts the body chamber marked by the last suture line. Specimen BL-Fahr-4 appears with 50 ribs and an average rib distance of 1.34 mm. Blau (1998) states that specimens with 5–6 cm in diameter show about 54 ribs per whorl. Within the ontogeny of the lectotype of *P. boehmi*, the rib frequency increases from 42 (diameter 10 mm) up to 53 (diameter 30 mm) and 51 (diameter 45 mm) ribs per whorl (Getty, 1973). Blau (1998) includes the specimens reported by Dommergues and Meister (1991) as *P. boehmi* into the synonymy of *Paltechioceras favrei* (Hug). This shows the difficulties in determination within the *Paltechioceras* group. Blau (1998) noted *Plesechioceras delicatum* Buckman, *Paltechioceras rothpletzi* (Böse) and *Paltechioceras tardescens* (Hauer) as exhibiting similar density in ribbing, with other specific species differences.

**Measurements:**

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**Occurrence and stratigraphic range:** At the Tannscharten, *P. boehmi* occurs in beds 26–30, which are part of the *E. raricostatum* zone. *P. boehmi* appears in the Tethyan realm and Euroboreal realm in the late Sinemurian *E. raricostatum* zone (*E. raricostatum* subzone; Blau, 1998; Edmunds et al., 2003; Tibuleac, 2005).

**Paltechioceras oosteri** (Dumortier, 1867)

*Fig. 8l, m; Tab. 10*

*1867 Ammonites oosteri – Dumortier, p.164, pl. 30, figs 3, 4
1998 P. oosteri (Dumortier, 1867) – Blau, p. 213, pl. 10, figs. 14, 17, 19; pl. 14, fig. 2
2000 P. oosteri (Dumortier, 1867) – Blau et al., p. 267, figs. 11.4, 11.6, 11.7
2003 Paltechioceras ebriolum (T&W) – Edmunds et al., p. 72, fig. 6.4

**Number of specimens:** One specimen (BL 2017/0010)

**Description:** The very evolute to advolute specimen shows an almost quadratic to rectangular whorl section. Keel is sharp and appears throughout ontogeny. The median keel on the rounded venter is accompanied by narrow furrows on both sides throughout ontogeny (= tricarinate and bisulcate). The ribs start from the rounded umbilical edge and run over the rounded flanks up to the less prominent and smaller side keels. The most specific and characteristic feature of *P. oosteri* is the irregularly preserved looping of ribs. This special rib morphology distinguishes *P. oosteri* from all other species (Blau et al., 2000). In our specimen, 4 looped rib pairs are observed on the last whorl. In specimen BL 2017/0010 (Fig. 8l, m) with a diameter of 36.63 mm, 44 radial to slightly rursiradiate ribs (incl. looped ribs) were counted on the final whorl. The average rib distance is 2.32 mm on the last whorl. The penultimate whorl shows 34 widely spaced ribs. Rib distance is up to three times the rib thickness. Blau (1998) stated that ribs appear to swell at the ventral area and projected anteriorly. The present specimens are quite similar to the ones shown by Blau (1998) from the Lienz Dolomites. According to Blau (1998), *P. oosteri* differs from the most similar *P. tardescens* (Hauer) by the looping and swellings at the ventral ends of the ribs.

**Measurements:**

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**Occurrence and stratigraphic range:** At the Tannscharten, *P. oosteri* was not observed but has been found in the *E. raricostatum* zone of the nearby Fahrenberg locality (same syncline). *P. oosteri* occurs in the Tethyan realm and the Euroboreal realm in the late Sinemurian *E. raricostatum* zone (*P. aplanatum* subzone; Blau, 1998; Blau et al., 2000; Edmunds et al., 2003; Tibuleac, 2005). According to Blau (1998), *P. oosteri* is in the Lienz Dolomites and is the index species of the *P. oosteri* biohorizon.

6. **Late Sinemurian stratigraphy of the Tannscharten section**

The age and biostratigraphy of the marly and silicious limestones from the forest road at the Tannscharten were not known until now. On the geological map of Großraming (Geological map 69, 1:50,000; Egger and Faupl, 1999), the area is characterized by the occurrence of the Lower Jurassic Allgäu Formation. The ammonite assemblage includes the following late Sinemurian genera and species: *P. striatocostatum* (Meneghini), *J. libertus* (Gemmarl), *Paroxynoticeras* sp., *G. paniceum* (Quenstedt), *E. raricostatoides* Vadász, *E. quenstedti* (Schafhautl), *L.
meigeni (Hug), G. gr. macdonnelli (Portlock), P. boehmi (Hug) and P. oosteri (Dumontier). Ammonites are accompanied by two belemnite specimens, four brachiopods and one bivalve.

The ammonite species and resulting ammonite zones identified herein (based on index taxa and assemblages) for the Allgäu Formation allow a correlation of the late Sinemurian (O. oxynotum zone to E. raricostatum zone) strata at the Tannscharten and Fahrenberg localities with the recent standard zonation (Blau, 1998; Meister and Friebe, 2003; Ogg and Hinov, 2012). If a particular zonal index ammonite is absent, the zonal boundary is interpreted by comparison with taxa that characterize the zone and its boundaries elsewhere (literature data) in the late Sinemurian (Lothingian). The ammonite standard zones are recognised by the determination of the index ammonites at the Tannscharten fauna. Genera and species with known stratigraphical ranges (from other geographic areas) are compared with other well-known areas in the Tethyan realm and southern Boreal realm.

The occurring taxa and biostratigraphy are mainly matched to well-known and described faunas from Austria (Blau and Meister, 1991; Blau, 1998; Meister and Friebe, 2003), Germany (Schröder, 1927; Schlegelmilch, 1976; Blau, 1998), France (Dommergues and Meister, 1989), Switzerland (Schlatter, 1987), Romania (Tibuleac, 2005) and England (Edmunds et al., 2003).

The new ammonite data from the Tannscharten area correlate with reported other late Sinemurian assemblages from the Upper Austroalpine Units (Lienz Dolomites in East Tyrol and Carinthia, Southern Austria; Blau, 1998). Blau and Meister (1991) reported P. striatocostatum from the late Pliensbachian A. margaritatus zone of the Blasbründl locality (Lienz Dolomites). A precursor work to Blau (1998) and Blau and Grün (1995) was mostly dealing with lithofacies and microfossil descriptions on the Ammerngebirge Syncline in the Lienz Dolomites. The authors already mentioned the E. raricostatoides, P. boehmi, L. meigeni and L. macdonnelli biohorizons (Blau and Grün, 1995, p. 54), based on the occurrence of the index ammonites. The most extensive work on the same localities (23 genera and 46 species) was performed by Blau (1998) on late Sinemurian ammonites (A. obtusum, O. oxynotum and E. raricostatum zones) of the same Allgäu Formation from the Lienz Dolomites. Identical faunal elements with the ones from Tannscharten are P. striatocostatum, J. libertus, Paroxynoticeras sp., G. paniceum (Gleviceras rigidum) from the Lienz Dolomites, E. raricostatoides, E. quenstedti, L. meigeni, L. gr. macdonnelli, P. boehmi and P. oosteri. Blau (1998) compared the assemblages from the Lienz Dolomites with additional faunas from the Northern Calcareous Alps, the Totes Gebirge Mountains (Austria) and the Chiemgau Alps and Ammergau Alps (both Germany). Within the Lienz Dolomites, the authors separated 17 local faunal biohorizons, with all of them in the E. raricostatum zone. The E. quenstedti, E. raricostatoides, P. boehmi (E. raricostatum subzone), L. meigeni, L. macdonnelli (L. macdonnelli subzone) and P. oosteri (P. aplanatum subzone) horizons are mainly marked by the first occurrence or range of the index ammonites, of which some occur also at the Tannscharten section. Hence, these biostratigraphic markers can be traced and correlated over wide distances as noted by Blau (1998). From the Totes Gebirge locality Rotkogel, E. raricostatum was reported (Schäffer and Steiger, 1986) and by Blau (1998), E. raricostatoides. Additional localities in the Allgäu Formation of the Totes Gebirge (Rettenbachmühle, with E. cf. raricostatum in Schäffer and Steiger, 1986, p. 61) and the Osterhorngruppe, Glasenbachklamm, yielded only few ammonite species such as E. raricostatum (= A. raricostatus in Vortisch, 1970, p. 148; Del-Negro, 1979).

Sinemurian and Plenobian assemblages were documented from the Wundergraben section (Chiemgau Alps, Southern Germany) with E. raricostatum and L. macdonnelli (= Vermiceras raricostatus and V. cf. macdonnelli) in Schröder, 1925, p. 263; Blau 1998; see also Langheinrich, 1967). Ganss (1956) reported from the same locality E. raricostatum and L. macdonnelli (= V. raricostatus and V. cf. macdonnelli) in Ganss, 1956, p. 20, fossil list of K. Hoffmann) in the Dampfgarben section and the Einfang section, respectively. Schröder (1925) noted additionally P. striatocostatum (= Phylloceras partschi Stur in Schröder, 1925, p. 262) and J. libertus (= R. libertus Gemm. in Schröder, 1925, p. 263) from the Tiefenbach locality near Ruhpolding. Sections of the Ammergau Alps (Southern Germany), the Pechkopf, the Weißer Rißkopf and the Klammgraben were reinvestegated by Blau (1998). The only co-occurring taxon between the Klamgraben and the Tannscharten is E. raricostatoides.

A similar fauna was reported by Jacobshagen (1963) from the lower Allgäu Formation (= Älttere Allgäu Schichten) of the western Northern Calcareous Alps (i.e. Wettersteingebirge, Lechtal Alps to Rhein river, Western Austria and Southern Germany). Especially, L. meigeni from the E. raricostatum zone at Gramais in the Lechtal Alps appears to be an identical element (Jacobshagen, 1963, p. 306). An extended version with additional ammonite lists was given in Jacobshagen (1965). Therein, L. meigeni was reported from the locality Seitekopf (northeast of Gramais, central Lechtal Alps), from the Holzgau Lermooser Syncline in the Haglertal valley at Häselgärh P. cf. boehmi (Hug). J. cf. libertus (Gemmellaro) was referred from the Bernhardstal valley at Unter-Gumpen. Additionally, J. libertus was mentioned from the Vilser Alps in the Tannheim valley (Besler, 1959; Jacobshagen, 1965). Besler (1959) listed numerous ammonite taxa from different localities of the Allgäu Formation of the Tannheim valley (Tyrol); the Wieslerbach section with L. macdonnelli (= V. macdonnelli) Portl. in Besler 1959, p. 412) and J. libertus (= R. cf. libertus Gemm. in Besler 1959, p. 412) and the Steinabach bei Zöblen and Kienzerlebach with J. libertus (= R. libertus Gemm. in Besler 1959, p. 418, 420, 423). Besler (1959, p. 447) distinguished in the Lower Jurassic, a
Vermicerasstufe (= E. raricostatum zone), a biostratigraphic zone dominated by the occurrence of different echioceratid taxa (e.g. L. macdonnelli). This zone is most likely equivalent to the late Sinemurian.

Meister and Friebe (2003) reported several matching taxa from the Allgäu Formation of the Northern Calcareous Alps in Vorarlberg (Lechtal Nappe, W. Austria). P. gr. striatocostatum, J. libertus, E. gr. quenstedti and L. gr. meigeni were found at the Lorűns quarry, Rothorn, Eingemaueru, Goppelspitze and the Schröcken area.

Schröder (1927) described J. libertus (= R. libertus Gemm., p. 143) from the Lahgraben locality near Lenggries and L. macdonnelli (= V. macdonnelli Portl., in Schröder 1927, p. 183) from the Pech kopf near Hohenschwangau in the Bavarian Alps (Southern Germany). Additionally, several E. quenstedti (= Vermiceras var. quenstedti Schaff. in Schröder 1972, p. 188) and P. striatocostatum (= P. partschi, in Schröder 127, p. 122) were reported from these localities.

Koch and Stengel-Rutkowski (1959) reported similar faunas from the Lechtal Alps (Tyrol, Austria). From the lower Allgäu Formation (= Ältere Fleckenmergel in Koch et al., 1959) in the Krabachtal, L. cf. meigeni (Hug) was reported. From the area around the Wildhorn (East bank of lake Zürser See) in the Lechquellenengebirge, E. (P.) sp. aff. boehmi (Hug) and numerous specimens of Leptechioceras, Paltechioceras and Echioceras are mentioned.

A single ammonite specimen, E. raricostatus (Zieten), was reported by Ehrendorfer (1988) from the Allgäu Formation near Großraming in the Frankenfels Nappe (Rettenbach Syncline).

Aberer (1951) noted a specimen of A. raricostatus Ziet. (= E. raricostatus) from east of Maria Neustift in Upper Austria ("Krittergut" in the Frankenfels Nappe).

Getty (1973, p. 188, pl. 2, fig. 7; BS AS.IX.21) designated the lectotype for E. quenstedti (Schaffhaut) on a specimen from the Allgäu Formation (E. raricostatoides subzone) at the Kochelsee in the Northern Calcareous Alps (Bavarian Alps, Southern Germany). The neotype for E. raricostatoides (Vadász) was designated by Getty (1973, p. 13, pl. 1, fig. 12) from the E. raricostatoides subzone of the "Calcaire ocreux" from Seichamp near Nancy (Lorraine; École des Mines, Paris, Puzos Collection B14, 7).

Blau et al. (2000) described late Sinemurian and early Pliensbachian ammonite faunas from the Herford-Diebrock area (clay pit Stork 3, Northwest Germany). Therein, L. meigeni, L. macdonnelli (both L. macdonnelli/L. meigeni biohorizon; base of L. macdonnelli subzone) and P. oosteri (P. tardecrescens) biohorizon, base of P. aplanatum subzone) were figured. All the latter species form characteristic elements of the late Sinemurian in Northwest Germany and Austria with the locality Tannscharten in the Northern Calcareous Alps.

Edmunds et al. (2003) discussed the ammonite biostratigraphy of the late Sinemurian–early Pliensbachian at St Peter’s Field (Radstock, Somerset, UK). The authors figured L. meigeni, P. ebriolum and L. macdonnelli. Additionally, a specimen of P. ebrilolum was figured (p. 72, fig. 6.4), which is herein supposed to be a P. oosteri. Edmunds et al. (2003) stated that P. ebriolum is probably a pathological or mutational form of P. oosteri.


Dommergues and Meister (1989) reported on specimens from a late Sinemurian succession at Chablais Méridional and Klippes des Savoie (Préalpes medians, Haute-Savoie, France). E. quenstedti, L. meigeni and P. boehmi (Mont Lachat de Châtillon and Le Môle) were figured.

Pia (1914) discussed the genus Oxynoticeras and mentioned the species G. panicum (= O. panicum, p. 33, pl. 6, fig. 3) from the late Sinemurian A. obtusum zone, figured originally by Quenstedt (1884) from Germany.

Tibuleac (2005) reported on new taxa from the olistolith of Prașca Peak (Rarău Syncline, Eastern Carpathians, Romania). He figured the late Sinemurian species E. raricostatoides, L. meigeni and P. boehmi.

Blau (1998) separated in the Allgäu Formation of the Lienz Dolomites within the E. raricostatum zone (E. raricostatum subzone) the E. quenstedti, the E. raricostatoides and the P. boehmi biohorizons (only those biohorizons were mentioned that can be correlated with the Tannscharten locality). The E. quenstedti biohorizon is characterized by the co-occurrence (only those species were noted that also occur at Tannscharte; for details see Blau, 1998) of E. quenstedti and J. libertus. Blau (1998) stated Echioceras as Euroboreal and J. libertus as Tethyan faunal element. The E. raricostatoides biohorizon is Euroboreal influenced and characterized by the co-occurrence of E. raricostatoides, Gleviceras sp. and J. libertus. The P. boehmi biohorizon is characterized by the co-occurrence of J. libertus, P. boehmi, P. striatocostatum and others. The dominant index species P. boehmi occurs in the Euroboreal and the Mediterranean realms. Tethyan elements are less common in that level. The L. macdonnelli subzone of the E. raricostatum zone include the L. meigeni and L. macdonnelli biohorizons. The L. macdonnelli biohorizon is characterized by the co-occurrence of J. libertus, L. macdonnelli, L. meigeni, P. striatocostatum and others. The dominating genus Leptechioceras is an Euroboreal element and co-occurs with the Tethyan genera Juraphyllites and Partschiceras. The L. meigeni biohorizon is characterized by the co-occurrence of J. libertus, L. macdonnelli, L. meigeni and others. In accordance to Blau (1998), we follow the idea that L. macdonnelli appears later than L. meigeni. The P. aplanatum subzone of the E. raricostatum zone includes the P. oosteri biohorizon. The P. oosteri biohorizon is characterized by the co-occurrence of J. libertus, P. oosteri, P. striatocostatum and others. The biohorizon is dominated by Tethyan faunal elements. G. panicum can be observed in the
O. oxynotum zone. It presumably can be correlated with the G. rigidum biohorizon of Blau (1998). G. panicum seems to be restricted to the Tethyan realm (i.e. Alpine area), as stated also for G. rigidum (Blau, 1998).

The presented data from the Tannscharten locality allow a more precise reconstruction of the palaeogeographic setting of the studied section. Accordingly, the described specimens were found in deep-water deposits of the Allgäu Formation basin situated on the Lower Jurassic Adriatic (Alpine-Apennine) Plate (Fourcade et al., 1993; Lukeneder, 2010) of the western Tethys.

The studied locality offers one of the few opportunities to investigate Upper Sinemurian ammonite faunas. Hence, the Tannscharten section represents a key locality for a detailed investigation of an ammonite fauna affected by an environmental turnover (i.e. drowning and deepening). The almost worldwide distribution of Lower Jurassic (e.g. Sinemurian) pelagic to hemipelagic ammonites during that time makes these cephalopods suitable for biostratigraphic correlations within the Tethyan realm. In the case of the Tannscharten assemblage, a mix of Euroboreal and Mediterranean elements is observed. The ammonite fauna from Tannscharten mirrors the connective palaeoceanographic position of the basinal area of the Austroalpine Units on the northern end of the Alpine-Apennine Plate in the Lower Jurassic.

7. Conclusions
The so far undescribed macrofauna of the Tannscharten section (Reichraming Nappe, Northern Calcareous Alps) is mainly represented by ammonites, scarce belemnites and brachiopods. A total of 46 ammonite specimens, four belemnites and two brachiopods were collected and supplemented by nine ammonites and one brachiopod from the Fahrenberg section (to the east in Schneeberg Syncline).

During the deposition of the Tannscharten sequence, a significant facies change took place – from the shallow-water deposits of the Rhaetian oolites and red limestones of the Adnet Formation to the deep-water marly limestones and limestones of the Lower Jurassic Allgäu Formation (= “Lias Fleckenmergel”).

J. libertus, P. striatocostatum, G. panicum, E. quenstedti, E. raricostatoides, P. boehmi, L. meigeni, L. macdonnelli and P. oosteri are described for the first time from the Tannscharten section point to be part of the E. raricostatum zone (E. raricostatoides subzone). Although, there are some fossils with long stratigraphic ranges (e.g. J. libertus, P. striatocostatum), only G. panicum can be assigned to be older and a constituent of the upper part of O. oxynotum zone.

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Petra LUKENEDER & Alexander LUKENEDER


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Petra LUKENEDER(1) & Alexander LUKENEDER(2)
(1) Museum of Natural History Vienna, Burgring 7, 1010 Vienna, Austria; (2) Corresponding author: petra.lukeneder@gmx.at