GEOLOGIJA 66/1, 87-105, Ljubljana 2023

https://doi.org/10.5474/geologija.2023.003

Taxonomic and stratigraphic remarks on *Placites urlichsi* Bizzarini, *Pompeckjites layeri* (Hauer), *Carnites floridus* (Wulfen) and *Sageceras haidingeri* (Hauer)

Taksonomija in stratigrafski razpon vrst *Placites urlichsi* Bizzarini, *Pompeckjites layeri* (Hauer), *Carnites floridus* (Wulfen) in *Sageceras haidingeri* (Hauer)

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Prejeto / Received 19. 8. 2022; Sprejeto / Accepted 12. 4. 2023; Objavljeno na spletu / Published online 4. 8. 2023

Key words: ammonoids, Triassic, Carnian, Wettersteinkalk, Bleiberger Sonderfazies, Upper San Cassian Formation
Ključne besede: amoniti, trias, karnij wettersteinski apnenec, pliberški facies, Zgornja San Cassianska formacija

Abstract

Investigations of an Lower Carnian Wettersteinkalk ammonoid fauna found in the Hochobir massif (Carinthia/Austria) gave rise to problems in the taxonomic relationship within the Triassic ammonoid Family Pinacoceratidae. The morphological parameters of the ammonoid genus *Pompeckjites* are rather unclear. Morphological variation of at least two ammonoid species as *Pompeckjites layeri* Hauer on one end, *Placites urlichsi* Bizzarini on the other end have to be take into account. Numerous field surveys, studies and excavations on upper Wettersteinkalk sites within the Karavank Mountains and Hallstatt-facies sites in the Northern Calcareous Alps were implemented and compared with the reference sites in the Dolomites. As a consequence of our investigations, the Hochobir Wettersteinkalk ammonite assemblage is thought to be equivalent in time to the ammonoid fauna of the Upper San Cassian Formation. The frequent occurrence of the Julian (Lower Carnian) ammonoid *Placites urlichsi* Bizzarini may be a powerful tool in field investigations for a refined correlation of the upper Wettersteinkalk reef limestone to the coeval basinal facies of the Upper San Cassian Formation (Lower Carnian/upper *Trachyceras aonoides* Zone). As a result of this study *Placites urlichsi* was included in the genus *Pompeckjites*. This paper could be an attempt to recognize the differences in juvenile forms of *Pompeckjites layeri* and *Placites urlichsi* and other similar disciform ammonoid genera like *Carnites floridus* and *Sageceras* sp. based on suture lines, polished transversal-sections and morphological features.

Izvleček

Rezultati raziskave amonitne favne v spodnjekarnijskem wettersteinskem apnencu, ki se pojavlja na Obirju, na avstrijskem Koroškem, odpirajo problem v taksonomskem razlikovanju triasnih amonitov družine Pinacoceratidae. Razlikovanje na podlagi morfoloških parametrov amonitov rodu *Pompeckjites* je precej nejasno, pri čemer je treba upoštevati morfološke variacije najmanj dveh vrst, in sicer *Pompeckjites layeri* Hauer na eni ter *Placites urlichsi* Bizzarini na drugi strani. Številni ogledi nahajališč v zgornjem wettersteinskem apnencu Karavank in hallstattskem faciesu Severno apneniških Alp, njihova izkopavanja ter raziskave, poleg tega pa tudi primerjava z referenčnimi najdišči v Dolomitih kažejo, da je zbrana amonitna združba wettersteinskega apnenca najverjetneje časovni ekvivalent amonitni favni zgornje San Cassian formacije. Pogosto pojavljanje julijskega (spodnji karnij) amonita *Placites urlichsi* Bizzarini je na terenu lahko močno orodje za oceno korelacije med grebenskim zgornjim wettersteiskim apnencem ter ekvivalentnim bazalnim faciesom zgornje San Cassian formacije (spodnji karnij/zgornji del *Trachyceras aonoides* cone). Kot rezultat te raziskave je bil *Placites urlichsi* vključen v rod *Pompeckjites*. Pričujoči članek na podlagi suturnih linij, poliranih rezov in morfoloških značilnosti, pomaga prepoznati razliko med juvenilnimi oblikami *Pompeckjites layeri in Placites urlichsi* ter drugimi amoniti diskoidne oblike kot sta *Carnites floridus* in *Sageceras* sp.

Introduction

The Julian (Lower Carnian) *Trachyceras aonoides* and *Austrotrachyceras austriacum* ammonoid zonation was originally established in the fossiliferous Hallstatt Limestones of the Northern Calcareous Alps (Mojsisovics 1892, 1893; Frech 1911a, 1912, subsequently better defined by Krystyn 1978 and verified by Hornung et al. 2007). Later on it was compared with the biostratigraphic framework of the San Cassian Formation of the Southern Calcareous Alps/Dolomites (see reference lists of Mietto et al. (2012) and Urlichs (2017). It was recognized that the San Cassian Formation spans more than the previously thought late Ladinian to earliest Carnian (*Trachyceras aon* Zone) age (Bizzarini 1987, 2000; Mastandrea 1995; Di Bari & Baracca 1998). Consequently, attempts were made to correlate both facies on the basis of occuring Trachyceratidae (Urlichs 1994, 2017). However, other co-occurring ammonoid genera (except *Lobites*, see Urlichs 2012) were never part of such studies. From the Julian part of the Wettersteinkalk (Bleiberger Sonderfazies of Holler 1960) such comparative ammonoid studies were not carried out until today. Current biostratigraphic studies in the UNESCO Geopark Karawanken/Karavanke (A/Slo) evidence a *T. aonoides* Zone age of these strata that is based on the occuring Trachyceratidae (Poltnig & Spatzenegger 2022). The co-occuring ammonoids of the Family Pinacoceratidae show striking similarities to the Pinacoceratidae of the Upper San Cassian Formation East of Cortina d' Ampezzo that were revised by Bizzarini (1987). A small disciform ammonoid fauna, found in the uppermost Wettersteinkalk (Bleiberger Sonderfazies, Holler 1960) caused severe taxonomic classification problems that hampered a clear Carnian/Julian ammonoid subzone (see Fig. 2, middle column) identification already in the field. Because of syndiagenetic dolomitization and recrystallization during lithogenesis, only very few ammonoids showed well preserved suture lines. This fact made it complicated to distinguish between the Julian contemporaneous ammonoid genera *Pompeckjites*, *Sageceras* and *Carnites*. To make matters worse, some juvenile growth stages of *Placites urlichsi* show strong homeomorphism to *Sageceras* sp. and *Pompeckjites layeri*.

To facilitate the classification on poorly preserved ammonoids of the genera above mentioned we provide our results based on polished hand specimens and morphological features.

Study areas

Fladung mining area on Obir massif/Austria

The abandoned Fladung lead-zinc mining area is located about 8 km west of Bad Eisenkappel on the southern slope of Hochobir (see Fig. 1, A). It is easily accessible via the toll road to the Eisenkappler Hütte. During several field excursions the majority of the ammonoids were sampled from the ravine directly east of the Fladung Berghaus (see Figs. 1, B and D with sites 1a, 1b, 1c). The western ravine wall (approximately 1200 m above sea level) crops out of a steeply dipping (55 degrees towards east-south-east) Wettersteinkalk succession that shows a slope angle parallel to the bedding. Therefore, all ammonoid locations (site 1 a-c) found in this wall originate from approximately the same stratigraphic layers. Location 2 is situated 500 m further eastwards of the Fladung Berghaus directly beside the toll road near a junction with a forest road (see Fig. 1, B). It is in tectonically stressed contact (not well visible in the field) with Cardita shale and Cardita limestone. Lipolt (1856:337f) mentions from the Fladung mining district light ore bearing "Hallstätter Kalk" (=Wettersteinkalk) and cited Carnian ammonoids from the locality ("*Ammonites Aon*, *Ammonites Joannis Austriae*, *Ammonites Jarbas* and *Ammonites Gaytani*"). The "Bleiberger Schichten des Ovir (=Obir)" with *Carnites floridus*, also mentioned in Lipolt (1856), correspond to the first Raibl shale horizon and should not be confused with today's Bleiberger Sonderfazies of Holler (1960). For further information we refer to Poltnig & Spatzenegger (2022).

Our newly discovered fossiliferous strata correspond to the Bleiberger Sonderfazies (Holler 1960) of the uppermost Wettersteinkalk and mark the area between the sediment hosted lead-zinc mineralization (Bechstaedt 1979; Mondillo et al. 2019) and the tectonically sheared off and subsequently eroded first Raibl shale horizon.

Unterpetzen mining area near Podpeca/Slovenia

The former mining district Unterpetzen/Podpeca is situated roughly 6.5 km southwest of the town Mežica/Slovenia. (see Fig. 1, A) on the south eastern slope of the Petzen massif. It should not be confused with the Helena mining district in the village Podpeca itself that is situated one kilometer eastwards. Two field campaigns were carried out in this area to verify our stratigraphic results from Hochobir. Main sampling was done alongside the forest road (sites Pod. 1-3, roughly E 46.476450, N 14.808636) to the abandoned Mariahilf mine

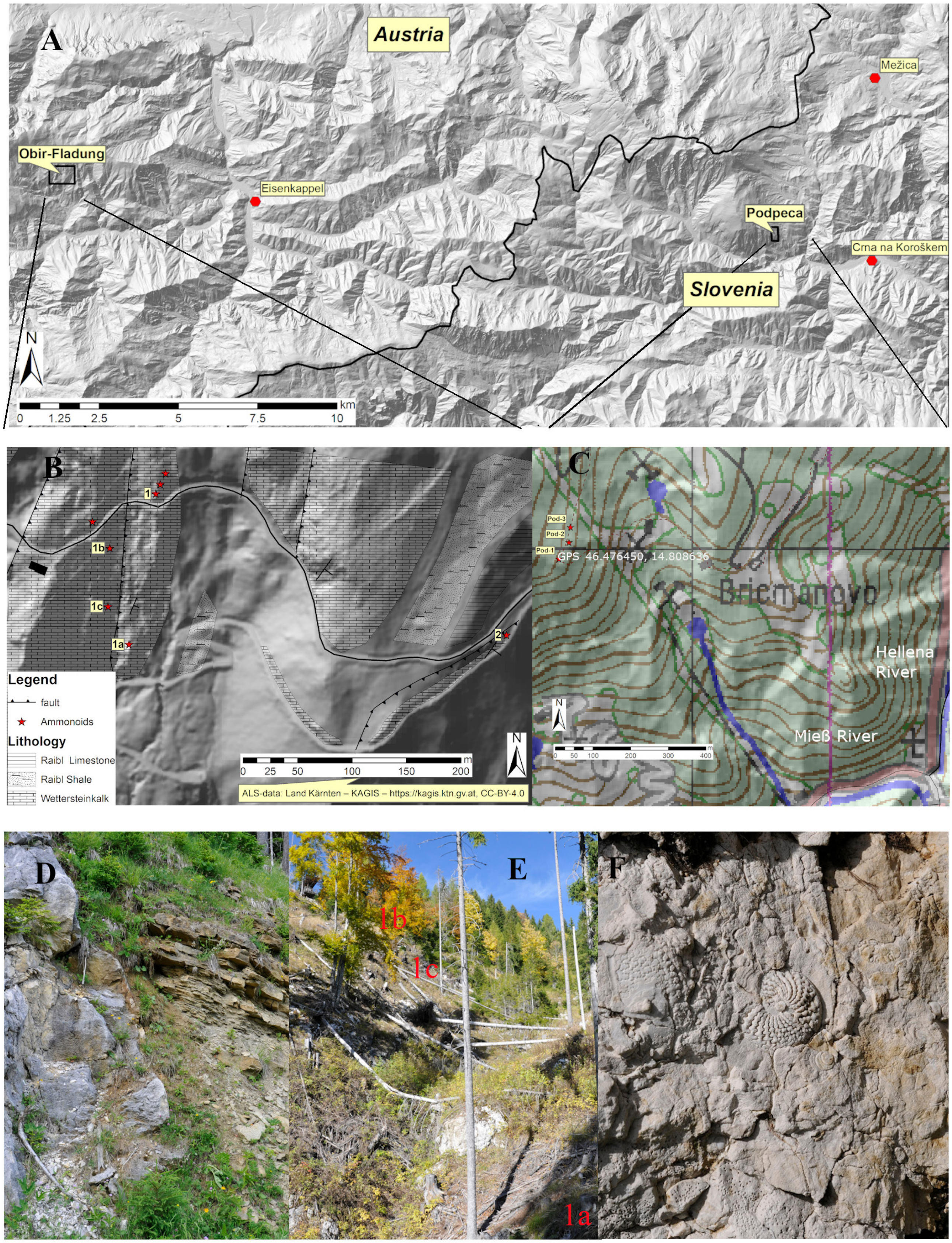

Fig. 1. Overview of the Studied Areas.

A, geographic situation of the Obir/Fladung area in Austria and of the Unterpetzen/Podpeca area in Slovenia. B, enlarged overview of the Fladung sites with mapped lithologic strata (debris and soil are not mapped). C, Unterpetzen/Podpeca mining area with sites Pod 1–3 alongside the forest road to the Mariahilf mine gallery. D, tectonically stressed contact of Wettersteinkalk (left) to Raibl shales (right) in the Fladung area. E, view from Fladung site 1a towards 1b and 1c. F, weathered in situ Wettersteinkalk ammonoid (*Joannites klipsteini*), Fladung, site 1c.

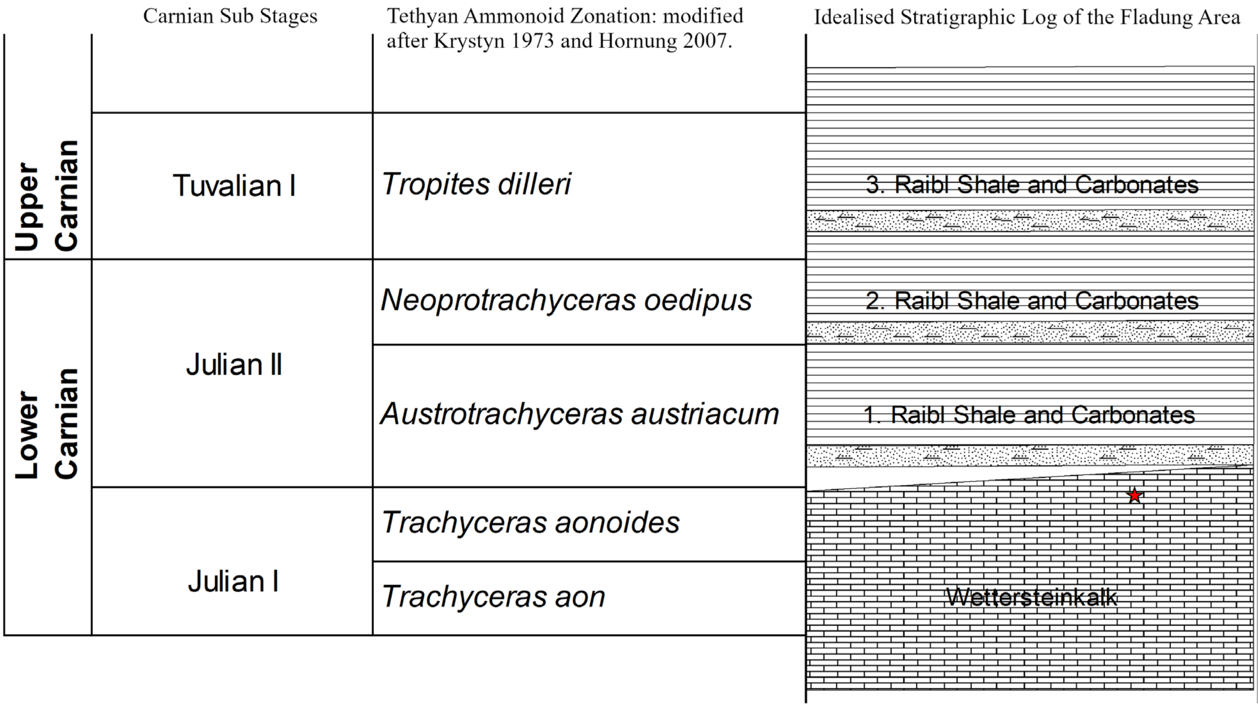

Fig. 2. Simplified stratigraphic log of the Fladung area.
The left column shows the Lower Carnian (Julian) sub-stages. The middle column shows the ammonoid zonation modified after Krystyn (1973) and Hornung et al. (2007). The right column shows an idealized lithologic log of the Fladung area and the stratigraphic position of the found ammonoid fauna (red star).

gallery (see Fig. 1, C). From Unterpetzen several ammonoid finds in Wettersteinkalk have been cited in Mojsisovics (1871, 1873, 1882, 1893, 1902).

Material and methods

All ammonoid concentrations found at both locations originate from the vicinity of algal laminites and do show a partial current sorting of the fossils. This suggests a deposition in the tidal to subtidal zone. Most ammonoids in this study were completely recrystallized and partially encrusted by a several millimeters thick dolomitic crust. Towards the surface and near mineralized layers better preservation was found. In some limestone parts the ammonoids showed calcitic shell replacement that was sometimes covered with a fine limonite crust between ammonoid shell and sediment. If this coating was missing, preparation was difficult and of poor result. Another common feature of ammonoids found near the surface was the dissolution of the ammonoid shell by humic acids. The result was an internal mold (steinkern) covered by a crumbled powder of the former ammonoid shell. The identification of ammonoids that showed steinkern preservation was also hindered by the lack of visible suture lines. Preparation was done by the authors exclusively. The best results were obtained by using coarse and fine pneumatic engravers. Limestone lacking preparable ammonoids was used for making polished transversal-sections (see Figs. 7, A, B, F and 9, C). Such sections gave good insights into the depositional conditions and were found to be very helpful in identification of some ammonoids.

All collected fossils originate from the Bleiberger Sonderfazies (Holler, 1960) of the mining district Fladung and are stored in the administration center of the UNESCO Geopark Karawanken/Karavanke in Tichoja and in the private collection of Andreas Spatzenegger (A-5113 St. Georgen). All fossils are accessible by prior appointment.

Systematics

More than 300 ammonoid specimens were collected during fieldwork. The general preservation of the ammonoid assemblages found was moderate to poor. Sample richness in ammonoid quantity was very high and similar to the ammonoid accumulations within the Hallstatt limestone. For the species mentioned in the systematic part, the most important synonyms provided in the literature and the original papers describing the holotypes were carefully reviewed. The systematic paleontology below is thus based upon a careful revisitation of previous Triassic ammonoid literature (Hauer 1846, 1847; Mojsisovics 1873, 1882; Hyatt 1884; Mojsisovics 1902; Gemmellaro 1904; Arthaber 1905; Hyatt & Smith 1905; Arthaber 1911; Frech 1911a; Welter 1914; Diener 1915a, 1915b, 1916; Smith 1927, 1932; Johnston 1941; Spath 1951; Tozer

1967; Silberling & Tozer 1968; Tozer 1971; Krystyn 1973, 1978, 1980; Tozer 1981; Krystyn 1982; Tozer 1984; Sestini 1992; Tozer 1994; Doguzhaeva et al. 2007; Balini 2008; Konstantinov 2008; Mietto et al. 2008; Balini et al. 2010, 2012; Hyatt & Smith 2012; Konstantinov 2012; Lukeneder & Lukeneder 2014; Ritterbush et al. 2014; Jenks et al. 2015) and our own investigations based on morphology and transversal sections. For each ammonoid species, remarks are provided with respect to the original identifications and descriptions provided in the literature. The main subject of the systematic part is the Lower Carnian/Julian genus *Pompeckjites* of the Family Pinacoceratidae Mojsisovics, 1879. The additionally described genus *Carnites* (Carnitidae Arthaber, 1911) is not a member of Pinacoceratidae but included with the latter in the Superfamily Pinacoceratoidea (Tozer, 1981). The genus *Sageceras* (Superfamily Sageceratoidea Hyatt, 1884) is shown here only for comparison purposes to highlight some morphological similarities with the above mentioned genera in transversal sections. For the higher taxonomic nomenclature of ammonoids the work of Hoffmann et al. (2022) was used. In regards to the taxonomy of ammonite families and subfamilies we used the classification of Tozer (1971, 1981) and Krystyn (1982). For the detailed descriptions of *Carnites floridus* and *Pompeckjites layeri,* we refer to the original descriptions (Hauer 1847; Mojsisovics 1873, 1902). The description of *Placites urlichsi* Bizzarini, 1987 is more detailed because of its importance for this work.

Superorder Ammonoida Haeckel 1866
Order Ceratitida Hyatt, 1884
Pinacoceratoidea Mojsisovics, 1879
Carnitidae Arthaber, 1911
Carnites Mojsisovics, 1879

Type species: *Carnites floridus* (Wulfen, 1793)

1793 *Nautilus bisulcatus* Wulfen, p. 103, fig. 10.

1793 *Nautilus floridus* Wulfen, p.113, fig. 16.

1793 *Nautilus nodulosus* Wulfen, p. 115, fig. 17.

1793 *Nautilus redivivus* Wulfen, p. 116, fig. 18.

1846 *Ammonites floridus* Hauer, p. 2, pl. 1, figs. 5-14.

1855 *Ammonites floridus* Hauer, p. 150.

1873 *Pinacoceras floridum* Mojsisovics, p.58, pl. 22, figs. 15, 16; pl. 25, figs. 1-6.

1882 *Carnites floridus*, Mojsisovics, p.228, pl. 50, figs. 5-8; pl. 51, figs. 1-8.

1911b *Carnites floridus*, Frech, p. 19, figs. 24 a, b, non c.

1911b *Carnites floridus*, Frech, p. 19, figs. 25 a, b, c.

non 1911b *“Carnites” falcifer*, Frech, p. 21, figs. 26, 27.

2007 *Carnites floridus*, Hornung et al., pl. 6, figs. b1-b4.

Description: For the detailed morphological description we refer to (Hauer, 1846) and (Mojsisovics, 1873, 1882).

Remarks: The juvenile development of *Carnites floridus* (Wulfen, 1793) was first described in detail in Hauer (1846) and is excellently pictured in his plate. Hauer recognized the different growth stages of *Carnites floridus* which were assigned by Wulfen (1793) to four different Nautilus species. Hauer (1846) established on contemporary nomenclature and the “ammonitic” suture line *Ammonites floridus*. Mojsisovics (1873) confirmed the growth development illustrated and described by Hauer (1846) and identified it as *Pinacoceras floridum*. Mojsisovics (1879a) first mentioned the genus name *Carnites* and formally established the genus *Carnites* in Mojsisovics (1879b) with *C. floridus* as its type species. The original type specimen of *C. floridus* was found in the first Cardita shale horizon of Bad Bleiberg. Its stratum typicum in the so called first Raibl shale horizon (= first Cardita shale horizon) was clearly named and described too.

The hitherto considered large stratigraphic range of *C. floridus* most probably has its origin in the descriptions of Hauer (1846) and Mojsisovics (1873) where both authors refer to a great morphologic variability in the mature growth stages of *C. floridus*. Alas, some subsequent authors (Leonardi & Polo, 1952) didn’t focus on the juvenile development of *C. floridus* and mis-identified specimens showing divergent juvenile development and mature *Carnites* shape as *C. floridus*.

Carnites floridus (see Figs. 3, E-E2 and F-F1) found in the Hallstatt Limestone of the Rappoltstein hill (= historic „Mons Tuval“, located in Bavaria) show the same development in juvenile

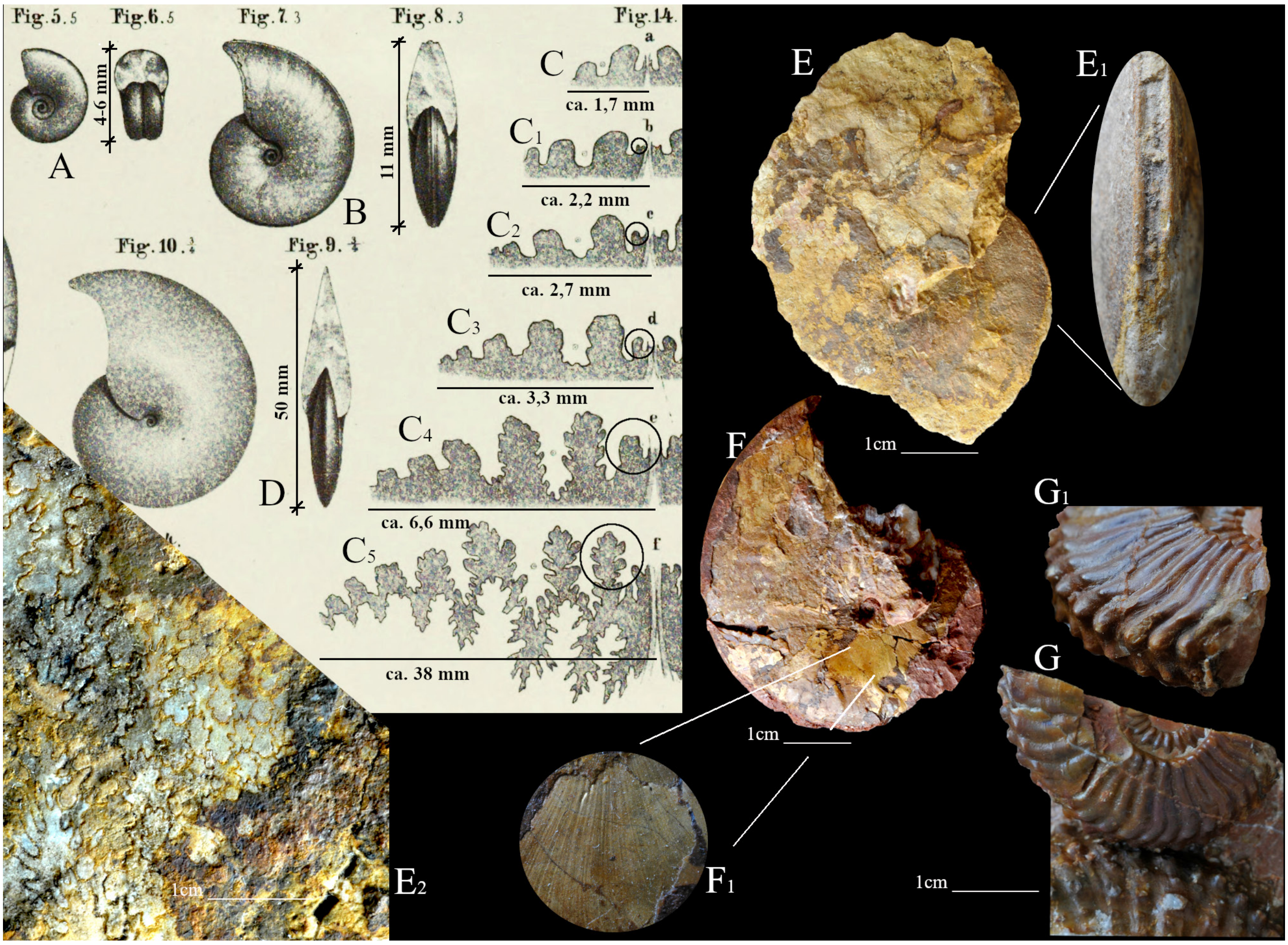

Fig. 3. *Carnites floridus*.

A, B, D, different growth stages of *C. floridus* with added metric measurements (modified after Hauer 1846: pl. 1, figs. 5-14). C–C5, original suture drawings in Hauer (1846). The development of an adventitious saddle is focused on the black circles. E–E1, side and venter view of *Carnites floridus* from Carnian Hallstatt Limestone of Rappoltstein. F, *C. floridus* from Rappoltstein in iridescent shell preservation. F1, enlargement of the faint growth lines on ammonoid F. G–G1, *Neoprotrachyceras thous*, found together with *Carnites floridus* on Rappoltstein. E2, sutureline of *C. floridus* from Rappoltstein.

stage as in *C. floridus* from the first shale horizon of Bad Bleiberg. At Rappoltstein *C. floridus* was found with *Austrotrachyceras* sp., and *Neoprotrachyceras thous* (see Figs. 3, G, G1) what allows a correlation with the beginning of the *A. austriacum* Zone (Hornung et al. 2007). This indicates that the first Raibl shale horizon can be correlated as well, which implies that the uppermost Wettersteinkalk (Bleiberger Sonderfazies) occurring below roughly corresponds to the upper *T. aonoides* Zone. Frech (1911b: 19ff) established *"Carnites" falcifer* as a new *Carnites* species from presumably Tuvalian (Upper Carnian) strata. Our own investigations on Rappoltstein revealed that *"C." falcifer* belongs to the genus *Parahauerites*. It is of early Tuvalian age and was found with *Pleurotropites* sp. and *Trachysagenites* sp. Therefore, we can exclude an occurrence of *Carnites* in lower Tuvalian (*Tropites dilleri* Zone) strata.

To illuminate the juvenile morphological development and the development of the suture line of *C. floridus* we have pictured the modified plate of Hauer (1846: pl. 1), (see Figs. 3, A-D) with additional metric measurements. The added black circles in the suture line drawings (see Figs. 3, C-C5) focus on the development of an adventitious lobe/saddle what is a diagnostic feature for *C. floridus*. Fully mature specimens of *C. floridus* show two adventitious elements that both emerged in the same way. In the largest suture (see Fig. 3, C5), the genesis of the second adventitious element is visible in the small adventitious bulgy saddle near the venter on the right side of the black circle. The juvenile specimen illustrated in Figure 3, A shows a ventral furrow with a faint keel in the middle (not visible in Hauers drawing). According to Hauer (1846) this is not the regular development. Most juvenile cores at this size show a normal rounded venter. The Figure 3, B in this text, shows the subsequent development of the tricarinate venter that is also an important morphological feature of *C. floridus* too (see Figs. 3, E1 and 9, A1).

Following this stage, the shape of *C. floridus* diverges considerably. There can occur equal sized specimens with almost sharp (Fig. 3, D) or with rounded venter. Some specimens showed fold-like nodes at the mid flank, which were sometimes accompanied by nodes on the ventro-lateral margin. This is in contrast with other totally smooth specimens of the same size. Between these extremes, many variations exist. The suture line is identical in all of these variations. All these different forms are based on an identical juvenile stage showing similar measurements in ratio of diameter to thickness. This was not really taken into account in earlier classifications of similar ammonoids to *Carnites floridus*, which led to an enlarged stratigraphic range of true *C. floridus*.

The ammonoid fauna of the San Cassian Formation laid a base for an extended stratigraphic range of *C. floridus* as well. Early authors (Mojsisovics, 1869, 1882, Mojsisovics et al., 1895; Zittel, 1899) assigned the San Cassian layers as a whole into the former Cordevol (*T. aon* Zone). All ammonoid forms similar to *Carnites*, were assigned to *C. floridus*. This opinion prevailed until the 20th century and can be seen clearly in the identifications on the ammonoid plates in Leonardi and Polo (1952), where ammonoids from the upper San Cassian Formation East of Cortina d' Ampezzo (Boa Staolin, Boa Tamarin, Costalares) were compared and identified with upper Ladinian to lower Carnian ammonoid species of the classic San Cassian locations (Stuores Wiesen, Pralongia). For example, the genus *Sirenites* that begins in the upper *T. aonoides* Zone, was not recognized in Boa Staolin because it does not occur in San Cassian. It was identified as (*Pro)trachyceras ladinum* in Leonardi and Polo (1952: pl. 2, Figs. 32-35). Bizzarini (1987, 2000) took these differences into account and attempted to improve the identifications by establishing *Placites urlichsi* (for *C. floridus* in Leonardi and Polo 1952) and by enlarging the stratigraphic log of the upper San Cassian Formation to include the *T. aonoides* and *A. austriacum* ammonoid Zones. For further literature regarding to the San Cassian Formation, we refer to the reference lists of Mietto et al. (2012) and Urlichs (2017).

Occurrence: *Carnites floridus* occurs in Carnian Hallstatt Limestone of Feuerkogel/Austria and Rappoltstein/Germany, in the first Raibl shale in Austria and Germany (Bavaria), in the Reingraben shales in Austria (Frech 1911b; Lukeneder & Lukeneder, 2022). Hungary (Frech 1911b), Slovenia (Jurkovšek et al., 2002) and Italy.

Pinacoceratidae Mojsisovics, 1879

The Family Pinacoceratidae probably has its origin in the late Anisian to lower Ladinian age with *Praepinacoceras damesi* (Mojsisovics). In the subsequent Carnian stage the Family Pinacoceratidae is subdivided into several genera whose phylogenetic relationships to each other are not very clear. A close relationship exists among the genera *Pompeckjites* and *Eupinacoceras* in the development of the suture line and in some morphological parameters.

Genus *Pompeckjites* Mojsisovics, 1902

Type species: *Pompeckjites layeri*, (Hauer, 1847)

1847 *Ammonites layeri* Hauer, pl. 9, figs. 1-3.

1873 *Pinacoceras layeri*, Mojsisovics, pl. 23, figs. 1-6.
1902 *Pompeckjites layeri*, Mojsisovics, pl. 19, figs. 3-5; pl. 20, fig. 1.

Description: For detailed description see in (Hauer, 1847) and in (Mojsisovics, 1873, 1902)

Remarks: In the Hallstatt Limestone, *Pompeckjites layeri* (see Figs. 4, A-E) spans the entire Julian stage (*T. aon*, *T. aonoides* and *A. austriacum* ammonoid Zones). Our own measurements on *P. layeri* from the *T. aonoides* and *A. austriacum* Zones show slight differences in the development of the juvenile whorls. In the *A. austriacum* Zone the inner whorls are thicker and do show a somewhat persisting rounded venter stage (see white arrows in Fig. 7, C) than in the *T. aonoides* Zone where the early juvenile whorls are thinner and more fastigated (see Fig. 7, D) at equal size. According to Krystyn (1973: 125, see in faunal list of *T. aon* Zone) *P. philopater* is synonymous with *P. layeri*. In contrast to this opinion *Pinacoceras philopater* (Laube) was assigned to *Pompeckjites* by Bizzarini (1987).

Occurrence: According to Krystyn (1978), *P. layeri* occurs in the *T. aon*, *T. aonoides* and *A. austriacum* Zones of the Hallstatt Limestone. San Cassian Formation/Italy.

"Placites" urlichsi Bizzarini, 1987

Type species: *Placites urlichsi* Bizzarini, 1987, pl. 1 figs. 1, 2a,b, 3a,b, 6a,b, 7, 8. Holotype: pl. 1, fig. 1, from Boa Staolin. Paratypes: pl. 1, figs. 6-8, from Boa Staolin. Depository of types (see Bizzarini, 1987: 50).

1952 *Carnites floridus*, Leonardi & Polo, pl. 1 figs. 26, 44, 45, 47- 49, 55, 57; pl. 2, figs. 39, 40, 41, 42, 43.

2000 *Placites urlichsi* Bizzarini, pl. 3, figs. 3, 4.

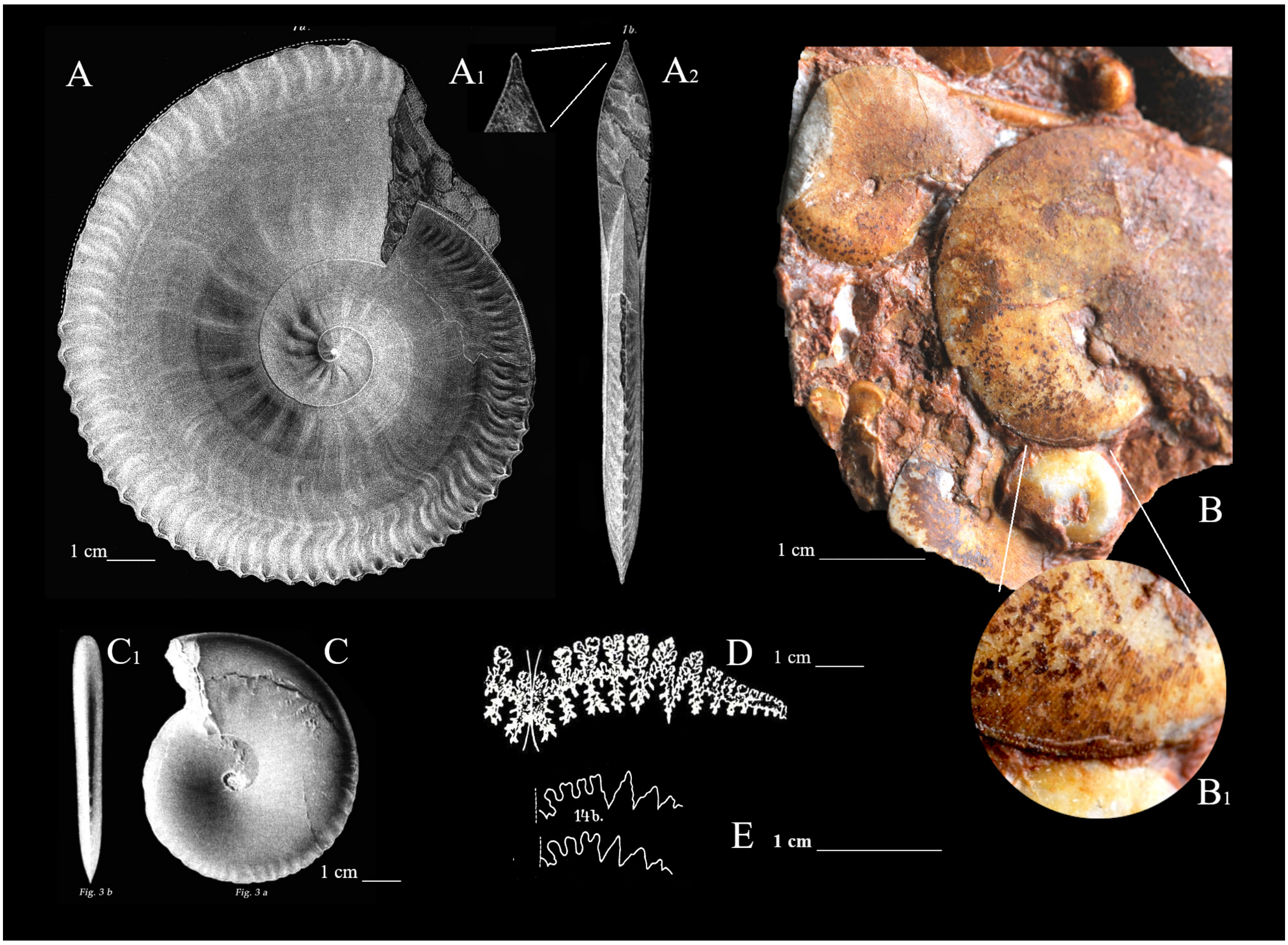

Fig. 4. *Pompeckjites layeri.*

A-A2, *Pompeckjites layeri* (Mojsisovics, 1902: pl. 20, fig. 1), side and venter view. B, *Pompeckjites layeri* from Hallstatt Limestone (*T. aonoides* Zone) of Rappoltstein. B1, enlarged detail of the preserved wrinkle layer. D, suture of *P. layeri* (Hauer, 1847: pl. 9, fig. 3). E, suture of *P. layeri* (Diener, 1915: pl. 2, figs. 14 a, b). C-C1, *P. layeri* (Mojsisovics, 1873: pl. 23, fig. 3) side and venter view.

Description: The early juvenile stage shows an open umbilicus and a rounded venter (Figs. 5, A1, B and C). Then the wide umbilicus narrows quickly, leaving a deep narrow navel. During further growth stages the venter is at first sub to high-trapezoidal rounded and finally develops a broad tabulate venter stage (see Figs. 7, A2, B1 and F1). At this growth stage *Placites urlichsi* resembles *Sageceras* sp. in form and cross-section (see Fig. 9, E1) but shows a totally different suture line. The suture line of *P. urlichsi* shown in Bizzarini, (1987: 51) is comparable with the suture lines of equal sized specimens from Fladung, site 2 in the Hochobir massif. Well preserved flanks of bigger specimens of *P. urlichsi* from the same site show faint growth lines with a distinct bend towards the aperture in the middle of the flank.

Remarks: Our specimens from Fladung, site 2 reach 25 mm in diameter (see Figs. 5, D and 6, D) and show a body chamber of about a half to three quarters of the coiling. Visible sutures were found on a few specimens only. In the Hochobir massif, two morphotypes of *Placites urlichsi* can be recognized. Both variants show the same tabulate venter in sub-mature growth stages. Morphotype 1 (see Figs. 5, A1, A2 and C) is somewhat thinner and shows a sharp high-trapezoidal venter development in juvenile stage at roughly 15 mm in diameter. At this stage, specimens of morphotype 1 (see Fig. 5, A2; Figs. 6, E and 7, E2) are difficult to distinguish with the naked eye from *Pompeckjites layeri* (see Fig. 6, A). In its juvenile stage morphotype 2 develops a thicker, more rounded sub-trapezoidal venter.

Placites urlichsi in Bizzarini (1987: figs. 3a, b) is identical to the same sized specimens of the morphotype 2 from Fladung, site 2. The Figures 2a, b in Bizzarini (1987) are identical to morphotype 1 from Fladung, site 1 a-c. The suture line is identical in both morphotypes. The steinkern of *Pompeckjites philopater* pictured in Bizzarini (2000: pl. 2, fig. 6) from Boa Tamarin is surmised to be a *Placites urlichsi* because on the steinkern the distinct ventro-lateral margins (compare to Fig. 5, A2) of *P. urlichsi* morphotype 1 are visible. From a stratigraphic point of view, the ammonoid fauna of

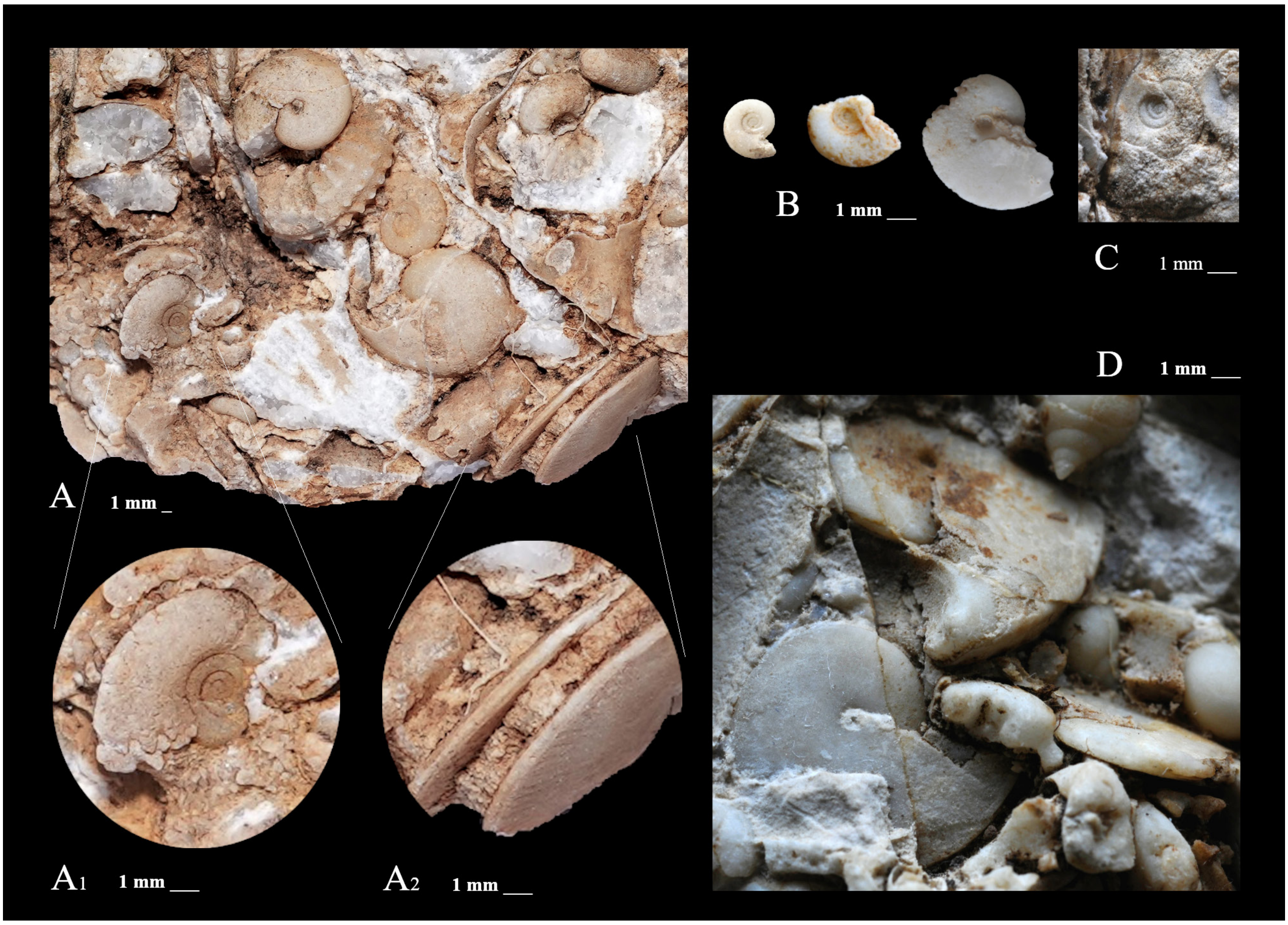

Fig. 5. *Placites urlichsi* from Obir.

A, ammonoid fauna from Fladung site 1c. A1, enlarged juvenile internal mold/steinkern of *P. urlichsi,* (morphotype 1). A2, enlarged venter (steinkern) of *P. urlichsi*, (morphotype 1). B, early juvenile growth stages of *Placites urlichsi* (morphotype 2). C, *Placites urlichsi* (morphotype 1) showing partial shell preservation. D, *Placites urlichsi* (morphotype 2) showing partial shell preservation.

Boa Tamarin in Bizzarini (2000: 22), is thought to be slightly older than the ammonoid fauna of Boa Staolin whence *Placites urlichsi* morphotype 2 occurs. Similar minor age and shape (from slender to thicker specimens) differences are also recognizable at the Hochobir sites. In *P. layeri* a similar development from slender to thicker specimens was observed from the *T. aonoides* Zone towards the *A. austriacum* Zone (see Figs. 7, C and D).

Occurrence: Morphotype 2 (see in Figs. 5, B and D) from Hochobir/Fladung exclusively at site 2 but is very common there. Morphotype 1 (see in Figs. 5, A1, A2 and C) occurs at Fladung, sites 1a, b and c. Unterpetzen/Podpeca and San Cassian Formation.

Arguments to replace *Placites urlichsi* Bizzarini to the genus *Pompeckjites*

The genus *Placites*, (Superfamily Pinacoceratoidea Mojsisovics, 1879, Family Gymnitidae Waagen, 1895) is characterized by its platycone cross-section and its rounded venter. According to (Mojsisovics, 1873) all species of *Placites* are distinguished mainly on their whorl sections and suture lines. Furthermore, all species descriptions of *Placites* in Mojsisovics (1873) were based on sub mature and mature stages of growth.

The type species *Placites platyphyllus* (Mojsisovics, 1873) as the closely related species *Placites polydactylus*, *P. oxyphyllus* and *P. myophorus* show all a closed umbilicus and an external saddle with one strong side branch on the ventral side. Their confirmed age is middle to late Norian. According to Diener (1915b) no real adventitious lobes/saddles occur. The same feature was noted by Spath (1951) who described in *Placites platyphyllus* a simple suture line as in *Gymnites* with an individualized outer branch of the external saddle. Subsequently this similarity to *Gymnites* led to a ranking of *Placites* within the Family Gymnitidae. *Paragymnites* (Hyatt, 1900), whose generic type is *Placites sakuntala* (Mojsisovics, 1896) was established for those species of *Placites* which do not show this strong side branch on the external saddle. *Placites placodes* and *Placites perauctus*, described in Mojsisovics (1873) are, according to

Krystyn and Siblik (1983), of late Carnian (Tuvalian 3) and early Norian (Lacian 1) age. They both differ from other *Placites* sp. and from *Paragymnites* sp. by a highly individualized external saddle and additionally in *P. placodes* by a small open umbilicus.

Based on the above mentioned differences, *Placites urlichsi* has to be compared to the type species *Placites platyphyllus* exclusively.

Already Bizzarini (1987: 45), mentioned the close relationship of his newly established species *Placites urlichsi* to the genus *Pompeckjites* and stated: "The two species described here present characteristics of the external saddle and the suspensory lobe that seem intermediate between the genera *Placites* and *Pompeckjites*". The above mentioned suture line characteristics were well recognized by Bizzarini (1987) in his own findings from the Upper San Cassian formation of Boa Staolin (horizon B, in Bizzarini, 1987) and in the pictured and classified specimens of "*Carnites floridus*" in Leonardi and Polo (1952). Unfortunately, Bizzarini (1987) recognized more analogies to the genus *Placites* than to *Pompeckjites*. The main reason for his supposed similarity to *Placites* was the use of exclusively juvenile specimens showing not fully developed suture lines.

As mentioned above, *Placites platyphyllus* is restricted to the upper Norian stage. This makes a comparison of juvenile suture lines of early Carnian *Placites urlichsi* with sub-mature suture lines of late Norian *Placites platyphyllus* not very realistic. *P. urlichsi* differs from *P. platyphyllus* in its strongly dissolved external saddle, its persistent open umbilicus and its sub-mature tabulate ventral stage.

Based on these differences *Placites urlichsi* is hereby transferred to the genus *Pompeckjites*.

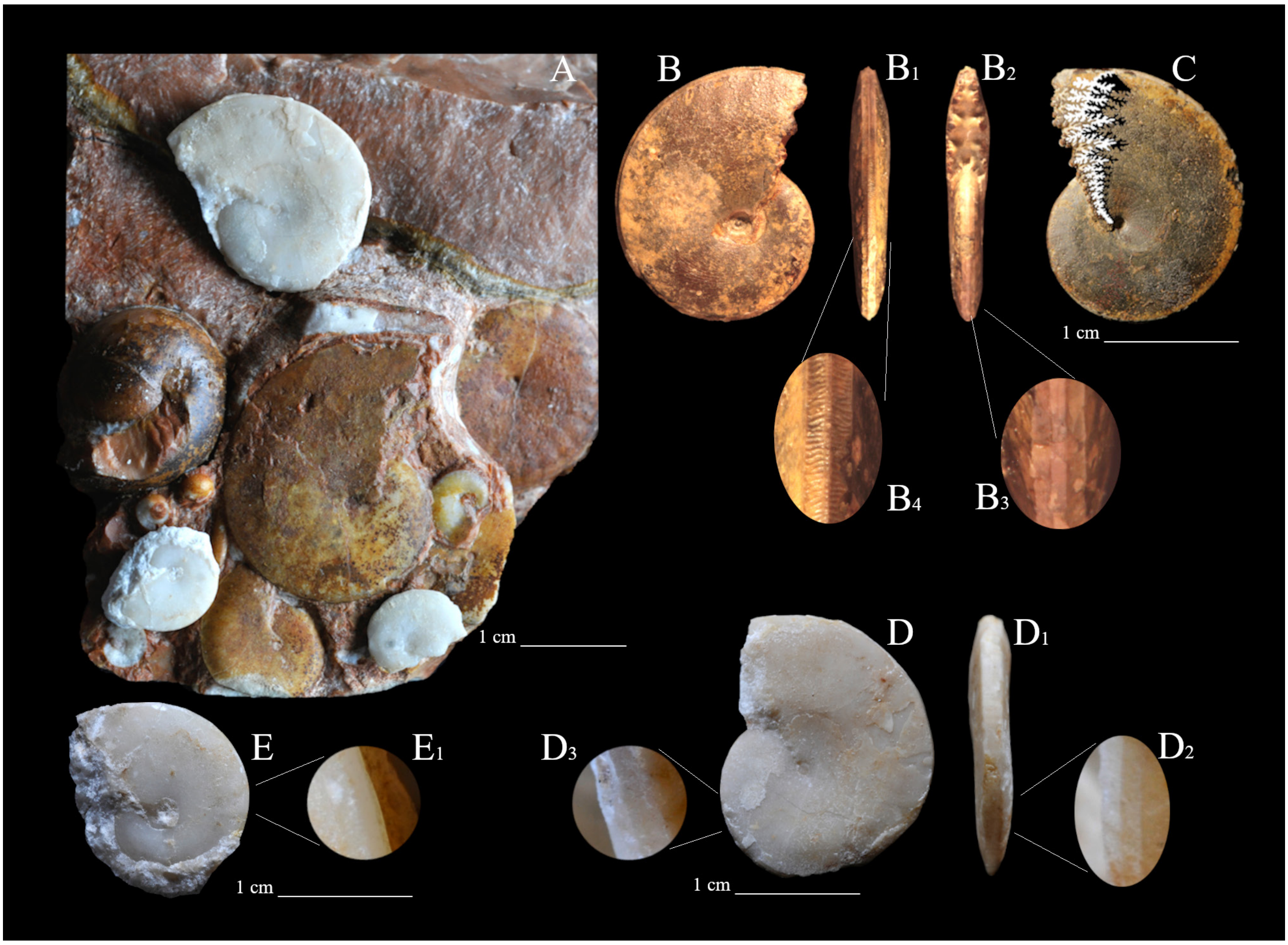

Fig 6. Comparison of *Pompeckjites urlichsi* from Wettersteinkalk to *P. urlichsi* from the upper San Cassian Formation.

A, direct comparison of *Pompeckjites layeri* in red Hallstatt Limestone from Rappoltstein to white specimens of *Pompeckjites urlichsi* (morphotype 1, from Fladung, site 1c). B, phragmocone (showing partial shell) of *Pompeckjites urlichsi* from the upper San Cassian Formation of Boa Staolin. B1 and B2, venter views of ammonoid B, B3 and B4, enlarged details of the trapezoidal venter development. C, backside of ammonoid B with marked suture lines. D, *Pompeckjites urlichsi* showing preserved shell on the body chamber and with parts of shell on the phragmocone. D1 - venter view of ammonoid D. D2 and D3, enlarged venter details (without shell) of ammonoid D. E - small specimen of *P. urlichsi* (morphotype 1, Fladung, site 1c) that is difficult to distinguish from same sized specimens of *P. layeri*. E1, enlarged trapezoidal venter detail of E.

***Pompeckjites urlichsi* (Bizzarini, 1987)**

Type species: The designated holotype and the paratypes of *Placites urlichsi* in Bizzarini, 1987 are hereby accepted as holotype and as paratypes of *Pompeckjites urlichsi* (Bizzarini, 1987).

1987 *Placites urlichsi* Bizzarini, p. 50-52, pl. 1, figs. 1, 2a, b, 3a,b, 6a,b, 7, 8; text figs. 2b, 3; tab. p. 52.

1952 *Carnites floridus* (Wulfen), Leonardi & Polo, pl. 1 figs. 26, 44, 45, 47-49, 55, 57; pl. 2, figs. 39, 40, 41, 42, 43.

2000 *Placites urlichsi* Bizzarini, pl. 3, figs. 3, 4.

We propose the following characteristics to differentiate *Pompeckjites layeri* (Hauer) from *Pompeckjites urlichsi* (Bizzarini). Note that the early juvenile stage (up to 5 mm in diameter) in both species is identical in showing a round venter and an open umbilicus. In further growth both species show an eccentric umbilical ingression towards to a closed or nearly closed umbilicus. After the umbilicus is closed or nearly closed an eccentric umbilical egression evolves in both species.

***Pompeckjites layeri* (Hauer 1847):** Persisting sharp acute venter up to more than 30 mm diameter. Mature sculpture on body chamber is very variable but never showing a tabulate venter. The deeply incised external saddle shows four stems already in juvenile specimens. Large mature size up to 15 cm.

***Pompeckjites urlichsi* (Bizzarini 1987):** A rounded sub to high-trapezoidal ventral stage that persists to roughly 15 mm diameter. In morphotype 1 a distinct tabulate middle keel occurs at this size on steinkerns (Fig. 7, A1; Figs. 8, D, D2). Sometimes this tabulate part of the trapezoidal

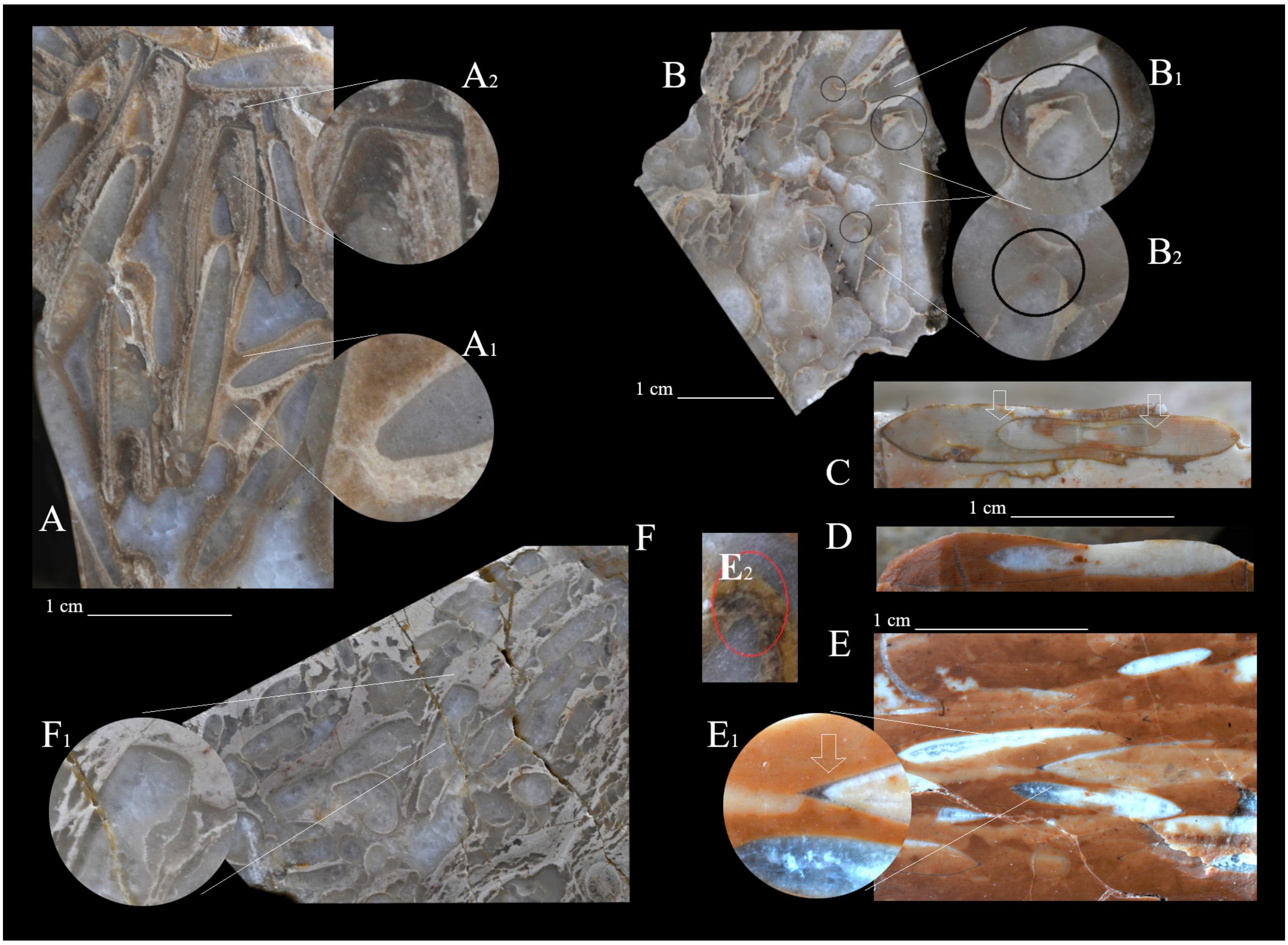

Fig. 7. Differences of *P. urlichsi* to *P. layeri* in transversal and cross-sections.

A, polished hand specimen showing frequent transversal-sections of *Pompeckjites urlichsi,* (morphotype 1, Fladung, site 1c). A1, enlarged trapezoidal venter detail of the internal mold/steinkern. A2, enlarged tabulate venter detail with preserved shell, B, transversal-sections of *P. urlichsi* (morphotype 2) from Fladung, site 2. B1 and B2, enlarged tabulate venter details. C, cross section of *Pompeckjites layeri* from the *A. austriacum* Zone (Hallstatt Limestone of Feuerkogel). D, cross section of *P. layeri* from the *T. aonoides* Zone of Rappoltstein. E, transversal-section with frequent juvenile specimens of *P. layeri* (*T. aonoides* Zone) of Rappoltstein. E1, the white arrow shows the two different venter preservation modes in *P. layeri*. Blunt triangular without shell (preserved in white calcite on the internal side) compared to the acute venter with shell (preserved in darker calcite). E2, shows a comparable venter development on a steinkern of *P. urlichsi* morphotype 1.

venter is very small (Fig. 7, E2). It is more rounded trapezoidal in morphotype 2 steinkerns (Fig. 7, B2) and in specimens of morphotype 1 preserved with shell. After that stage the sub-mature tabulate venter starts to evolve (Figs. 7, A2, B1). The incised external saddle shows three stems in juvenile morphs. The mature size of *P. urlichsi* remains unknown. Specimen found at Hochobir reached a size of 25-30 mm showing a body chamber length of roughly a half to three quarters of a whorl.

Species differentiation of *Pompeckjites urlichsi, Pompeckjites layeri, Sageceras haidingeri* and *Carnites floridus* based on morphology and polished transversal-sections

Morphological similarities between *Pompeckjites urlichsi* (Bizzarini, 1987), *Pinacoceras philopater* (Laube, 1869) and *Pompeckjites layeri* (Hauer, 1847)

The second species treated by Bizzarini (1987), was *Pinacoceras philopater* (Laube, 1869). Bizzarini (1987) tried to examine the type of *P. philopater* (Laube, 1869), together with Mojsisovics' (1882) samples, stored in the GBA (Geologische Bundesanstalt Austria). Unfortunately, the original specimens have not been found. Therefore, we compared our specimens of *P. urlichsi* morphotype 1 from Fladung/Obir exclusively with the specimens of *P. philopater* and *P. urlichsi* pictured in Bizzarini (1987: pl. 1) in regards to their form and suture line. Diener (1915b: 189) does not comment on *Pinacoceras philopater* as to whether it is synonymous to *Pompeckjites layeri*. He just stated that the small specimens are impossible to compare with other Pinacoceratidae at generic level. The same conclusion was reached by Mojsisovics (1882). According to Krystyn (1973: 125, see in faunal list of *T. aon* Zone) *Pinacoceras philopater* is synonymous with *Pompeckjites layeri*. Contrary to this opinion Bizzarini (1987) established *Pompeckjites philopater* as a separate species in *Pompeckjites*. Our own found specimens from Unterpetzen are well comparable to the specimens shown in Bizzarini (1987: pl. 1, figs. 4a, 4b, 5a, 5b). They mainly differ from *P. layeri* in less acute venter development.

Typical for both species are the similar adventitious saddle elements that according to Diener (1915b) evolved from a broadly developed external saddle. In further growth stages these adventitious saddle stems show a bifid ending in both species. The redrawn original suture line of *Pinacoceras philopater* (1869: pl. 41, fig. 10) pictured in Figure 8, C4, does not clearly show the position of the lateral saddle. It is not clear if there are three or four adventitious stems in the external saddle. The amount of suture line elements shown in Laube (1869) is similar to *Pompeckjites layeri*. In contrast the suture line of *Pinacoceras philopater* in Mojsisovics (1882: pl. 52, fig. 12a) show three stems (redrawn in Fig. 8, C2). The pictured suture line of *P. philopater* in Bizzarini (1987: p.49, Fig. 2, A) shows three stems in its external saddle also (redrawn in Fig. 8, C3).

In *Pompeckjites urlichsi* morphotype 1 from Fladung, site 1a-c, the suture line is nearly identical to the suture line of *P. philopater* in Bizzarini (1987: 49). Morphotype 1 of *P. urlichsi* shows a sub to high-trapezoidal juvenile venter and a tabulate sub-mature to mature ventral stage that isn't described in *P. philopater*. In fact, some juvenile specimens of *P. urlichsi* morphotype 1 (see figs. 6, E-E1) can show a very acute venter. Such specimens cannot be distinguished from *Pompeckjites layeri* or *Pinacoceras philopater* with the naked eye. This can mislead to a classification as *Pompeckjites layeri* when the tabulate venter is not evolved, broken off or not visible in the matrix. Under enlargement the venter on the steinkern of *Pompeckjites urlichsi* morphotype 1 is always trapezoidal, though the tabulate part of the trapezoidal venter is sometimes very small (see Fig. 5, A2; Figs. 6, B4, E, E1 and F 7 E2). In *Pompeckjites layeri* the venter is juvenile or sub-mature always acute. The most acute venter in *P. layeri* can be seen in specimens with well-preserved shell (see Fig. 7, E1).

The Figure 8, A shows a fully chambered steinkern of *P. urlichsi* from Boa Staolin, which was incorrectly classified as *Carnites floridus*. The clearly visible suture line is comparable to *P. urlichsi* morphotype 1 from Fladung/Obir. Figure 8, A1 show remains (white arrows) of an eccentric umbilicus in further growth like in *Pompeckjites layeri*. Here, *P. urlichsi* shows a body chamber length from a half to three quarters of a whorl which is similar to *P. layeri*. D and D1, (with small part of shell) in figure 8, show the ventral development in *Pompeckjites urlichsi*, morphotype 1 that differs clearly from *Pompeckjites layeri*. The wavy band (distinctly visible on the steinkern, less distinctly visible in shell preservation) on both sides of the venter show reminiscence to the sculpture of large mature specimens of *P. layeri* from the Hallstatt Limestone where a similar, broader wavy sculpture occurs on the ventral flanks (see Fig. 4, A). The enlarged cross-section of *P. layeri* in Fig. 7, E1 shows a blunt triangular internal venter development preserved in white calcite (see white arrow). This feature can create distinct ventro-lateral margins on steinkerns. Since similar ventro-lateral

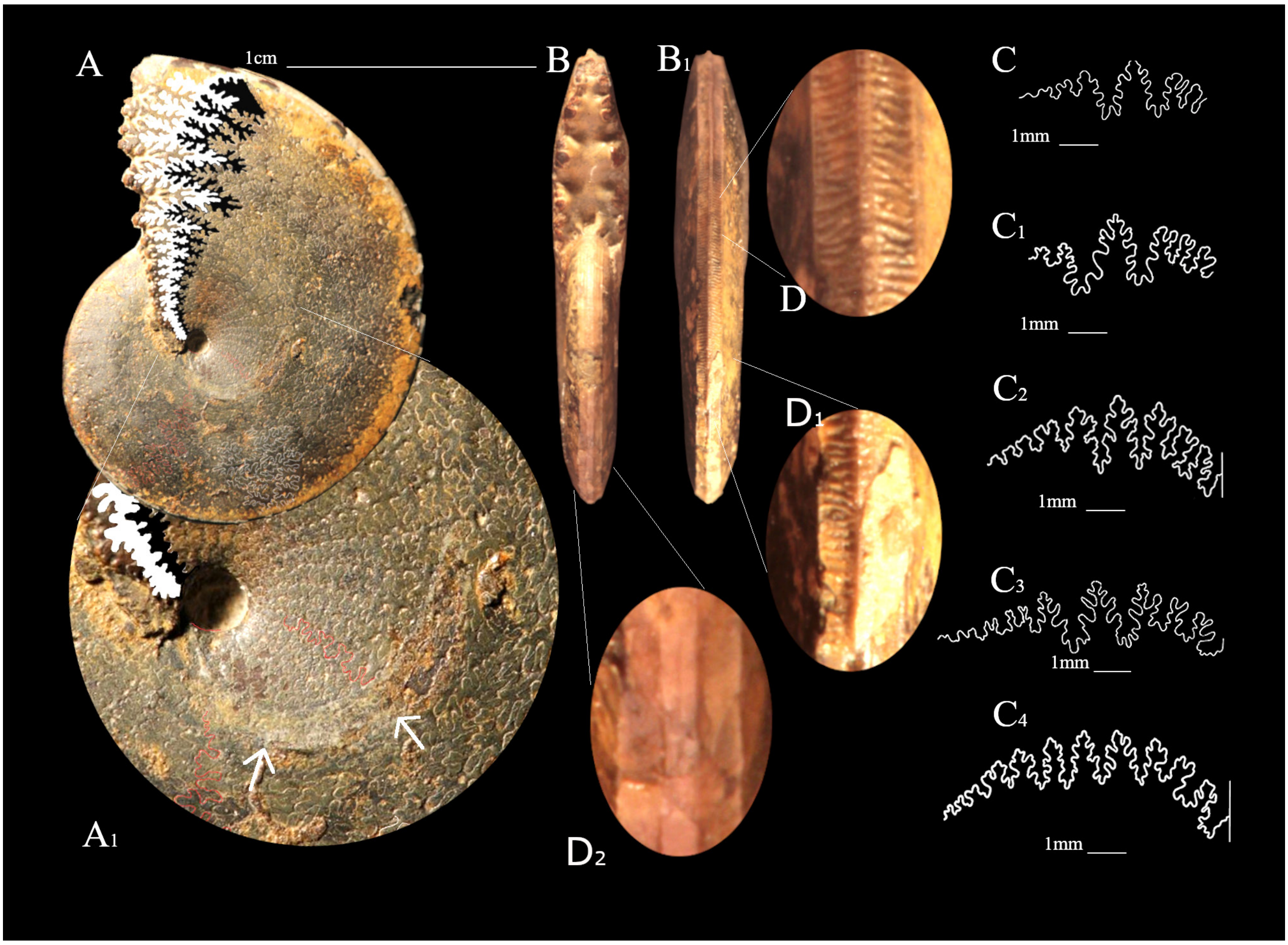

Fig. 8. *Pompeckjites urlichsi* from the San Cassian Formation.

A, interal mold/steinkern of *Pompeckjites urlichsi* from Boa Staolin (coll. Alberto Rubini). A1, reminiscence of an eccentric umbilicus (white arrows) in further growth of *P. urlichsi*. B-B1, venter views of ammonoid A. C-C1, suture of *"Placites" urlichsi* in Bizzarini (1987: p. 51, fig. 3, D and E). C2, redrawn suture of *"Pinacoceras" philopater* (Laube), in Mojsisovics (1882: pl. 52, fig. 12a). C3, suture of *Pompeckjites philopater* (Laube) in Bizzarini (1987: p. 49, fig. 2, A). C4, redrawn suture of *"Ammonites" philopater* Laube, 1869: pl. 41, fig. 10. D, enlarged detail of the wavy bands beside the small tabulate keel. D1, small part of shell that indicates a more rounded trapezoidal venter in specimens preserved with shell.

margins occur on steinkerns of *P. urlichsi* morphotype 1 too (see Figs. 5, A2 and 7, E2) this also may point at a common ancestor of *P. urlichsi* and *P. layeri*.

Morphological similarities between *Pompeckjites urlichsi* (Bizzarini, 1987), *Carnites floridus* (Wulfen, 1793) and *Sageceras* sp.

Diener (1915b) described in *Carnites floridus* a development of the adventitious elements from the external lobe, precisely from the ascending part of the external lobe to the median saddle (see black circles in Figs. 3, C-C5). *Pompeckjites* shows, according to Diener (1915b) no real adventitious elements. It shows a broadly created, deeply incised external saddle instead. The fundamental differences in *Carnites* and *Pompeckjites* are that the adventitious elements evolves in *Carnites* on the ventral side of the external lobus and in *Pompeckjites* on the ventral side of the external saddle.

Species differentiation of *P. urlichsi* from *C. floridus* and *Sageceras* sp.

The bifid stem endings in the adventitious external saddle elements of *Pompeckjites urlichsi* originate from a stronger growth of one side branch of former juvenile pyramidal stems. In *C. floridus* this bifid split of the saddle elements does not exist. In very small specimens of *P. urlichsi*, before this bifid growth feature takes place, the suture line of *P. urlichsi* is similar to the suture line of *Carnites floridus*. That may hint at a common ancestor of *Carnites* and *Pompeckjites*. The trapezoidal venter development in *P. urlichsi* may point in this direction too. But these similarities may be just homeomorphic features too. Therefore, it is not surprising that subsequent authors (Leonardi & Polo, 1952,) often assigned small specimens of *P. urlichsi* to *C. floridus*.

Both morphotypes of *Pompeckjites urlichsi* show in the sub-mature growth stage a tabulate venter which makes them look homeomorphic

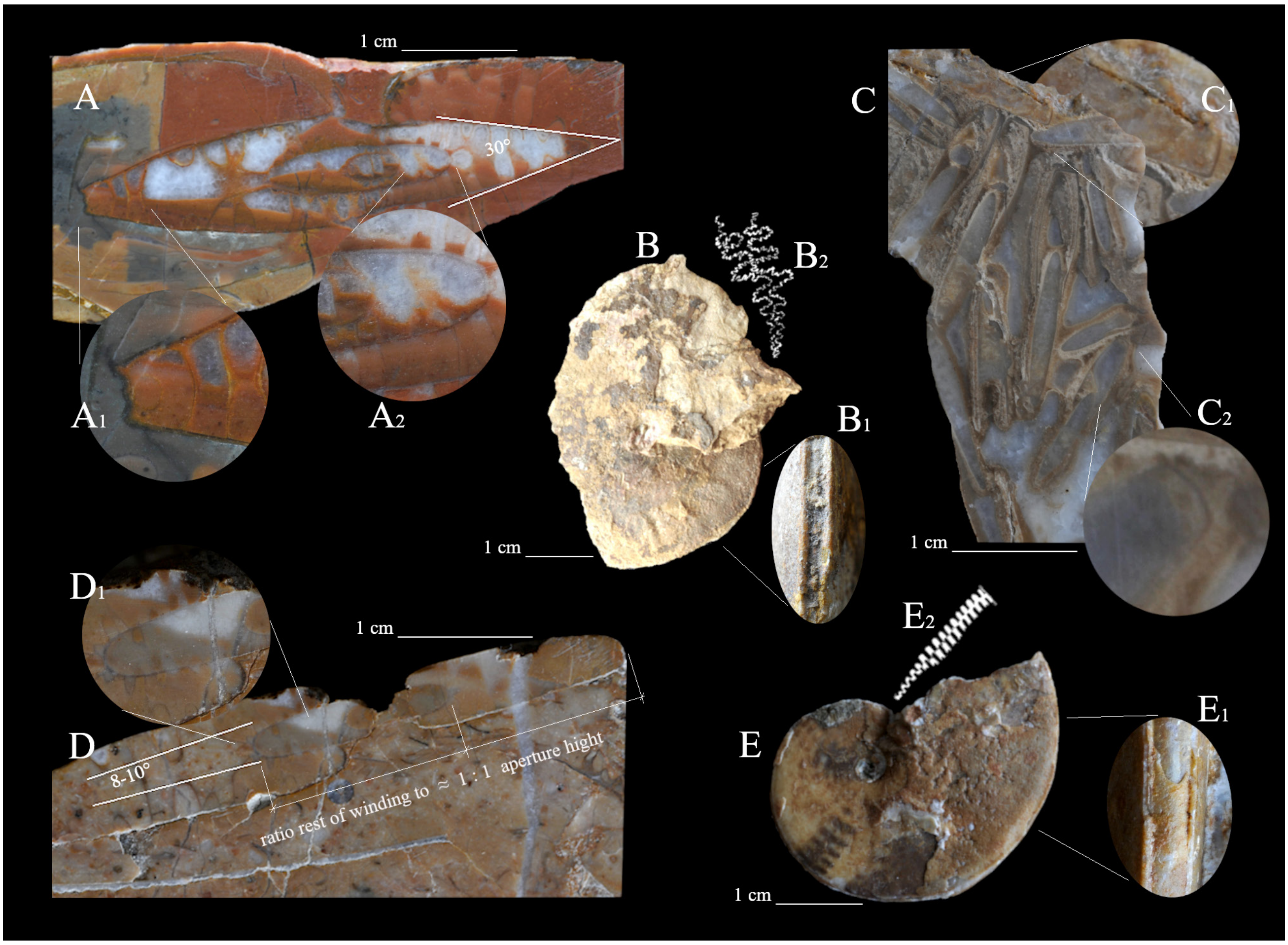

Fig. 9. Species differentiation of *P. urlichsi* from *C. floridus* and *Sageceras* sp.

A, polished cross-section of *Carnites floridus* from Hallstatt Limestone of Rappoltstein. A1 and A2, enlarged development of the tricarinate venter. B, *C. floridus* from Rappoltstein. B1, view of the tricarinate venter. B2, suture line of *C. floridus* in Mojsisovics (1873: pl. 25, fig. 4). C, transversal-sections of numerous *Pompeckjites urlichsi* (morphotype 1) from Fladung/Obir. C1 and C2, enlarged tabulate venter development of *P. urlichsi*. E, *Sageceras haidingeri* from the *T. aonoides* Zone of Rappoltstein. E1, venter of *Sageceras* sp., E2, suture line of *Sageceras*. D, cross-section of *Sageceras* sp. from Hallstatt Limestone of Rappoltstein with outlined flank angle and ratio of aperture height to the rest of the winding. D1, enlarged detail of the juvenile venter.

to *Sageceras* sp. (see Figs. 7, A2; 9 C1, E1). In cross-sections, *P. urlichsi* can be distinguished from *Sageceras* sp. by the different developments of the juvenile whorls (see Fig. 7, A1 compared to Fig. 9, D1). The height of the shell aperture is a helpful distinguishing feature in cross-sections too. *Sageceras* sp. shows roughly a proportion of 1:1 in the ratio of aperture height to the rest of the whorl (see Fig. 9 D). In *Carnites floridus* and *P. urlichsi* the ratio of aperture height to the rest of the whorl is closer to 1:2.

Juvenile whorls of *Sageceras* sp. and *Carnites floridus* are very similar in polished transversal-sections. The flatter angle of the flank is in *Sageceras* sp. (see in Fig. 9, D,) during growth relatively constant at 8-10°, whereas in *C. floridus* (see Fig. 9, A) the angle increases up to 30°. Both in figures. 9, A-A2 and B-B1, shown *C. floridus* originate from Hallstatt Limestone of Rappoltstein (Hornung et. al 2007) and were found together with a sparse *A. austriacum* Zone ammonoid fauna with *Neoprotrachyceras thous* and *Austrotrachyceras* sp.

If the suture lines can be checked, a confusion of *Sageceras* sp. with *Carnites floridus* or *Pompeckjites* sp. can be excluded.

Stratigraphic conclusions

Our data suggest that *Carnites floridus* Hauer is restricted to the first strong pulse of the CPE (Carnian Pluvial Episode) at the border *T. aonoides* Zone to *A. austriacum* Zone (for further literature regarding to the CPE we refer to the reference lists of Dal Corso et al. 2018; Hornung et al. 2007; Mueller et al. 2016 and Preto et al. 2019). An early Julian *T. aon* Zone age or an early Tuvalian *Tropites dilleri* Zone age of true *C. floridus* can be excluded. Based on true *Carnites floridus* the first Raibl shale horizon on Hochobir can be correlated with the beginning of the *A. austriacum* Zone. This is evidenced in the Hallstatt Limestone of Rappoltstein where *Carnites floridus*, *Neoprotrachyceras thous* and *Austrotrachyceras* sp. were found (Hornung et al. 2007) and in the Reingraben shales of Austria where *Carnites floridus* was referred to the *A. austriacum* Zone in Lukeneder & Lukeneder (2022). Therefore, the underlying Bleiberger Sonderfazies (Holler 1960) with *Pompeckjites urlichsi* can indirectly be correlated with the upper *T. aonoides* Zone. A correct species recognition of *P. urlichsi*, allows a direct correlation of some parts/layers of the Upper San Cassian Formation with layers of the Bleiberger Sonderfazies (upper Wettersteinkalk). Minor morphologic differences in juvenile whorls of *P. urlichsi* further allow for a differentiation in a morphotype 1 and a slightly younger morphotype 2.

Furthermore, the onset of the *A. austriacum* Zone can be fixed with true *C. floridus* in strata where *Austrotrachyceras* sp., was not found. *Pompeckjites urlichsi* in contrast allows for a fixing of the upper *T. aonoides* Zone in strata where *Trachyceras* s. str. was not found or is missing.

Discussion

A transitional ammonoid fauna spanning the period from the *T. aonoides* to the *A. austriacum* ammonoid Zones is not adequately described at present. From an evolutionary view such a fauna should exist. *Pompeckjites urlichsi* (Bizzarini) seems to be an appropriate ammonoid species showing a close stratigraphic range that may fit as an index ammonoid to close this gap. It may be of future importance for a finer stratigraphic correlation between the basinal facies of the upper San Cassian Formation and the coeval algal rhytmites of the upper Wettersteinkalk. Within the condensed pelagic deposits of the Hallstatt Limestone *P. urlichsi* has not been found so far. This might have its origin in a collecting hiatus, in a confusion with small specimens of *Pompeckjites layeri* or *Carnites floridus* or in the possibility of a habitat restriction to the reef fronts and their directly adjacent basins. The above mentioned close morphologic similarity of *P. urlichsi* to small *Carnites floridus* raises some doubts on *Carnites floridus* classifications from the upper *T. aonoides* Zone of the Rio del Lago Formation (Preto et al. 2005). Such small *C. floridus* are surmised to be *Pompeckjites urlichsi* (Bizzarini) and thus may need further revision.

According to Krystyn (1978) *Pompeckjites layeri* spans the entire Julian stage and *Pinacoceras philopater* is thought to be synonymous (Krystyn 1973: 125, see in faunal list of *T. aon* Zone). Contrary to that opinion, Bizzarini (1987) established *Pompeckjites philopater* as a separate *Pompeckjites* species. Here we classify all *Pompeckjites* species that show a sub-mature tabulate venter as *Pompeckjites urlichsi*. The transfer from *Placites* to *Pompeckjites* in *P. urlichsi* is based on the similar sutureline, the similar juvenile venter development and the similar eccentric umbilical egression compared with *Pompeckjites layeri*. Especially juvenile specimens of *Pompeckjites urlichsi* morphotype 1 show a close similarity to *Pompeckjites layeri*. *Pompeckjites philopater* as pictured in Bizzarini (1987) is intermediate in shape between *P. layeri* and juvenile *P. urlichsi* morphotype 1 before evolving the tabulate venter. Juvenile specimens of *P. urlichsi* morphotype 2 do show some similarity in shape and suture line to *Pinacoplacites* Diener, 1916. A presumed evolutionary connection of Julian *Pompeckjites urlichsi* to upper Tuvalian *Pinacoplacites* sp. may exist via *"Placites" placodes* but it is not confirmed at present. Further research to this assumption was hindered by lacking data.

Acknowledgements

We sincerely thank the UNESCO Geopark Karawanken/Karavanke (A/Slo) for the permission to carry out fieldwork and research in its area, Matija Križnar (Slovenian Museum of Natural History, Ljubljana) and Ivan Ocepek (Mežica), for the possibility to visit the historical mining area Unterpetzen/Podpeca (Slovenia), Peter Englmaier, ECONSULT expert consultancy, Vienna and University of Vienna, for the help in the fieldwork, writing and literature search, Alberto Rubini (Italy) for the pictures of the ammonoid from Boa Staolin on Figures. 6 B-C, 8 A-D, Roger Furze (Germany), Heidi Henderson and Karen Lund (Vancouver/Canada) for their help to improve our English.

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