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STRATIGRAPHIC IMPLICATIONS OF A NEW LOWER CRETACEOUS AMMONOID FAUNA FROM THE PUEZ AREA (VALANGINIAN – APTIAN, DOLOMITES, SOUTHERN ALPS, ITALY)

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With 6 figures and 8 plates

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Abstract

Lower Cretaceous ammonoids (n = 424) were collected at the Puez locality in the Dolomites of Southern Tyrol. The cephalopod fauna from the marly limestones to marls here indicates Late Valanginian to Early Aptian age. The deposition of the marly limestones and marls of this interval occurred during depositionally unstable conditions. The underlying Biancone Formation (Maiolica Formation) is of Early Valanginian, whereas the lowermost Rosso Ammonitico is of Jurassic to Berriasian age.

The ammonoid fauna consists of 27 different genera, each represented by 1-2 species. The assemblage at the Puez section is dominated by the Phylloceratina (30%) and the Ammonitina (34%). *Phyllopachyceras* (17%) and *Phylloceras* (13%) (both Phylloceratina) are the most frequent components, followed by *Lytoceras* (12%) (Lytoceratina), and *Barremites* (10%) and *Melchiorites* (8%) (both Ammonitina). The cephalopod fauna is purely of Mediterranean origin.

Zusammenfassung

Unterkreide Ammonoideen (424 Exemplare) der Puez Lokalität in den Dolomiten Süd-Tirols wurden untersucht. Die Fauna der mergeligen Kalke und Mergel von Puez zeigen ein Alter von Ober-Valanginium bis Unter-Aptium an. Die mergeligen Kalke und Mergel dieses Abschnitts lagerten sich unter instabiler Bedingungen ab. Die unterlagernde Biancone Formation (Maiolica Formation) zeigt Unter-Valanginium an, wogegen die tiefste Formation des Rosso Ammonitico auf Ober-Jura bis Berriasium hindeutet.

Die Ammonoideen Fauna besteht aus 27 unterschiedliche Gattungen, von denen jede durch 1-2 Arten vertreten ist. Das Vorkommen vom Puez Gebiet wird von den Phylloceratina (30%) und den Ammonitina (34%) dominiert. *Phyllopachyceras* (17%) und *Phylloceras* (13%) (beide Phylloceratina) sind die häufigsten Komponenten, gefolgt von *Lytoceras* (12%) (Lytoceratina), und *Barremites* (10%) und *Melchiorites* (8%) (beide Ammonitina). Die Cephalopodenfauna setzt sich ausschließlich aus Mediterranen Elementen zusammen.

1. Introduction

Cretaceous pelagic sediments cover wide areas in various European areas (e.g., NCA - Northern Calcareous Alps, Vocontian Trough, Southern Alps/Dolomites, Umbria-Apennines, Western Carpathians, Gerecse and Mecsek Mountains and others).

Lower Cretaceous deposits form a major element of the Southern Alps and especially of the Dolomites (Baccelle and Lucchi-Garavello 1967a, b; Costamoling and Costamoling 1994; Haug, 1887, 1889; Hoernes, 1876; Uhlig, 1887; Rodighiero, 1919; Stöhr, 1993, 1994). The geology of the Dolomites and adjacent areas has been described and summarized in detail by Bosellini (1998), Bosellini *et al.* (2003), Geyer (1993), Heissel (1982) and Pozzi (1993).

In the Dolomites, Lower Cretaceous cephalopod-bearing deposits are mainly recorded from two different facies, the Biancone Formation (calcareous limestones, = Maiolica Formation) and the overlying Puez Formation (marls-marly limestones).

The Lower Cretaceous relics are situated on the Triassic carbonates of the Dolomites (Hauptdolomit, up to 1000 m thick). At most of the localities where we found Lower Cretaceous sediments in the Dolomites, we also observed a relatively thin red nodular limestone of the Rosso Ammonitico Formation (10–20 m) between the Triassic and Lower Cretaceous. The Triassic-Jurassic succession is overlain by relic areas formed of Lower Cretaceous sediments. This "volcanic-conus"-like formation is especially evident on the Puez-Odle-Gardenaccia plateau (= Gherdenacia). Well known are the Col de la Soné (2633 m) and Muntejela (2666 m). The Piz de Puez (Puez Spitzen, 2846 m) together with the Col Puez (Puezkofel, 2725 m) form the major Lower Cretaceous wall starting at about 2400 m above sea level. Other well-known Lower Cretaceous localities in this area are Piz Boè (Sella Group), the plateaus of the area around Ampezzo (Rote Wand, Fosses, Fanes) and near Cortina d'Ampezzo at Ra Stua (= La Stua) and Antruilles.

The section studied is located in the Southern Alps (Dolomites) of northern Italy. The stratigraphy of the Lower Cretaceous sediments here is based on ammonoids. During the late 19th and early 20th century, a rich fauna of cephalopods was collected from Lower Cretaceous sediments from this area and determined by Haug (1887, 1889), Hoernes (1876), Uhlig (1887) and Rodighiero (1919). After this phase of stagnancy in Lower Cretaceous papers, small scaled ammonoid faunas were described from different localities near the Puez area, e.g. from Ra Stua (La Stua) by Baccelle and Lucchi-Garavello (1967a, b) and Stöhr (1993, 1994). No paper, however, dealt with the fauna from the Puez locality itself. Faraoni *et al.* (1996) reviewed the papers published on Cretaceous ammonoids of the Maiolica Formation from the Venetian Alps (Venetia), which directly adjoin to the south. An additional paper was published the following year by Baudin *et al.* (1997) dealing with a comparable ammonoid fauna (Hauterivian) of the Lessini Mountains and the southern Trento Plateau.

The cephalopod fauna presented herein was collected in marly limestones and marls of the Puez Formation. The main goal is to present a more appropriate and modern stratigraphy of Lower Cretaceous sequences from the Puez area referring to the ammonoid fauna. We update the ammonoid drawings in the scarce and old literature from the Puez area with new and better illustrations (photographs) combined with an improved stratigraphy of the well-preserved ammonoid fauna from this locality.

2. Geographical setting

The ammonoids described herein were collected from huge outcrops located at the southern margin of the Puez Plateau. They are located within the area of the Puez-Odle-Geisler natural park in the northern part of the Dolomites (Trentino – Alto Adige; South Tyrol). The Dolomites (Permian to Cretaceous) are an internal part of the Southern Alps. The exact position is about 30 km northeast of Bolzano (Bozen) (Fig. 1). The locality is accessible from the village Wolkenstein (1560 m) in the Val Gardena (Grödner Tal) by following the Val Lunga (Langental) to its eastern end and then hiking on path 16 up the steep dolomite wall. The outcrops are located near the Rifugia Puez (Puez Hütte, 2475 m). The Lower Cretaceous crops out running between the Col da la Pieres 2747 m) at the west flank and the Col de Puez (2725 m) at the eastern border (Fig. 2).

The grey, green to red succession, comprising the ammonoid-bearing beds, is located on the southern side of the Piz de Puez (2846, 1:25 000, sheet 05 Val Gardena). The section is well exposed on the steep flanks. 2700 m high mountains and steep terrain made sampling very difficult.

3. Geological setting

The Southern Alps are a Northern Italian chain that emerged during the deformation of the passive continental margin of the Adriatic (Bosselini *et al.*, 2002). The geological landscape of the Puez region is dominated by the giant Triassic carbonate plat-

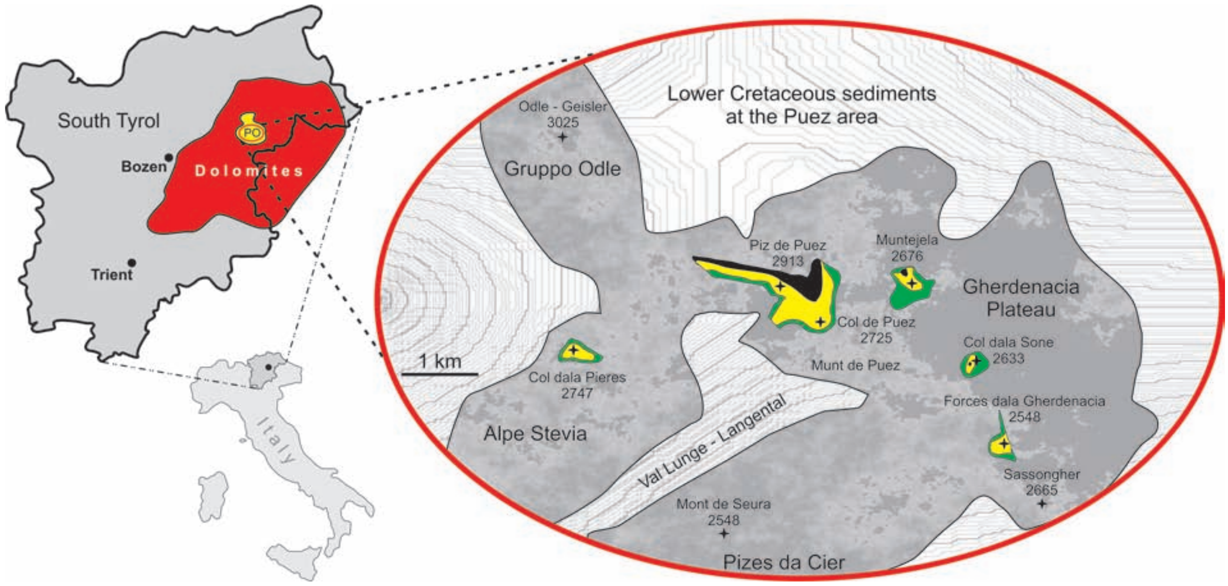


Fig. 1: Map of Italy with included locality map of South Tyrol showing the outcrop of Lower Cretaceous sediments (ellipse: grey shaded - carbonate platforms (plateaus), yellow - Puez Formation; green – Biancone Formation) around the Puez section investigated within the Dolomites. PO Puez-Odle natural park.

forms. The top of these carbonates bears relics of Lower Cretaceous sediments which were formerly much more widespread but have been eroded through time. The Lower Cretaceous sediments here are overthrusted ("Gipfelüberschiebung") by older Triassic Haupdolomit. This phenomenon can only be observed at the Puez-Gardenazza and Sella areas located directly to the south (Heissel, 1982). The thickness of the overthrusting Dolomite differs markedly at different localities (Col Pieres 0 m; Col Puez 120-150 m, Muntejela 0-10 m). Upper Jurassic (Kimmeridgian-Tithonian) to lowermost Cretaceous (Berriasian) Rosso Ammonitico (A.R. Superiore) limestone is overlain by the Lower Cretaceous Biancone Formation and Puez Formation (Valanginian-Aptian). Due to the bad outcrop situation of the lowermost part of the Puez section, Rosso Ammonitico is not observable there, but most probably present (Fig. 3, log idealized).

Biancone is the local name for the more broadly known Italian Maiolica Formation (Faraoni *et al.*, 1996; Wieczorek, 1988). The succession at the Puez area is very similar to the one of La Stua, which also shows Rosso Ammonitico, Biancone, "Ammonitenmergel", grey marls and Aptian marls (Stöhr, 1993). This sequence shows the evolution of the northernmost part of the Trento Plateau at this time. The Trento Plateau reaches from the south (around Trento) up to the Puez region and was formerly sur-

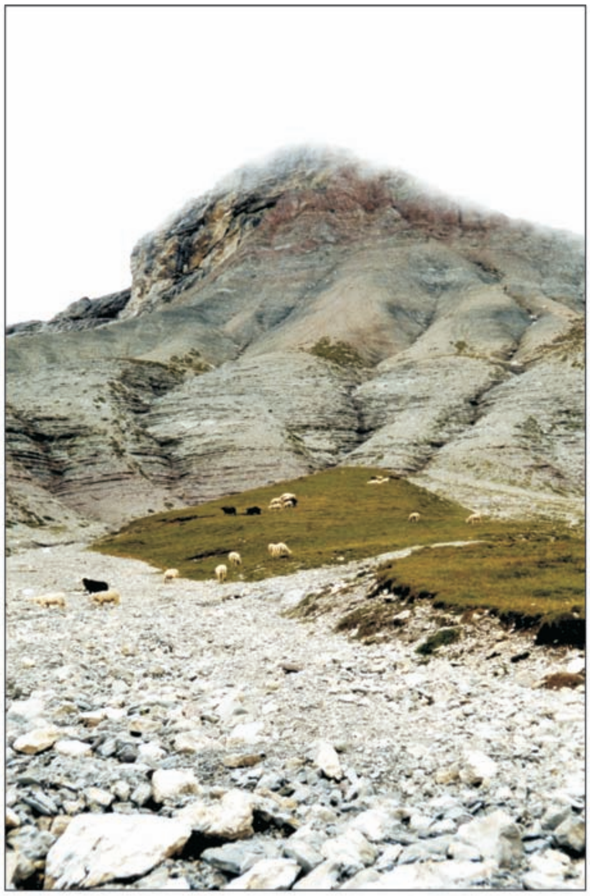


Fig. 2: Exposure of the Puez Formation and outcrop situation around the Piz de Puez and Col de Puez.

rounded by two basins: the Lombardian Basin to the west and the Belluno Basin to the east (Bosselini *et al.*, 1981). The reason for the Upper Jurassic to Lower Cretaceous separation into a basin-plateau-basin succession lies in the rifting history of the Piemonte-Ligurian Tethys Ocean (Penninic Ocean) (Mayer and Appel, 1999).

4. Lithology

The Puez section consists essentially of red to grey calcareous marls and grey, silty marlstones of the Puez Formation (150–200 m) accompanied by "real" green-grey calcareous limestones of the Biancone Formation and red nodular limestones of the Rosso Ammonitico. A very unique feature of the middle section of the Puez Formation is the numerous cherty and calcareous concretions (Fig. 3). They appear in different shapes but pear-shaped forms up to 20 centimetres in height dominate. Here, we refer to the whole sequence of Lower Cretaceous marly limestones and marls as the Puez Formation (Puez marls plus limestones) and not Biancone Formation. The Biancone Formation as traditionally defined (pelagic nannofossil limestone) occurs only at the lowermost part of the section. The outcrops are generally exposed on steep walls up to the Piz de Puez (Puezspitzen) and Col de Puez (Puezkofel). $CaCO_3$ (calcium carbonate contents, equivalents calculated from total inorganic carbon) displays values between 30 and 85 %.

The following microfacies types occur: radiolarian-wackestone (lowermost part), biogenic-rich mudstone and radiolarian wackestone (lower middle part), biogenic-rich radiolarian mudstone and radiolarian wackestone (upper middle part), mudstones (uppermost marly part).

Radiolarians, ostracods, echinoderms, sponge spiculae, brachiopods, and foraminifera are the most prominent constituents of the microfauna.

5. Material and methods

The material (Plates 1-8) originates from the Puez locality (Dolomites). Localities Puez, Col de Puez and Piz de Puez are considered to be the same locality complex. Most of the material was collected by Christian Aspmair for a project on the "Puez marls" for the South Tyrol Museum of Natural Sciences (from 1999-2003), by different collectors (A. Heinrich and others) for the Natural History Museum in Vienna (from 1883-1915) and by Alexander Lukeneder (2003).

Unfortunately, the specimens collected by private collectors or scientists (one hundred years ago) are from rock samples and not from bed by bed sampling. The authors can therefore only summarize the species now in the collections and cannot provide details on which bed the single specimens are from.

Conventions: NHMW Natural History Museum Vienna (Naturhistorisches Museum Wien; 2005 numbers), NMB South Tyrol Museum of Natural Sciences (Natur-Museum Bozen; PZO numbers). All specimens are stored either at the NHMW (n = 201) or in the collections of the NMB (n = 223). All specimens in Plates 1 - 8 were coated with ammonium chloride before photographing. The brachiopod systematics is in accordance with Sulser (1999). The authors follow the basic classification of Cretaceous Ammonoidea by Wright *et al.* (1996). The detailed ammonoid systematics was adopted and correlated with papers of Autran (1993), Avram (1994), Baudin *et al.* (1997), Bogdanova and Hoedaemaeker (2004), Cecca and Pallini (1994), Cecca *et al.* (1998), Company (1987), Company *et al.* (2003), Delanoy (1992, 1994, 1997), Dimitrova (1967), Fülöp (1964), Faraoni *et al.* (1995, 1996), Hoedemaeker (1994), Immel (1979, 1987), Kakabadze and Hoedemaeker (2004), Houša and Vašíček (2004), Klein (2005), Baccele and Lucchi-Garavello (1967a, 1967b), Lukeneder (2003a, b, 2004a, b, c), Reboulet (1995), Stöhr (1993), Thieuloy (1964), Uhlig (1883), Vašíček (2005), Vašíček *et al.* (1994), Vermeulen (2002), and Wippich (2001, 2003). Only papers with photographed specimens were taken into account to ensure correct determination of the ammonoid species.

Ammonoids represent almost the totality of the macrofauna (85%); they are well preserved (mostly in concretions) and appear as steinkerns without shell. Some specimens show suture lines.

During the course of this study, 424 ammonoid specimens, 6 nautiloids,10 lamellaptychi, 6 belemnites, 26 sea urchins (Disasteroida – Collyritidae), 12 bivalves, 21 brachiopods (*Pygope* and *Triangope*) and a huge number of encrusting

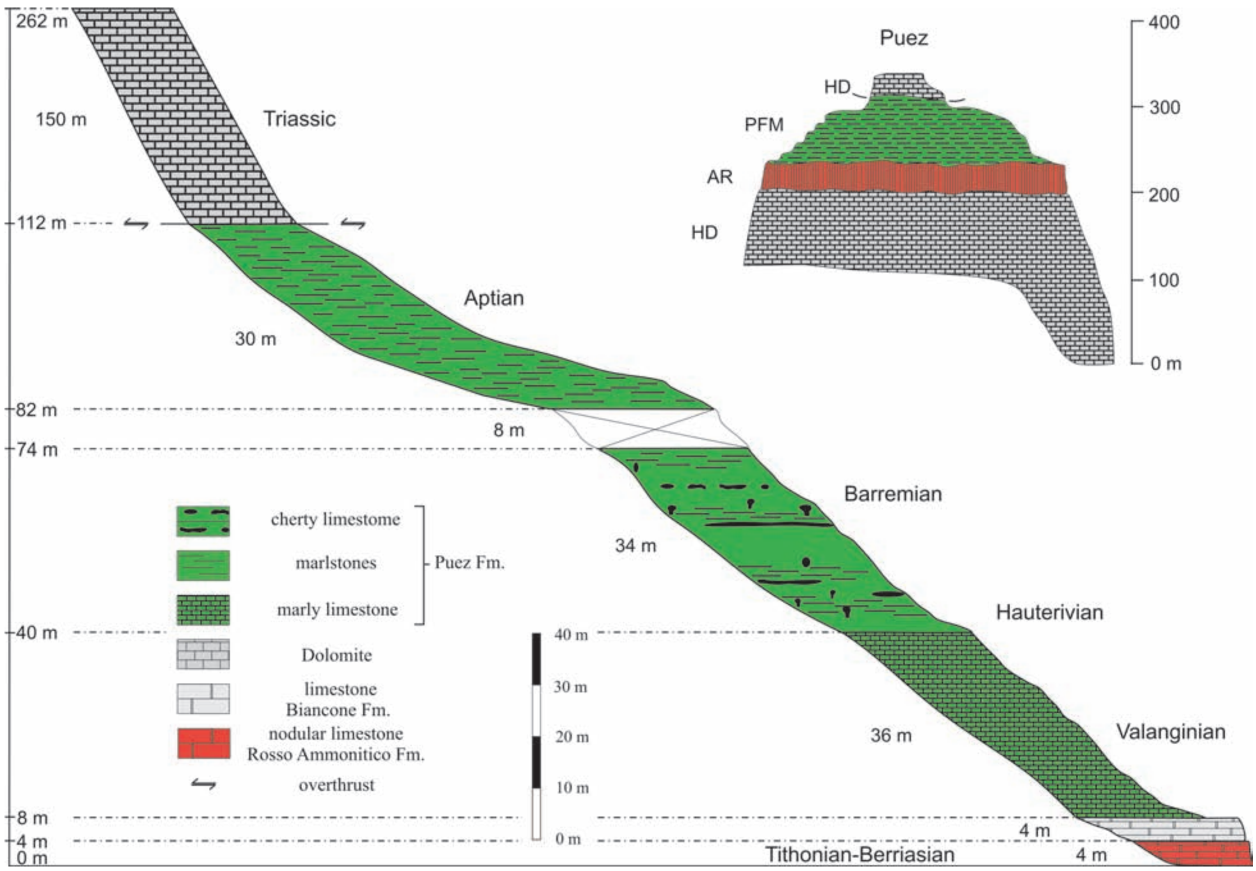


Fig. 3: Log of the Puez section with indicated age and thickness of the different members. In the right upper corner the overthrusting by Triassic Hauptdolomit is indicated. HD Haupdolomit, PFM Puez Formation, AR Ammonitico Rosso. Lower part (Ammonitico Rosso) is idealized because of bad outcrop situation.

species (serpulids and corals, Lukeneder in prep.) were examined.

The very abundant and generally well-preserved Lower Valanginian to Lower Aptian assemblage consists of 27 genera: from phylloceratids *Phylloceras*, *Phyllopachyceras*, from lytoceratids *Lytoceras*, *Eulytoceras*, *Protetragonites*, *Leptotetragonites*; from ammonitids *Neolissoceras*, *Barremites*, *Melchiorites*, *Abrytusites*, *Neocomites*, *Criosarasinella*, *Kilianella*, *Olcostephanus*, *Silesites*, *Jeanthieuloyites*, *Heinzia*, *Discoidellia*, *Acanthodiscus* and from the ancyloceratids *Pseudothurmannia*, *Macroscaphites*, *Dissimilites*, *Acrioceras*, *Crioceratites*, *Anahamulina*, *Hamulina*, *Ancyloceras*.

Calcium carbonate contents ($CaCO_3$) were determined using the carbonate bomb technique. Total carbon content was determined using a LECO WR-12 analyser. All the chemical analyses were carried out in the laboratories of the Department of Geology and the Department of Forest Ecology at the University of Vienna. Thin sections (37) were made to show the microfacies changes in the log.

6. Fauna

The extraordinarily rich invertebrate fauna consists of ammonoids, ammonoid jaws (aptychi), coleoids, bivalves, brachiopods, serpulids, sea urchins, ophiurids, corals, benthic/planktonic foraminifera and radiolarians. The benthic macrofossils observed in the ammonoid beds comprise bivalves, brachiopods and, surprisingly, corals (Lukeneder, in prep.). As far as genera are concerned, abundant and generally well-preserved cephalopods are dominated by *Phyllopachyceras* (17 %) (Fig. 4). The fairly fossiliferous parts of the section show remarkable abundances, contrasting with parts that are almost barren of macrofossils.

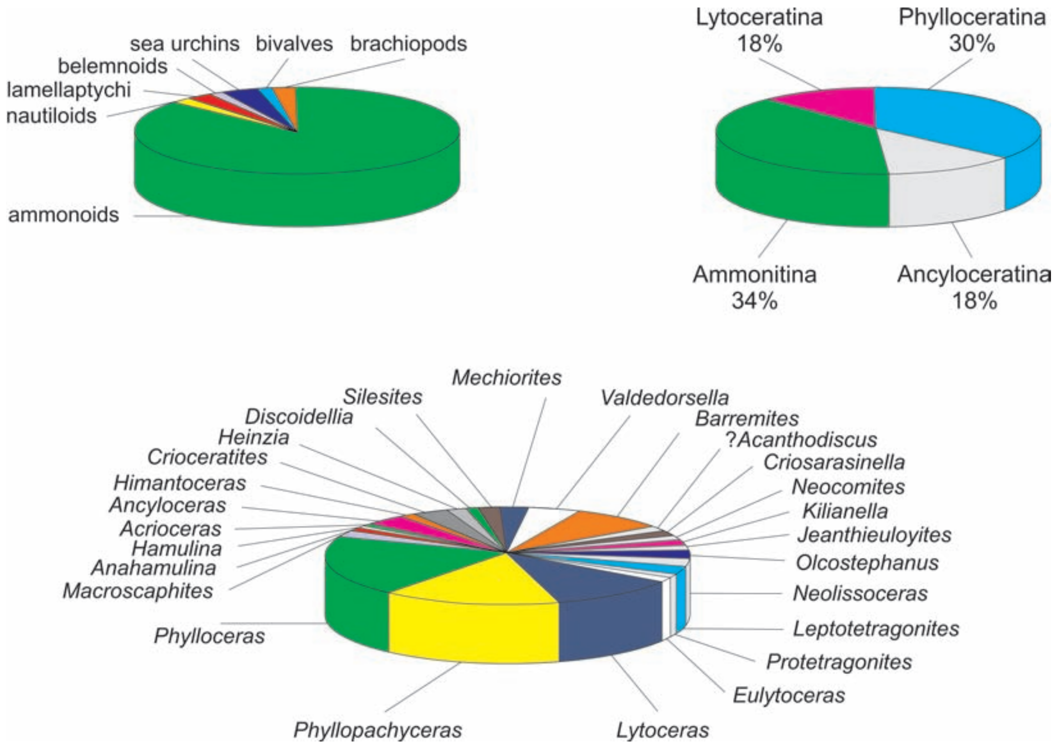


Fig. 4: Ammonoid spectrum from the Puez locality. Note the dominance of the Phyllopachiceratidae.

7. Biostratigraphy

The association indicates that the cephalopod-bearing beds of the Puez Formation comprise Valanginian, Hauterivian, Barremian and Aptian ammonoid assemblages. More specifically, ammonoid zones from the Early Valanginian up to the Early Aptian are represented (Hoedemaeker *et al*., 2003) (Fig. 5).

Following new (unpublished) results of the IUGS Lower Cretaceous Ammonite Working Group (Kilian Group) from the 7th International Cretaceous Symposium in Neuchatel (2005), *Heinzia sayni* will be erected as the new index fossil for the *H. sayni* Subzone, which is considered to be the lower Subzone of the new *Toxancyloceras vandenheckii* Zone (former *Ancyloceras vandenheckii* Zone) in the lowermost part of the Upper Barremian (Reboulet and Hoedemaeker (reporters) *et al*., submitted for Cretaceous Research).

The following ammonoids were determined: *Phylloceras thetys* (d'Orbigny), *Phyllopachyceras infundibulum* (d'Orbigny), *Phyllopachyceras winkleri* (Uhlig), *Lytoceras subfimbriatum* (d'Orbigny), *Eulytoceras phestum* (Matheron), *Leptotetragonites* cf. *honnoratianus* (d'Orbigny), *Protetragonites crebrisulcatus* (Uhlig), *Protetragonites quadrisulcatus* (d'Orbigny), *Neolissoceras grasianum* (d'Orbigny), *Olcostephanus densicostatus* (Wegner), *Olcostephanus (Jeannoticeras) jeannoti* (d'Orbigny), *Jeanthieuloyites* cf. *quinquestriatus* (Besairie), *Kilianella* cf. *roubaudiana* (d'Orbigny), *Neocomites* sp., *Criosarasinella furcillata* Thieuloy, *?Acanthodiscus* sp., *Barremites psilotatus* (Uhlig), *Abrytusites neumayri* (Haug), *Melchiorites cassioides* (Uhlig), *Silesites vulpes* (Coquand), *Discoidellia vermeuleni* (Cecca, Faraoni, Marini), *Heinzia sayni* (Hyatt), *Psilotissotia* sp., *Crioceratites nolani* (Kilian), *Crioceratites krenkeli* (Sarkar), *Crioceratites thiollierei* (Astier), *Discoidellia vermeuleni* (Cecca, Faraoni, Marini), *Himantoceras* sp., *Ancyloceras matheronianum* (d'Orbigny), *Ancyloceras* sp., *Acrioceras (Acrioceras) pulcherrimum* (d'Orbigny), *Acrioceras (Dissimilites) dissimilis* (d'Orbigny), *Acrioceras (Dissimilites) trinodosum* (d'Orbigny), *Anahamulina subcincta* (Uhlig), *Hamulina lorioli*

Uhlig, *Macroscaphites nodosostriatum* (Uhlig), and *Macroscaphites yvani* (Puzos) (Fig. 4).

The following index fossils were examined within the collections of the NHMW (Austria) and the NMB (Italy): for the latest Valanginian *Criosarasinella furcillata* (*C. furcillata* Zone and Subzone), for the middle Early Hauterivian *Olcostephanus (Jeannoticeras) jeannoti* (*O. (J.) jeannoti* Subzone) and *Heinzia sayni* for the earliest Late Barremian (*H. sayni* Subzone; Reboulet and Hoedemaeker (reporters) *et al.*, submitted).

Typical Valanginian species are: *Lytoceras subfimbriatum*, *Haploceras grasianum*, *Kilianella* sp., *Neocomites* sp., *Criosarasinella furcillata, Himantoceras* sp., *Jeanthieuloyites* cf. *quinquestriatus*, *Olcostephanus guebhardi*, *Leptotetragonites* cf. *honnoratianus*, *Protetragonites quadrisulcatus, Phylloceras thetys*.

Typical Hauterivian species are: *Phyllopachyceras infundibulum*, *Phyllopachyceras winkleri*, *Lytoceras subfimbriatum*, *Haploceras grasianum*, *Olcostephanus (Jeannoticeras) jeannoti*, *Neocomites* sp., *Discoidellia vermeuleni*, *Crioceratites nolani*, *Crioceratites krenkeli.*

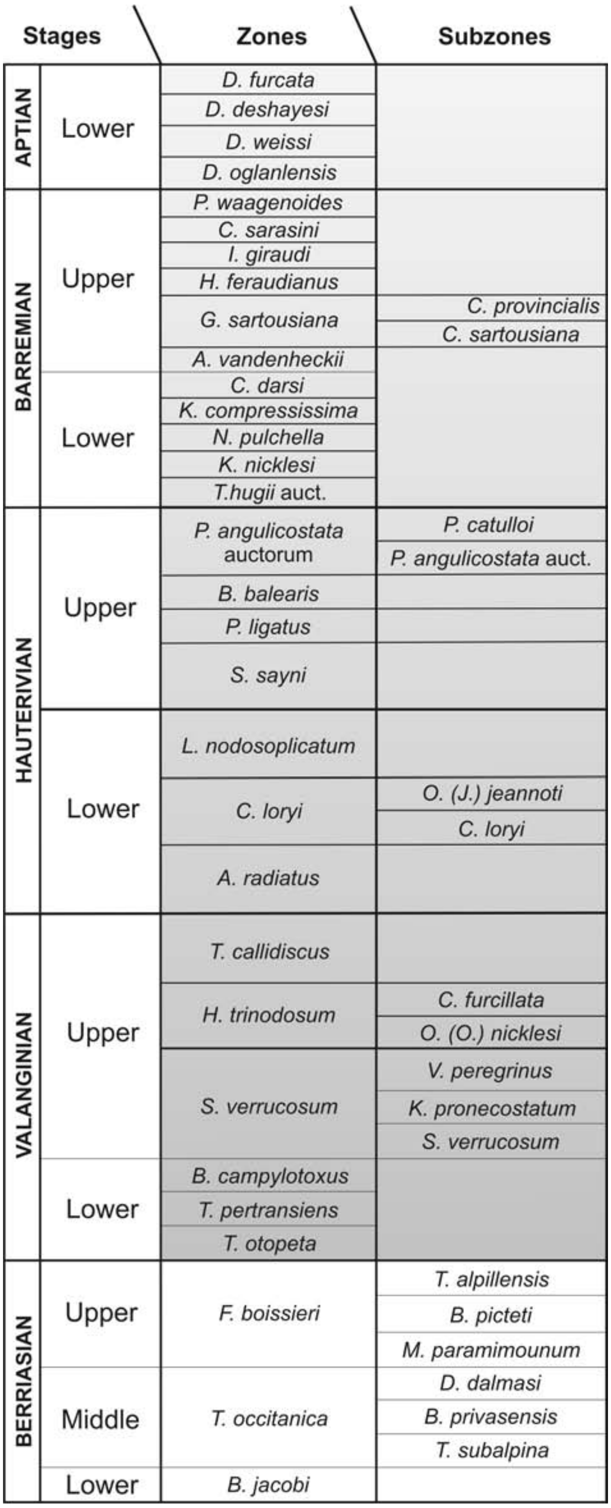
Typical Barremian species are: *Phyllopachyceras infundibulum*, *Eulytoceras phestum*, *Protetragonites crebrisulcatus*, *Barremites psilotatus*, *Abrytusites*, *Melchiorites cassioides*, *Anahamulina subcincta*, *Hamulina lorioli*, *Heinzia sayni*, *Crioceratites thiollierei*, *Acrioceras (Acrioceras) pulcherrimum*, *Acrioceras (Dissimilites) dissimilis*, *Acrioceras (Dissimilites) trinodosum*, *Macroscaphites yvani*, *Macroscaphites nodosostriatum*.

A typical Lower Aptian species is: *Ancyloceras matheronianum*.

Note that some of the species can pass over two stages but are mostly found in the emphasized stage of the Early Cretaceous.

8. Discussion

Since Uhlig's (1887) and Haug's (1887, 1889) description of Lower Cretaceous ("Neocomian") ammonoid faunas from the Puez locality, we know that the fauna of this area is one of the most important in the whole Alps. The well-preserved fauna is, compared to other Lower Cretaceous out-



Stages		Zones	Subzones
APTIAN	Lower	D. furcata	
		D. deshayesi	
		D. weissi	
		D. oglanlensis	
BARREMIAN	Upper	P. waagenoides	
		C. sarasini	
		I. giraudi	
		H. feraudianus	
		G. sartousiana	C. provincialis
			C. sartousiana
		A. vandenheckii	
	Lower	C. darsi	
		K. compressissima	
		N. pulchella	
		K. nicklesi	
		T.hugii auct.	
HAUTERIVIAN	Upper	P. angulicostata auctorum	P. catulloi
			P. angulicostata auct.
		B. balearis	
		P. ligatus	
		S. sayni	
	Lower	L. nodosoplicatum	
		C. loryi	O. (J.) jeannoti
			C. loryi
		A. radiatus	
VALANGINIAN	Upper	T. callidiscus	
		H. trinodosum	C. furcillata
			O. (O.) nicklesi
		S. verrucosum	V. peregrinus
			K. pronecostatum
			S. verrucosum
	Lower	B. campylotoxus	
		T. pertransiens	
		T. otopeta	
BERRIASIAN	Upper	F. boissieri	T. alpillensis
			B. picteti
			M. paramimounum
	Middle	T. occitanica	D. dalmasi
			B. privasensis
			T. subalpina
	Lower	B. jacobi	

Fig. 5: The stratigraphic position of the Puez-fauna (in grey) of the Puez Group within the Lower Cretaceous biostratigraphic scale (Early Valanginian to Early Aptian). Table after Hoedemaeker *et al.* (2003).

crops, extremely rich in species and numbers. 61 species were summarized by Haug (1889). The authors recently observed 30 species in the collections of the Natural History Museum (Vienna) and the South Tyrol Museum of Natural Sciences (Bozen). Most of the herein reported species have been observed in the older literature.

The ammonoid assemblage is very similar to ammonoid faunas of the Northern Calcareous Alps (Lukeneder, 2004c). This mainly reflects the palaeogeographic position of the Southern Alps in Lower Cretaceous time. The Southern Alps were located near to the south of the Northern Calcareous Alps (see Cecca, 1998; Lukeneder, 2004a; Vašíček *et al.*, 1994) (Fig. 6). During the Early Cretaceous the Mediterranean palaeogeographic domain was characterized by the presence of microplates located in the middle of the Tethyan oceanic corridor between the African and European landmasses (Stampfli *et al.*, 2002).

The region (Southern Alps) in which the investigated area was situated during the Early Cretaceous was formed on the Apulian block (Dercouret *et al.*, 1979) to the south-east of the Alpine-Carpathian Block, which was located at the western margin of the Tethys (Cecca, 1997, 1998; Vašíček and Michalík, 1999; Stampfli and Mosar, 1999; Zharkov *et al.*, 1998) (Fig 4). The fact that most depositional areas of the Mediterranean had some form of contact led to similar distribution patterns of Lower Cretaceous ammonoids. This explains the clear similarities in the respective regions and countries of Europe.

Large similarities in the faunal assemblage can also be observed with faunas from the Early Cretaceous of Hungary. As reported by Fülöp (1964), in the Bakony mountains *Olcostephanus* and *Holcodiscus* are missing. *Holcodiscus* is missing in the fauna of the Puez locality and *Olcostephanus* is only represented by a single specimen. *Holcodiscus* and *Olcostephanus* are also very common in the Northern Calcareous Alps.

Bochianites is totally absent at the Puez locality, but common in Lower Cretaceous sediments of various regions like the Northern Calcareous Alps (Lukeneder, 2003b) and Western Carpathians (Vašíček *et al.*, 1994). Note also that extensive accordances exist between the whole cephalopod fauna from the Puez and reported faunas from comparable sediments from the Northern Calcareous Alps (Lukeneder, 2003b), the Vocontian Trough (Bulot and Thieuloy, 1994), the Swiss Alps (Ooster, 1861), the Betic Cordillera (Hoedemaeker, 1994; Company *et al.* 1994), the Southern Carpathians (Avram, 1994) and the Western Carpathians (Vašíček, 1994; Vašíček *et al.*, 1994).

It is still unclear why certain ammonoid species are present in the Northern Calcareous Alps but absent in the Southern Alps (situated to the south at the Early Cretaceous). One explanation is current and drifting features combined with depth parameters. Some authors (Cecca, 1998; Reboulet, 1995) also suggested that reproductive strategies (r- or K-strategy) could have had some effect on the distribution of different ammonoid species from the Valanginian to the Barremian. An opportunistic behaviour of the eurytopic genus *Bochianites* was proposed by (Cecca, 1998). Cecca (1998) correlated the distribution of Valanginian and Barremian ammonoid species with their suggested living mode, related to their facies and combined with the faunal spectra.

Cecca (1998) reported no Boreal elements from various Italian localities of the Trento Plateau and the Umbria-Marche region in the Valanginian and Barremian stage. Hence it is not surprising that no Boreal ammonoids were observed at the Puez locality.

Most recently, Kakabadze *et al.* (2004) introduced a very valuable source for ideas on Early Cretaceous biogeography (Barremian-Albian) based on ammonoids. The latter authors explained the distribution of different ammonoid genera and the history of provincialism from the Barremian to Albian starting from the Colombian ammonoid fauna, correlating it with faunas from around the world.

Unsurprisingly, the biggest accordance in ammonoid assemblage exists with described fauna-spectra from the La Stua locality (Belluno). La Stua is located approximately 10 kilometres to the east of the Puez area in the "Dolomites d'Ampezzo" (Stöhr, 1993). Both localities are assigned to the northern Trento Plateau. Small ammonoid faunas from the same locality were also reported by Baccele and Lucchi-Garavello (1967a, 1967b) and Stöhr (1994). The cephalopod faunas reported by the latter authors confirm the affinity of both faunas. The fauna (43 species) investigated by Stöhr (1993) also comprises cephalopods from Lower

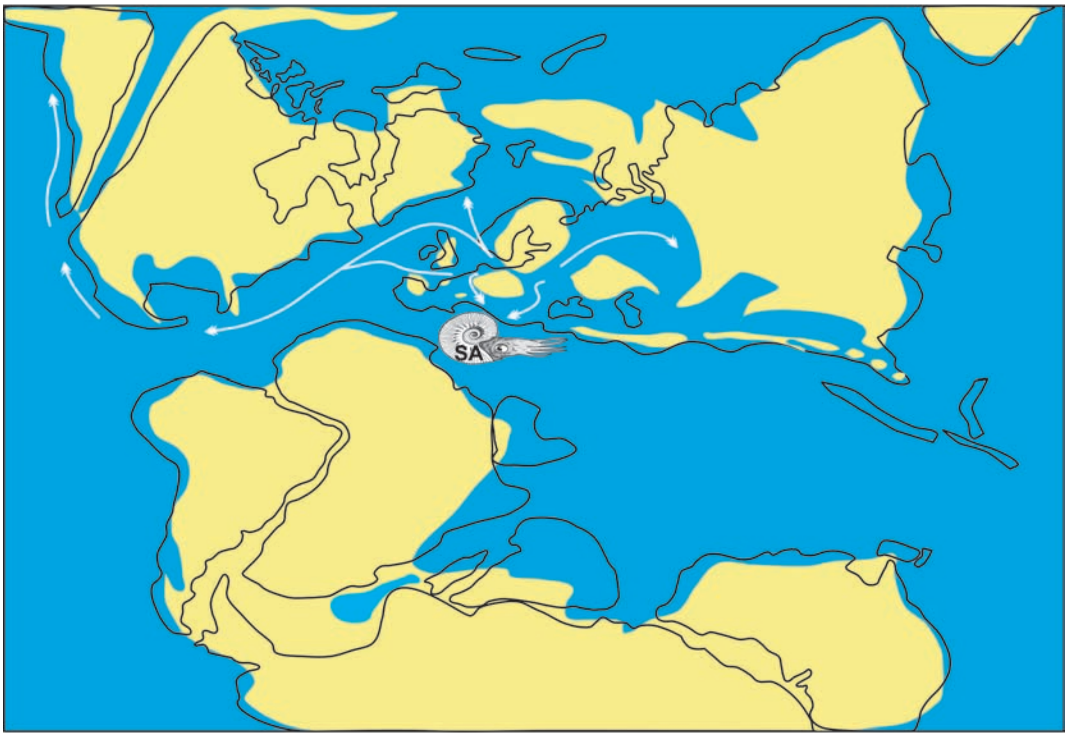


Fig. 6: Lower Cretaceous palaeogeography with indicated ammonoid migration-routes modified after Caracuel *et al.* (1998), Kiessling *et al.* (2003), Kotetichvili (1988), Lukeneder (2004), Scotese (2001), Wiedmann (1988) and Zharkov *et al.* (1998) with indicated position of the Southern Alps (marked by ammonoid).

Cretaceous sediments (Valanginian to Early Aptian, 191 m thick). He summarized the similarities between the fauna from La Stua and other localities of the West-Tethyan Realm, but noted the major similarities of faunas from the western Dolomites (Puez) with assemblages from the eastern Dolomites (La Stua). Most similarities can be observed in the abundance of Phylloceratidae and Desmoceratidae in both regions.

Stöhr (1993) proposed a migration route for the northern marginal faunas of the southern border of the European Plate (e.g., SE France - Vocontian Trough, Spain, Switzerland) down to the Southern Alps directly over the Carpathians. The latter author failed to mention that a huge area – the Northern Calcareous Alps – was situated between the Carpathians and the terrain of the Dolomites (Southern Alps). The migration had to pass the NCA before reaching the more southern Dolomites (Fig. 6). Stöhr (1993) missed Immel's (1987) paper on Lower Cretaceous ammonoid faunas from the NCA.

As noted by Uhlig (1887) and Haug (1887, 1889), the ammonoid fauna from the Puez area is of Valanginian to Aptian age. The latter authors also recognized that no Berriasian element (concerning the ammonoid fauna) could be detected. The present paper supports this conclusion, although the ammonoid zonation and most of the generic names of ammonoids have been changed and therefore the parameters are quite different today. The frequency of the ammonoids and the richness of the fauna have allowed the recognition of several Valanginian, Hauterivian, Barremian and Aptian ammonoid zones or at least time intervals which can be correlated with the Mediterranean standard zonation by Hoedemaeker *et al.* (2003).

A noticeable feature of the middle section (Hauterivian) of the Puez Formation is the numerous cherty and calcareous concretions. Most of these concretions bear ammonoids of all morphologies and sizes. This phenomenon was for example also reported by Fülöp (1964) for the Bakony mountains (Hungary) and by Lukeneder (2004c) for the Hauterivian limestones of the Northern Calcareous Alps (Austria). It is therefore apparently possible to correlate Hauterivian radiolarian-rich (cherty) sediments comprising chert-nodules, -layers and -concretions over wider distances or even countries.

9. Conclusions and perspectives

The macrofauna is represented especially by ammonoids, ammonoid jaws (aptychi), nautiloids, belemnoids, sea urchins, brachiopods and bivalves. The latter assemblage shows typical affinities to other Lower Cretaceous fossil communities in Europe (e.g., Northern Calcareous Alps, Carpathian mountains, Bakony mountains). The whole section yielded about 424 ammonoids. Good preservation within calcareous and cherty concretions (radiolarians) of the ammonoids allow precise determinations.

Some ammonoid zones defined by Hoedemaeker *et al.* (2003) can be recognized. The following index fossils were examined within the collections of the NHMW (Austria) and the NMB (Italy): for the latest Valanginian *Criosarasinella furcillata* (*C. furcillata* Zone and Subzone), for the middle Early Hauterivian *Olcostephanus (Jeannoticeras) jeannoti* (*O.(J.) jeannoti* Subzone) and *Heinzia sayni* for the earliest Late Barremian (*H. sayni* Subzone; Reboulet and Hoedemaeker (reporters) *et al.*, submitted).

The frequency of the ammonoids and the richness of the fauna make this section especially suited to accurately study the vertical ammonoid distribution. The main focus in the future will be to investigate in detail the stratigraphic framework of the Puez section. Bed-by-bed collecting is required to obtain crucial data on the ammonoid distribution and occurrence (range). A cooperative project with this aim is being planned by the South Tyrol Museum of Natural Sciences Bozen and the Natural History Museum Vienna.

A further study on the the palaeoecology and synecology of the cephalopod fauna of the Puez section is currently under preparation by Lukeneder. It focuses on the autecological features exhibited by different fossil groups (annelids, bryozoans, foraminifera, corals) on ammonoid shells, which act as cryptic habitats for different encrusters in the Lower Cretaceous biota of the Puez locality.

Hauterivian limestone intervals from the Puez area, containing cherty ammonoid bearing concretions, can be correlated with similar occurrences of different other areas of Europe as for example the Northern Calcareous Alps in Austria or the Bakony mountains of Hungary. This requires further attention and will be the focus of future work.

10. Results

The ammonoid fauna (27 genera) at the Puez section is dominated by *Phyllopachyceras* (17%) and *Phylloceras* (13%) from the Phylloceratina and *Barremites* (10%) and *Melchiorites* (8%) from the Ammonitina. The ammonoid families Phylloceatidae and Desmoceratidae are dominating the cephalopod-fauna.

The stratigraphic investigation of the cephalopods revealed that the Puez section (Pizes de Puez, Col de Puez, Puez) comprises Lower Valanginian to Aptian sediments.

The ammonoid fauna from the Puez locality contains only descendants of the Mediterranean Province (Tethyan Realm). Most affinities of the cephalopod fauna are observed with faunas from the adjacent areas of Italy (Lessini Mountains, Belluno, southern Trento Plateau), the Northern Calcareous Alps (Austria) and the Bakony, Gerecse and Mecsek Mountains of Hungary. This is explained by the neighbouring position of the latter areas during the Early Cretaceous on the Apulian/Adria block and the Alpine-Carpathian microplate.

11 ammonoid families were recorded by the following species: **Phylloceratidae**: *Phylloceras thetys*, *Phyllopachyceras infundibulum*, *Phyllopachyceras winkleri*; **Lytoceratidae**: *Lytoceras* subfimbriatum, *Eulytoceras phestum*, *Leptotetragonites* cf. *honnoratianus*, *Leptotetragonites crebrisulcatus*, *Protetragonites quadrisulcatus*; **Haploceratidae**: *Haploceras grasianum*; **Olcostephanidae**: *Olcostephanus guebhardi*, *Jeanthieuloyites* sp.; **Neocomitidae**: *Kilianella* cf. *roubaudiana*, *Neocomites* sp., *Criosarasinella furcillata*, ?*Acanthodiscus* sp.; **Desmoceratidae**: *Barremites psilotatus*, *Abrytusites neumayri*, *Melchiorites cassioides*; **Silesitidae**: *Silesites vulpes*; **Pulchelliidae**: *Heinzia sayni*, *Discoidellia vermeuleni*; **Ancyloceratidae**: *Crioceratites nolani*, *Crioceratites krenkeli*, *Crioceratites thiollierei*, *Himantoceras sp.*, *Pseudothurmannia*, *Ancyloceras matheronianum*, *Ancyloceras* sp. *Acrioceras (Dissimilites) dissimilis*, *Acrioceras (Acrioceras) pulcherrimum*; **Hamulinidae**: *Hamulina lorioli*, *Anahamulina subcincta*; **Macro-**

scaphitidae: *Macroscaphites yvani*, *Macroscaphites nodosostriatum*.

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Plate 1

Fig. 1: *Protetragonites crebrisulcatus* (Uhlig), Puez section, x 1, 2005z0245/0053
Fig. 2: *Protetragonites quadrisulcatus* (d'Orbigny), Puez section, x 1, 2005z0245/0054
Fig. 3: *Protetragonites crebrisulcatus* (Uhlig), Puez section, x 1, 2005z0245/0055
Fig. 4: *Leptotetragonites honnoratianus* (d'Orbigny), Puez section, x 1, 2005z0245/0030
Fig. 5: *Lytoceras subfimbriatum var. B* (d'Orbigny), Puez section, x 0.5, 2005z0245/0044
Fig. 6: *Lytoceras subfimbriatum var. A* (d'Orbigny), Puez section, x 1, 2005z0245/0040
Fig. 7: *Eulytoceras phestum* (Matheron), Puez section, x 1, 2005z0245/0042
Fig. 8: *Phylloceras thetys* (d'Orbigny), Puez section, x 1, 2005z0245/0014
Fig. 9: *Phyllopachyceras winkleri* (Uhlig), Puez section, x 1, 2005z0245/00038

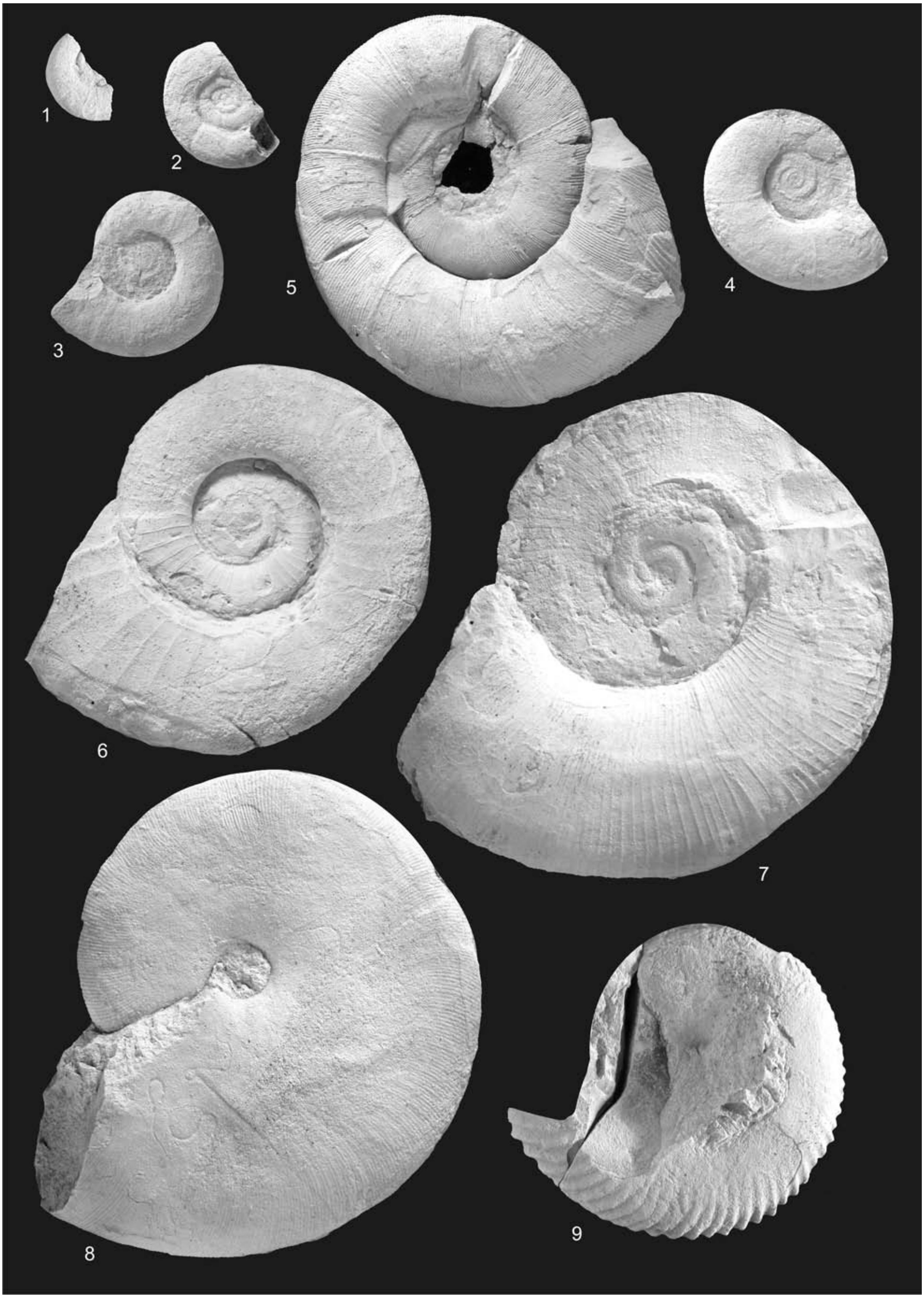
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Plate 2

Fig. 1: *Phyllopachyceras infundibulum* (d'Orbigny), Puez section, x 1, 2005z0245/0015
Fig. 2: *Phyllopachyceras infundibulum* (d'Orbigny), Puez section, x 1, 2005z0245/0016
Fig. 3: *Neolissoceras grasianum* (d'Orbigny), Puez section, x 1, 2005z0245/002
Fig. 4: *Neocomites* sp., Puez section, x 1, 2005z0245/0010
Fig. 5: *Olcostephanus densicostatus* (Wegner), Puez section, x 1, 2005z0245/0039
Fig. 6: *Olcostephanus jeannoti* (d'Orbigny), Puez section, x 1, 1884/0026/0570
Fig. 7: Neocomites sp., Puez section, x 1, 2005z0245/0021
Fig. 8: *Kilianella* aff. *roubaudiana* (d'Orbigny), Puez section, x 1, 2005z0245/0032
Fig. 9: *Jeanthieuloyites* cf. *quinquestriatus* (Besairie), Puez section, x 1, 2005z0245/009
Fig. 10: *Criosarasinella furcillata* Thieuloy, Puez section, x 1, 2005z0245/0013

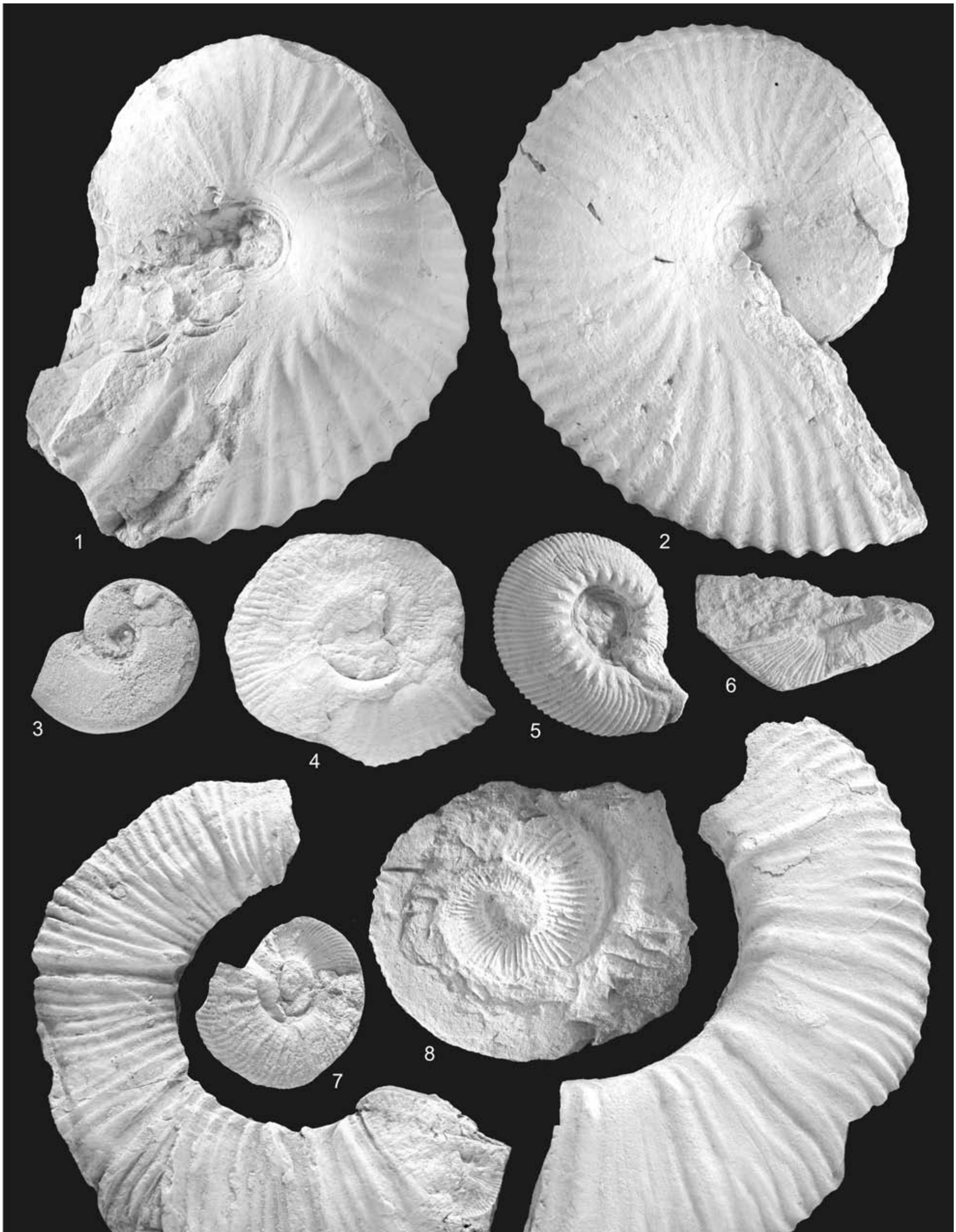
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Plate 3

Fig. 1: ?*Acanthodiscus*, Puez section, x 1, 1884/0026/0567
Fig. 2: *Barremites psilotatus* (Uhlig), Puez section, x 1, 1962/0002/2223
Fig. 3: *Barremites psilotatus* (Uhlig), Puez section, x 1, 2005z0245/0001
Fig. 4: *Melchiorites cassioides* (Uhlig), Puez section, x 0.5, 2005z0245/0017
Fig. 5: *Abrytusites neumayri* (Haug), Puez section, x 1, 2005z0245/0056
Fig. 6: *Abrytusites neumayri* (Haug), Puez section, x 1, 2005z0245/0057
Fig. 7: *Abrytusites neumayri* (Haug), Puez section, x 1, 2005z0245/0058
Fig. 8: *Melchiorites cassioides* (Uhlig), Puez section, x 0.5, 2005z0245/0045

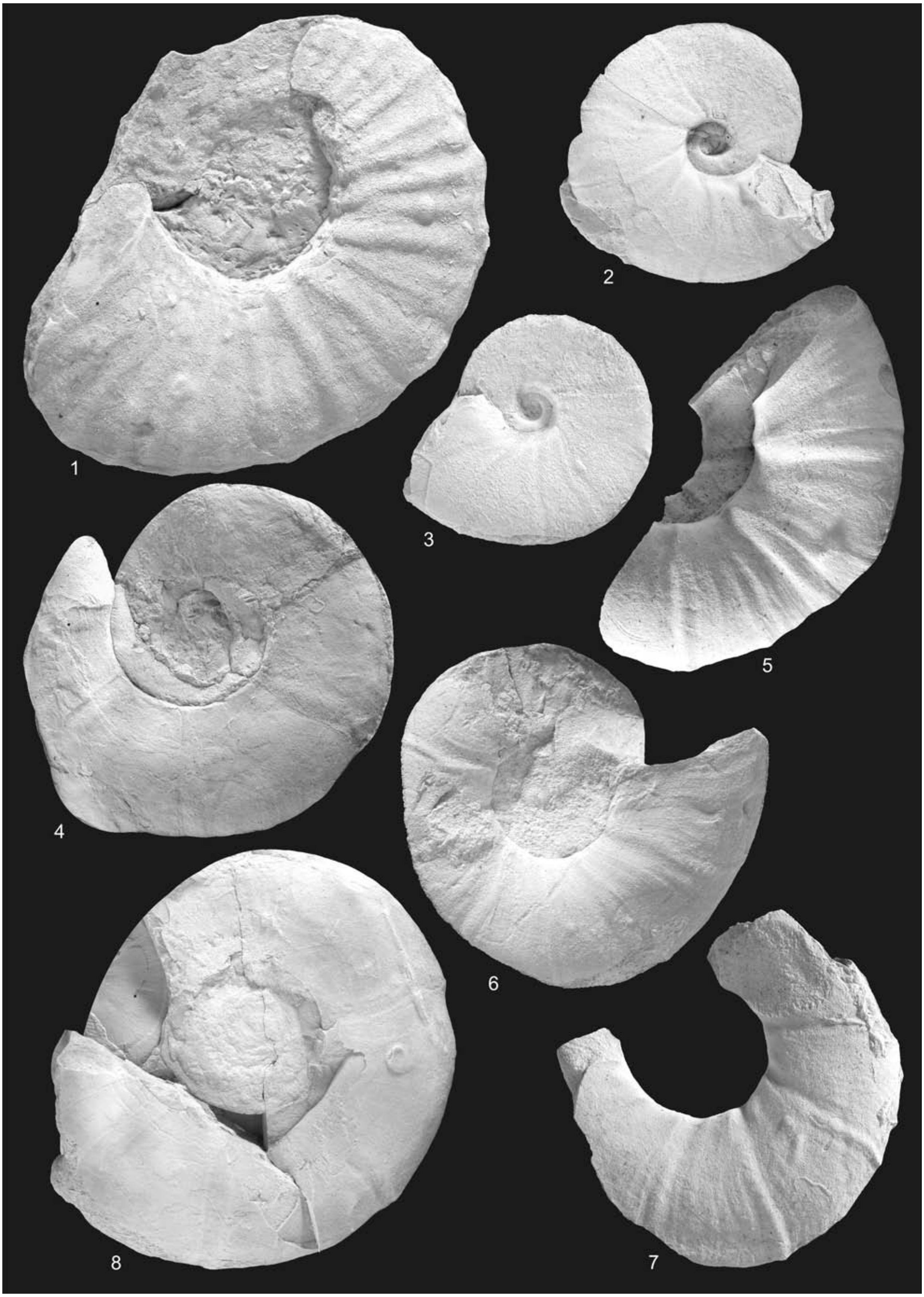
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Plate 4

Fig. 1: *Silesites vulpes* (Coquand), Puez section, x 1, 2005z0245/0029
Fig. 2: *Silesites vulpes* (Coquand), Puez section, x 1, 2005z0245/0037
Fig. 3: *Silesites vulpes* (Coquand), Puez section, x 1, 2005z0245/0041
Fig. 4: *Silesites vulpes* (Coquand), Puez section, x 1, 2005z0245/0043
Fig. 5: *Silesites vulpes* in concretion (Coquand) , Puez section, x 1, 2005z0245/0046

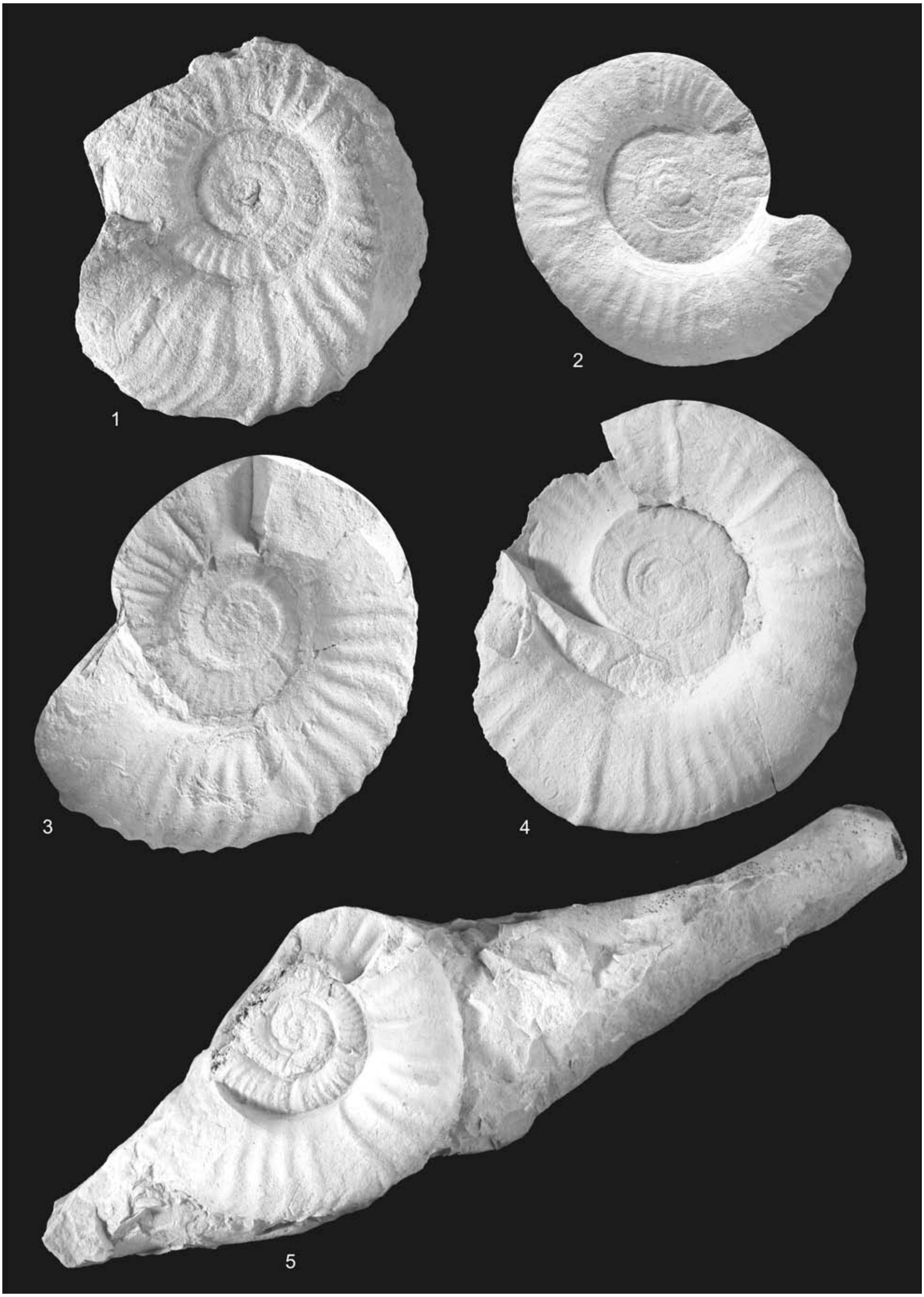
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Plate 5

Fig. 1: *Abrytusites neumayri* (Haug), Puez section, x 0.5, 1886/0008/0014
Fig. 2: *Heinzia sayni* (Hyatt) , Puez section, x 1, 2005z0245/0003
Fig. 3: *Heinzia sayni* (Hyatt) , Puez section, x 1, 2005z0245/0022
Fig. 4: *Heinzia sayni* (Hyatt) , Puez section, x 1, 1886/0008/0019
Fig. 5: *Crioceratites krenkeli* (Sarkar), Puez section, x 1, 2005z0245/0035
Fig. 6: *Crioceratites krenkeli* (Sarkar), Puez section, x 1, 2005z0245/0033
Fig. 7: *Crioceratites krenkeli* (Sarkar), Puez section, x 1, 2005z0245/0028
Fig. 8: *Crioceratites krenkeli* (Sarkar), Puez section, x 1, 2005z0245/0034
Fig. 9: *Crioceratites* sp., Puez section, x 1, 2005z0245/0050
Fig. 10: *Crioceratites nolani* (Kilian), fron view, Puez section, x 0.5, 2005z0245/0008
Fig. 11: *Crioceratites nolani* (Kilian), back view of Fig. 10, Puez section, x 0.5, 2005z0245/0008


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Plate 6

Fig. 1: *Himantoceras* sp., Puez section, x 1, PZO-P21
Fig. 2: *Ancyloceras matheronianum* (d'Orbigny), Puez section, x 0.5, 2005z0245/0012
Fig. 3: *Ancyloceras matheronianum* (d'Orbigny), Puez section, x 0.5, 2005z0245/0049
Fig. 4: *Ancyloceras matheronianum* (d'Orbigny), Puez section, x 0.5, 2005z0245/0048
Fig. 5: *Ancyloceras* sp., Puez section, x 0.5, 2005z0245/0011
Fig. 6: *Ancyloceras* sp., Puez section, x 0.5, 2005z0245/0047
Fig. 7: Acrioceras *(Dissimilites) dissimilis* (d'Orbigny), Puez section, x 1, PZO-CP56
Fig. 8: Acrioceras *(Dissimilites) trinodosum* (d'Orbigny), Puez section, x 1, PZO-CP68
Fig. 9: *Dissimilites (Dissimilites) trinodosum* (d'Orbigny), Puez section, x 1, 2005z0245/0036
Fig. 10: *Acrioceras (Acrioceras) pulcherrimum* (d'Orbigny), Puez section, x 1, 1926/0002/2221
Fig. 11: *Crioceratites thiollierei* (Astier), Puez section, x 1, PZO-P21


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Plate 7

Fig. 1: *Dissimilites (Dissimilites) trinodosum* (d'Orbigny), Puez section, x 1, 1886/0008/0017
Fig. 2: *Hamulina lorioli* Uhlig, Puez section, x 1, 2005z0245/0019
Fig. 3: *Anahamulina subcincta* (Uhlig), Puez section, x 1, 2005z0245/0005
Fig. 4: *Anahamulina subcincta* (Uhlig), Puez section, x 1, 2005z0245/0006
Fig. 5: *Macroscaphites nodosostriatum* (Uhlig), Puez section, x 1, 2005z0245/0020
Fig. 6: *Macroscaphites nodosostriatum* (Uhlig), Puez section, x 1, 2005z0245/0031
Fig. 7: Ammonites indet, Puez section, x 0.5, 2005z0245/0051
Fig. 8: Ammonites indet, Puez section, x 0.5, 2005z0245/0052
Fig. 9: *Macroscaphites yvani* (Puzos), Puez section, x 1, PZO-P17
Fig. 10: *Discoidellia vermeuleni* (Cecca, Faraoni, Marini*)*, Puez section, x 1, 1926/0002/2222

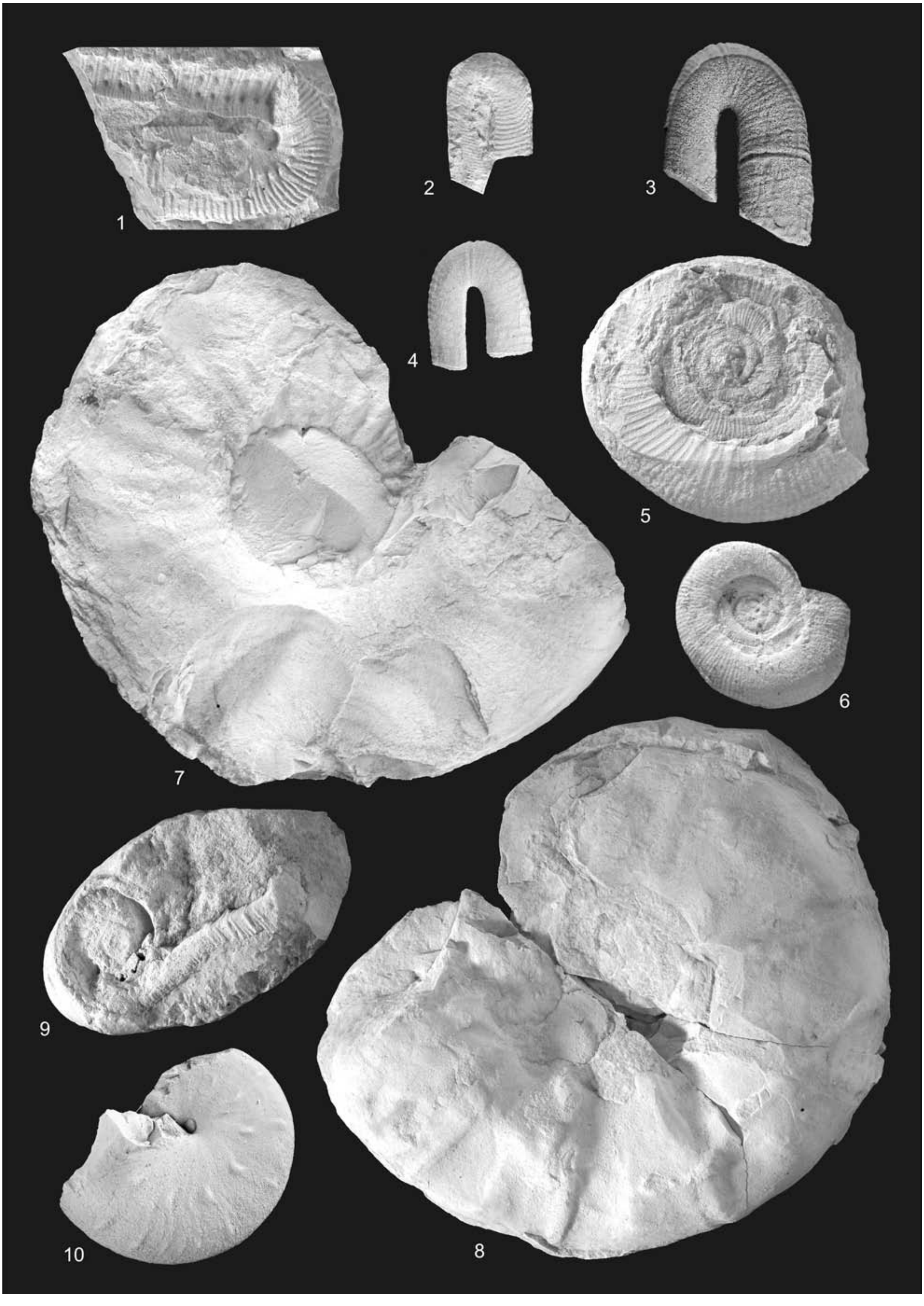
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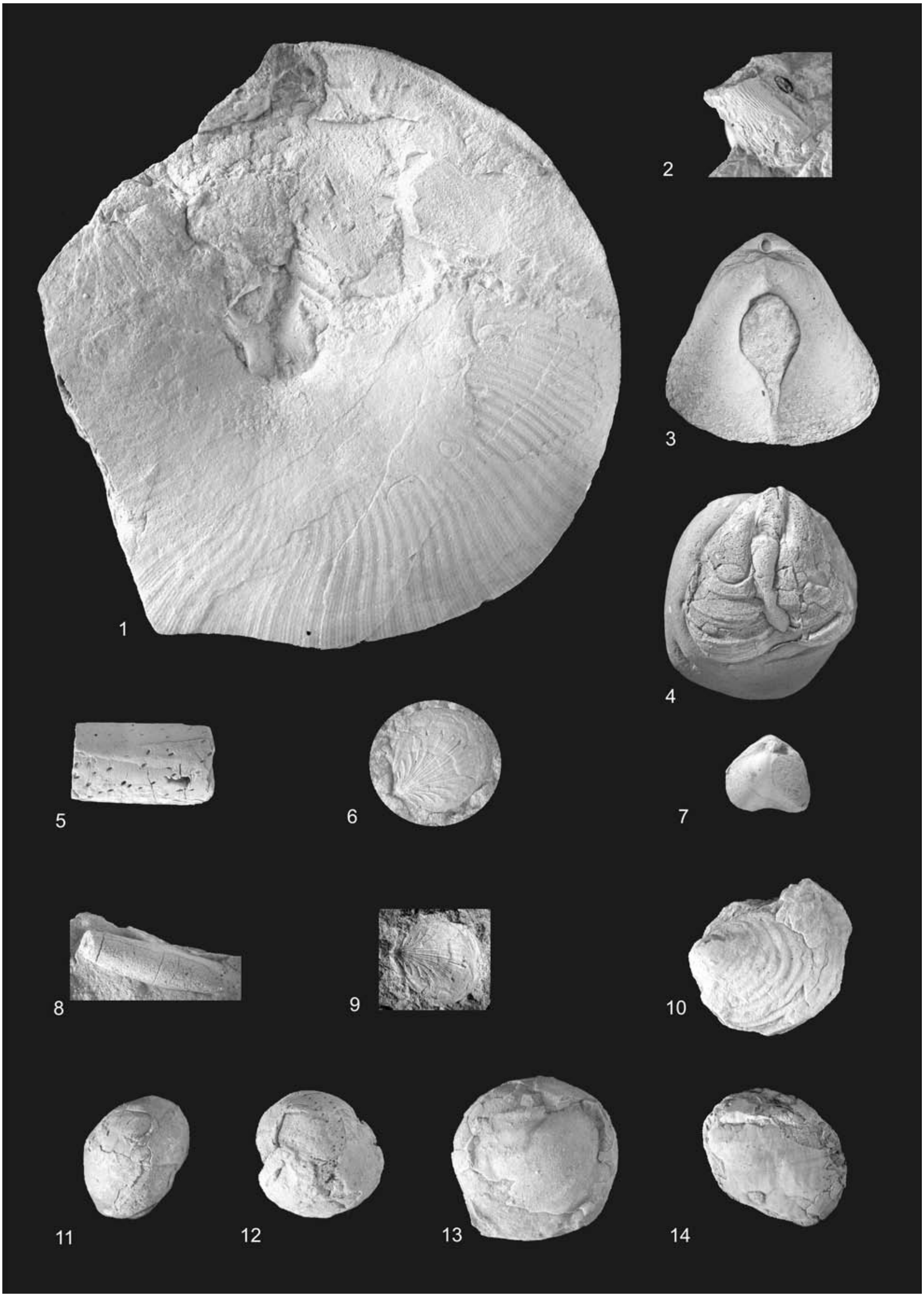
Plate 8

Fig. 1: *Cymatoceras* sp., Puez section, x 1, 2005z0245/0018
Fig. 2*:* *Lamellaptychus* sp., Puez section, x 1, 1886/0026/0576
Fig. 3: *Pygope* sp., Puez section, x 1, 1884/0026/0578
Fig. 4: *Pygope* sp., Puez section, x 1, 1886/0008/0001
Fig. 5*:* Belemnites indet with *Acrothoracica* borrows, Puez section, x 1, 1886/0026/0577
Fig. 6*:* *Propaeamussium* sp., Puez section, x 1, 2005z0245/0004
Fig. 7: Brachiopod indet, Puez section, x 1, 2005z0245/0026
Fig. 8: Belemnites indet, Puez section, x 1, 2005z0245/0025
Fig. 9: *Propaeamussium* sp., Puez section, x 1, 2005z0245/0027
Fig. 10: *Inoceramus* sp., Puez section, x 1, 2005z0245/0007
Fig. 11: Sea urchin (Disasteroida), Puez section, x 1, 2005z0245/0023
Fig. 12: Sea urchin (Disasteroida), Puez section, x 1, 1886/0008/0016
Fig. 13: Sea urchin (Disasteroida), Puez section, x 1, 1884/0026/0574
Fig. 14: Sea urchin (Disasteroida), Puez section, x 1, 2005z0245/0024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