

## A Systematic Study of upper Silurian (Ludfordian) Nautiloid Cephalopods from the Eggenfeld Section (Graz Palaeozoic, Styria, Austria)

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3 Text-Figures, 8 Plates

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Nautiloids  
Upper Silurian  
Messner Collection  
Eggenfeld Section  
Graz Palaeozoic  
Styria  
Austria

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### Abstract

A nautiloid cephalopod assemblage from the upper Silurian (Ludfordian) K1 dolomitic horizons of the Eggenfeld Section, Graz Palaeozoic, Styria, Austria is systematically described and illustrated herein. 18 genera and 33 species are represented in the collection from the Ormoceratidae, Michelinoceratinae, Kionoceratinae, Leurocycloceratinae, Anaspyroceratidae, Geisonoceratidae, Paraphragmitidae and Spyroceratinae. The assemblage is biostratigraphically constrained by conodonts within the *Polygnathoides siluricus* conodont biozone, confirming a Ludfordian age, and is comparable with that of the Cephalopod Limestone Biofacies interval defined by the presence of elements of the *Cardiola alata* – *Cardiola conformis* Bivalve Communities recognized in Bohemia and the Carnic Alps. The cephalopod fauna from the Graz Palaeozoic shows close affinities with the upper Silurian Bohemian and SW Sardinian *Kopaninoceras thyrus* – *Orthocycloceras fluminese* nautiloid assemblages and is comparable with Ludfordian nautiloid faunas from the Carnic Alps, Elbersreuth (Bavaria, Germany) and Morocco. The data suggest that during this late Silurian interval the Graz Palaeozoic was palaeogeographically close in position to terranes located along the North Gondwana margin. The presence of comparative faunas occurring in upper Silurian sequences of Poland, Kazakhstan and Middle Asia as well as the British Isles indicate faunal exchange with Baltica and Avalonia and across the Rheic Ocean by currents due to southward moving oceanic circulation patterns and suggests evidence for possible migratory events. The assemblage can be compared with the globally recognized Ludfordian *Kozłowski* Event.

## Systematische Untersuchung der obersilurischen (Ludfordium) nautiloiden Cephalopoden des Profils Eggenfeld (Grazer Paläozoikum, Steiermark, Österreich)

### Zusammenfassung

Ein Vorkommen von Nautiloideen aus dem obersilurischen (Ludfordium) K1 Dolomit-Horizont des Profils Eggenfeld im Grazer Paläozoikum wird systematisch beschrieben und abgebildet. In der Aufsammlung sind 18 Gattungen mit 33 Arten der Ormoceratidae, Michelinoceratinae, Kionoceratinae, Leurocycloceratinae, Anaspyroceratidae, Geisonoceratidae, Paraphragmitidae und Spyroceratinae vertreten. Das Vorkommen ist biostratigraphisch durch Conodonten eingegrenzt und liegt innerhalb der *Polygnathoides siluricus* Conodonten Biozone, die ein Ludfordium-Alter belegt. Die untersuchte Fauna ist somit vergleichbar mit Abfolgen einer Cephalopodenkalk-Biofazies, die durch das Auftreten von Elementen der *Cardiola alata* – *Cardiola conformis* Bivalven-Gemeinschaft geprägt ist, wie sie aus Böhmen und den Karnischen Alpen bekannt ist. Diese Fauna des Grazer Paläozoikums zeigt enge Beziehungen zu obersilurischen böhmischen und südwestsardinischen *Kopaninoceras thyrus* – *Orthocycloceras fluminese* Nautiloideen-Zusammensetzungen und ist vergleichbar mit ebensolchen Faunen des Ludfordiums der Karnischen Alpen, Elbersreuths (Bayern, Deutschland) und Marokkos. Die Ergebnisse lassen darauf schließen, dass die paläogeografische Position des Grazer Paläozoikums während dieses Abschnittes des späten Silurs in einem Gebiet entlang des Randes von Nord-Gondwana lag. Das Auftreten von vergleichbaren obersilurischen Faunen in Polen, Kasachstan und Mittelasien sowie der Britischen Inseln legen einen Faunenaustausch mit Baltica und Avalonia durch südwärts gerichtete Meeresströmungen des Rheischen Ozeans nahe, wodurch auf mögliche Migrationseignisse in diesem Zeitraum zu schließen ist. Die Zusammensetzung der Fauna kann mit dem weltweit aufgetretenen *Kozłowski* Event im Ludfordium verglichen werden.

### Introduction

This is the second of a series of papers on the nautiloid cephalopod fauna from the Eggenfeld Section of the Graz Palaeozoic located in eastern Austria in the Province of Styria (Text-Fig. 1). The first paper outlined the tectonic, sedimentological, and stratigraphical setting of the Eggenfeld Section from where the nautiloid faunas have been collected as well as illustration of the variety of taphonomic features observed within different cephalopod-bearing levels and a discussion of the palaeobiogeographical significance of the upper Silurian nautiloid faunas from the

Graz Palaeozoic (for details refer to HISTON et al., 2010). A preliminary list of genera was provided as well as illustrations of a few representative specimens of common taxa. Some of those preliminary assignments are revised herein.

This paper comprises a detailed systematic study of the mainly orthoconic nautiloid faunas from the K1 fossiliferous dolomitic level of the late Silurian, Ludfordian (*Polygnathoides siluricus* conodont biozone) part of the stratigraphic section (Text-Fig. 2). Due to the large number of specimens (more than 800) from this level alone within the Messner Collection, we propose to dedicate a separate publication to the cyrtoconic and coiled morphological forms from the



Text-Fig. 1.  
Location map of the Graz Palaeozoic and other remnants of Palaeozoic strata in Austria (Greywacke Zone, South Burgenland, Gurktal Nappe, Nötsch, the Carnic Alps, the Karawanken Mountains). The Periadriatic Line separates the Carnic Alps and the Karawanken Mountains (Southern Alps) from the Eastern Alps (after HISTON et al., 2010: Fig. 1).

K1 level. Another paper will follow shortly which will constitute the second part of the systematic study of the Ludfordian interval.

Study of the faunas from the higher K2 level bioclastic limestones/dolomites of the late Silurian/Early Devonian interval continues. The final paper in this series will address the Pridoli (*Ozarkodina remscheidensis eosteinhornensis* conodont biozone) to earliest Lochkovian (*Icriodus woschmidtii* conodont biozone) portion of the Messner Collection. This stratigraphical division is considered important, as the nautiloid assemblages will thus be described within precise biostratigraphical zonations, which are globally recognized and underline their use as biostratigraphical markers. The study is a contribution to the ongoing systematic description by diverse research groups of Silurian nautiloid cephalopods within a well-defined biostratigraphic framework in order to elaborate their use as a tool for biostratigraphic correlation and palaeobiogeographic reconstructions (see examples in EVANS et al., 2014; HISTON et al., 2010; MANDA & KŘÍŽ, 2006).

## Geological Setting

The Graz Palaeozoic, located in eastern Austria (Text-Fig. 1), extends over approximately 1,250 km<sup>2</sup> and is divided into a basal, intermediate and upper nappe group (FRITZ & NEUBAUER, 1990) based on lithological similarities, the tectonic position as well as the metamorphic superimposition of successions. The stratigraphic sequence indicates a sedimentation area changing from a passive continental margin with intraplate volcanism to shelf and platform geometries during Silurian to Devonian time (HUBMANN & MESSNER, 2007). The sequence of the Rannach Nappe starts with the predominantly alkaline, subordinately acidic metavolcanites (tuffs, lavas) of the Kehr Formation (Text-Fig. 2). The succeeding Kötschberg Formation is comprised predominantly of dolostones, argillaceous shales and silty shales representative of a pelagic environment during the Ludlow to Lochkovian interval (EBNER, 1976, 1994). The Eggenfeld Section belongs to the Eggenfeld Member (FLÜGEL & HUBMANN, 2000) of the Kötschberg Formation (Ludfordian–Lochkovian). Carbon-

ate levels K1, K2 and K3 of the section are dark grey, bedded dolomites and/or dolomitic limestones (Text-Fig. 2), locally rich in fossils and differentiated on the basis of their microfacies into: bioclastic dolosparites to biodolosparites, biodolosparites and biomicrites (microsparites). The nautiloid assemblage studied herein originates from the K1 level. A more detailed account of the geological and tectonic setting, sedimentology and stratigraphy of the Eggenfeld Section may be found in HISTON et al. (2010, and references therein).

## Previous Nautiloid Studies

Despite the abundance of nautiloid cephalopods in the upper Silurian of the Graz Palaeozoic, their study has been largely restricted to brief mentions of orthocones/orthoconerids in faunal lists, or as *Orthoceras* limestones in more general geological studies of the area: HERITSCH (1930); EBNER (1976, 1994); FLÜGEL & SCHÖNLAUB (1972); NEUBAUER (1989); HIDEN (1995); FLÜGEL & HUBMANN (2000); HUBMANN & MESSNER (2005). The only systematic study of nautiloids is related to the finding of a specimen of the graptolite *Bohemograptus bohemicus tenuis* at the base of the Eggenfeld Section, documenting the presence of the *Leintwardinensis* graptolite biozone (HIDEN, 1996). Three taxa of nautiloid cephalopods occurring in the overlying dolomite beds were described and figured: *Kionoceras* cf. *bronni* (BARRANDE, 1868), *Cyrtocycloceras* cf. *urbanum* (BARRANDE, 1866) and *Oonoceras?* sp., all comparable with taxa from the Ludlow in age Kopanina Formation in the Prague Basin (HIDEN, 1996: 81–84, Taf. 2, Figs. 1–4). Three additional figures show two polished longitudinal specimens determined as indeterminate Orthocerida as well as a polished block with various *Orthoceras* specimens (HIDEN, 1996: Taf. 1, Figs. 3–5). Another Text-Figure shows a small block with oriented orthocones (HIDEN, 1996: Abb. 4). A rose diagram of the current orientation of 79 orthoconic nautiloids on the bedding plane shows a dominant SW to NE trend (HIDEN, 1996: Abb. 3). The cephalopod-bearing level was correctly ascribed to the cephalopod limestone biofacies and compared to stratigraphically coeval occurrences from the *siluricus* conodont biozone in the Prague Basin, the Carnic Alps and in Sardinia. The author emphasises in this

very nice study that there is an abundance of cephalopods occurring within different levels at the Eggenfeld Section but that he has just selected a few well-preserved specimens to describe.

## Nautiloid Material Studied

### Messner Collection

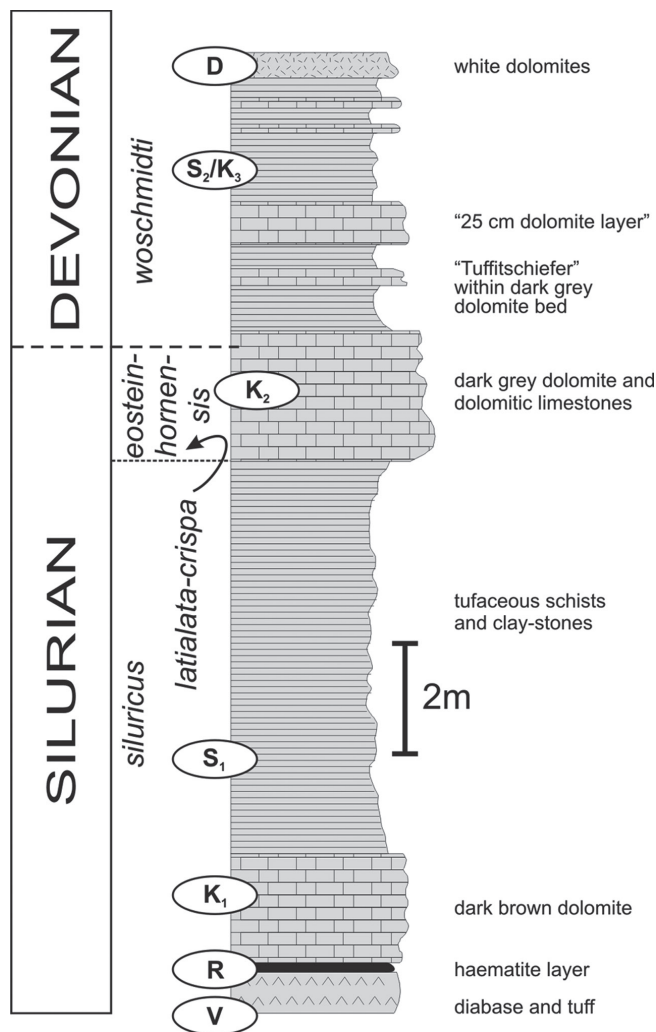
The Eggenfeld Section is not easily accessible, as it is located at an altitude of 440 m within a forest on a steep slope on the flank of Eggenberg Hill, located north of the village of Eggenfeld in the surroundings of Graz (Styria, Austria). The richness of Silurian fossils at this locality had long been noted during early geological surveys in the area, however, surprisingly few systematic studies or collections of these faunas were ever carried out (see above). The second author (F.M.) has been collecting fossiliferous material at this locality over many years, in particular in the interval between 2000 and 2009, from loose blocks in rockfalls below the K1 and K2 levels (Text-Fig. 2).

He has a profound knowledge of the faunas occurring in the area and has worked in close collaboration with research groups at the University of Graz on a variety of projects (HUBMANN et al., 2003; HUBMANN & MESSNER, 2005, 2007; MESSNER, 2009). Even if the specimens have not been collected *in situ*, there is no doubt about the age of the material, as individual units of the bioclastic limestone/dolomitic strata are quite distinctive. After collection, the specimens are individually numbered, catalogued, photographed and stored within the second author's own personal collection and, given a provisional identification and taxonomic assignment. The Messner Collection includes other fossil groups such as bivalves, brachiopods, corals, and trilobites of Silurian/Devonian age. After publication, specimens from the Messner Collection are housed at the Universalmuseum Joanneum, Department for Geology & Palaeontology (Graz, Austria) where they are accessible for further study.

The nautiloid specimens studied herein originate from the K1 level and were prepared using a pneumatic preparation tool and a small chisel. Longitudinal sections were made using a modified tile-cutting machine and then polished by hand using a 1,200 grade of grit sandpaper. Photographs taken using a Nikon Coolpix 5000, D70, D800 and D850 (F.M.) and Nikon D3000 with macro zoom lens and Traveler USB Microscope images (K.H.). The specimens were studied using a Reichert (Austria) binocular microscope and measurements taken using standard vernier calipers. The terminology and measurements used in descriptions accord with the Treatise Part K (TEICHERT, 1964).

### Stratigraphy and Associated Faunas

The associated faunas within the K1 horizon include conodonts denoting the *Polygnathoides siluricus* conodont biozone (EBNER, 1976). The discovery of *Bohemograptus bohemicus tenuis* within a tuffitic layer at the base of the section within the Kehr Formation (HIDEN, 1996) confirms the presence of the *Leintwardinensis* graptolite biozone, indicating that Level K1 is younger than the base of the *Leintwardinensis* graptolite biozone. Crinoids, rare small brachiopods and tabulate corals were figured in HUBMANN & MESSNER (2005: Pl. 3). A varied bivalve fauna has been collected from the K1 level by the second author (F.M.) and the specimens are figured herein with tentative generic assignments but are not systematically described (Pl. 8). The assemblage includes *Cardiola* sp., *Cardiola* cf. *alata*, *Cardiola* cf. *conformis*, *Cardiolinka* cf. *bohémica*, and forms compared with *Dualinids* (KŘÍŽ, pers. comm., 2020). The bivalve assemblage has been compared with the bivalve communities of Ludfordian age in the Prague Basin (KŘÍŽ, 1979; 1999a; 2007; MANDA & KŘÍŽ, 2006) and other localities such as SW Sardinia (KŘÍŽ & SERPAGLI, 1993), the Carnic Alps (KŘÍŽ, 1999b) and the Frankenwald in Germany (KŘÍŽ, 2011) in order to determine a precise placement of the K1 level within the cephalopod limestone biofacies intervals defined for the Silurian (KŘÍŽ, 1998). Both, the bivalve and nautiloid assemblages suggest that the level is comparable with the *Cardiola alata* – *Cardiola conformis* Bivalve Communities of Ludfordian age (KŘÍŽ, pers. comm., 2020).



Text-Fig. 2. Stratigraphy of the Eggenfeld Section. The haematite layer (R) separates rocks of the Kehr Formation (below) from the Kötschberg Formation (above). V – diabase and tuffs; K – carbonates; S – tufaceous schists; D – dolomite. After HIRSTON et al. (2010: Fig. 4).



## Taphonomy of the Nautiloid Assemblage

The variety of taphonomic features observed in the cephalopod-bearing horizons at the Eggenfeld Section were described and illustrated with four representative samples by HISTON et al. (2010: 70–71; Figs. 5–8) who discussed the palaeogeographical distribution, depositional setting and microfacies of the Silurian cephalopod limestones as well as the typical features of this recurring biofacies.

FERRETTI & KŘÍŽ (1995) carried out a detailed microfacies study of diverse horizons of the cephalopod limestone biofacies in the Prague Basin, recognising two distinct depositional environments: one in a deeper setting, but influenced by surface currents and one within a shallower setting affected by storm action. The cephalopod-bearing beds from the K1 portion of the Eggenfeld Section also show diverse orientation of the nautiloid conchs on the bedding surfaces and taphonomic features which are indicative of small-scale depositional cycles within this succession. The uni-directional orientation of fragmented conchs, sometimes showing opposed apical directions within a fossil hash (HISTON et al., 2010: Figs. 6–7; see also HIDEN, 1996: Fig. 3; HUBMANN & MESSNER, 2007: Pl. 1) may indicate deposition by surface currents as illustrated by HUBMANN & MESSNER (2007: Pl. 1, Fig. 3) for the Kotschberg Formation of the Graz Palaeozoic. Taphonomic features such as clustering of smaller orthoconic shells alongside oriented large specimens, sheltering by benthic faunas such as trilobites within empty shells (Pl. 1, Fig. 1) and telescoping of smaller shells within larger conchs are commonly observed (see also HIDEN, 1996: Fig. 4; HUBMANN & MESSNER, 2007: Pl. 1, Fig. 1). The perpendicular orientation of conchs to one another (HISTON et al., 2010: Fig. 5; see also HIDEN, 1996: Pl. 1, Fig. 5) may indicate deposition by a bi-modal current with episodes of higher energy within a more-shallower setting such as that illustrated by HUBMANN & MESSNER (2007: Fig. 3) for the underlying Kehr Formation.

The fossiliferous material has clearly also suffered the effects of dolomitization as corrosion of the conch surface and friability of the specimens, preserved for the most part as moulds has rendered identification of external ornament problematic, and sectioning to reveal internal morphology largely unsuccessful.

## Diversity and Palaeobiogeography

As stated in the general discussion in the first paper of this series on the Silurian nautiloid cephalopods from the Eggenfeld Section of the Graz Palaeozoic the importance of nautiloid cephalopods for biostratigraphy and palaeobiogeography is dependent on detailed systematic studies within precisely constrained stratigraphic intervals (HISTON et al., 2010: 70–72; EVANS et al., 2014). The Silurian Cephalopod Limestone Biofacies is well developed all along the northern Gondwana margin and these horizons with rich nautiloid and bivalve faunas may be traced from Morocco, the Ossa Morena Zone (SW Spain), Montagne Noire (France), SW Sardinia, the Carnic Alps, the Prague Basin as well as to North Asia (KŘÍŽ, 1998; HISTON et al., 2010 and references therein). The present systematic study of

the Ludfordian in age nautiloid assemblage from the K1 level (Text-Fig. 2) now also documents through comparison of the diversity of the mainly pelagic and nektonic species the presence of another example of this biofacies within the Graz Palaeozoic depositional setting.

## Diversity of the Nautiloid Fauna

Based on the study of over 800 specimens, the nautiloid cephalopod assemblage consists of 33 species belonging to 18 genera representing seven families and two orders. Most specimens are fragmented and form a fossil-hash accumulation within dark grey, bedded dolomites and/or dolomitic limestones differentiated on the basis of their microfacies into bioclastic dolosparites to biodolosparites (see details in HUBMANN & MESSNER, 2007; HISTON et al., 2010 and references therein). Thirty-two genera of the Orthocerida are documented and their longiconic forms with a nektonic mode of life include *Michelinoceras*, *Kopaninoceras*, *Plagiostomoceras*, *Temperoceras*, *Columenoceras* and *Geisonoceras*, which dominate the assemblage both in individual numbers and specific diversity. The frequently occurring orthoconic annulated forms, including *Metaspyroceras*, *Calorthoceras* and *Orthocycloceras*, as well as those with longitudinal ornament such as *Kionoceras* and *Parakionoceras* show a greater generic than specific diversity, and represent typical elements of pelagic communities in outer shallow shelf environments.

The orthoconic annulated forms have been distinguished on the basis of their ornamentation into three groups: reticulate, transverse, and longitudinal. The latter are by far the most numerous. It should be noted, however, that due to the poor preservation of the ornamentation, this has led to much difficulty in determination, especially where other features are not observed and hence some clarification is needed herein in support of these assignments. The reticulate annulated forms assigned to *Calorthoceras* show longitudinal ribbing that is quite dense and lacks the typical widely spaced stronger ribbing. This is thought to be due to the poor preservation of the conch surfaces and dolomitic nature of the sediment. *Metaspyroceras* taxa have been separated from the latter by their oblique annulations and suture form. Many of the longitudinally densely ribbed, more apically annulated forms are assigned tentatively to *Parakionoceras* as the ornament seems to justify this, however, other annulated forms showing only longitudinal striae are assigned with doubt as Gen. et sp. indet. to the Kionoceratinae. Juvenile *Columenoceras* specimens showing annulations and transverse striae have been distinguished from those of *Orthocycloceras* taxa on other features including the conch form, less rounded annulations, fading of annulations apically, cameral depth and siphuncle size. Yet again, this has proved to be problematic due to their preservation. *Cyrtocycloceras* has been distinguished from the latter on the basis of its more rapidly tapering form.

The assemblage may be compared with longer ranging elements of the coeval Southwest Sardinian occurrences (GNOLI & SERPAGLI, 1991) of the *Merocycloceras declive* – *Cryptocycloceras? deludens* Silurian nautiloid assemblage occurring in the *A. ploeckensis* and *P. siluricus* conodont biozones. However, six of the seven taxa of the succeeding *Kopaninoceras thyrus* – *Orthocycloceras fluminese* assemblage of the later

*Oz. crista* – *Oz. snajdri* to *O. easteinhornensis* – *I. waschmidtii* conodont biozones are documented from the K1 horizon. Therefore, the Eggenfeld assemblage shows more affinities with the *Merocycloceras declive* – *Cryptocycloceras? deludens* assemblage, which is dominated by a more cosmopolitan nektonic fauna even though this assemblage seems to be slightly younger in age. The assemblage compares well with that of the cephalopod limestone interval of the *Cardiola alata* – *Cardiola conformis* Bivalve Communities defined by Kříž (1998) as eight of the 15 commonly occurring in this assemblage nautiloids are present.

There has been no findings of juvenile taxa such *Sphaerorthis* or *Hemicosmoceras*, which may be indicative of a turbulent environment not suited to their preservation, however, they are frequently found in coeval assemblages from similar depositional settings in the Carnic Alps, SW Sardinia and the Prague Basin therefore their absence here may have significance. In addition, there is also the absence of any new taxa, especially at specific level. Some poorly preserved orthoconic specimens are left in open nomenclature for now pending further study as indeterminate orthocones (approx. 5 % of the collection) and have not been described systematically below. However, nearly all have been assigned at least to generic level. The lack of juveniles and new taxa may indicate that the assemblage represents a *Biotic Migration Event* as defined by STIGALL et al. (2017) which record the large-scale dispersal of taxa from one biogeographic area to another and such faunas in particular are lacking new species. This episode of migration of nautiloid faunas into this depositional area could have been facilitated during the Ludfordian *Kozłowskii* Event marked by a global sea-level highstand.

### Palaeobiogeography of the Nautiloid Fauna

Those taxa representing shallower water pelagic nautiloid species described here are common to Bohemia (MANDA & Kříž, 2006), the Graz Palaeozoic and the Carnic Alps, indicating free faunal exchange between the three areas, and their likely close proximity during the Ludfordian interval of the late Silurian. The more nektonic elements of the faunas reflected exchange between the various North Gondwana terranes, as well as with Baltica and the Urals; the latter possibly via the Southern Tropical Current (MANDA, 2008). The presence of the cosmopolitan nektonic longiconic form *Temperoceras* is significant. *Temperoceras* occurs within the Ludfordian all along the North Gondwana area, sometimes forming a distinctive layer of aligned specimens on the bedding plane often referred to in the literature as the *Temperoceras* beds, horizons or limestone. The *Temperoceras* beds were identified as a *Time Specific Facies* by HISTON (2012a, b). *Temperoceras*, is widespread in the Wenlock and in particular the Ludlow strata of England and the Welsh Borderlands, emphasizing the possibility of migration events originating from Avalonia.

The presence of a bivalve assemblage representative of the *Cardiola alata* – *Cardiola conformis* Bivalve Communities (see chapter “Stratigraphy and associated faunas” above and Plate 8) recognized in Bohemia and the Carnic Alps provides additional support of faunal exchange during this interval between the Peri Gondwana Terranes. Both, the nautiloid and bivalve assemblages documented herein al-

low a precise comparison with the *Neocucullograptus kozłowskii* Event during the Ludfordian in the Prague Basin, which coincides with both climatic and ocean circulation changes leading to a globally recognized sea level highstand (MANDA & Kříž, 2006). As this event is placed within a stratigraphic interval which post-dates the *Bohemograptus bohemicus tenuis* graptolite biozone and is contemporaneous with the *Polygnathoides siluricus* conodont biozone (MANDA & Kříž, 2006) it may be inferred that deposition of the K1 cephalopod-bearing level at the Eggenfeld Section was also a consequence of this event, as there is a sudden change from a shallow-shelf environmental setting as a distinct nektonic and pelagic fauna is introduced into the assemblage. This change may be compared to the deposition of the cephalopod limestones of the *Cardiola* Formation in the Carnic Alps during the highstand maximum of the *Polygnathoides siluricus* conodont biozone interval (BRETT et al., 2009).

In contrast to studies on the late Silurian faunas from the Austrian Carnic Alps, the Italian Carnic Alps, SW Sardinia, Morocco and the Prague Basin, to date, the Graz Palaeozoic assemblages have not played a part in palaeobiogeographic reconstruction models for inference of microterran positions, sea level oscillations and tropical/cool current regime and migrational seaways along the North Gondwana Margin and across the Rheic Ocean (FRANKE et al., 2017; TORSVIK & COCKS, 2013, 2017; VON RAUMER et al., 2013, 2015). The K1 level cephalopod limestone was deposited contemporaneously with those in the Ludfordian of Morocco (KRÖGER, 2008), Elbersreuth in the Frankenthal of Germany (HELLER, 1925; Kříž, 2011), the Carnic Alps of Austria (BRETT et al., 2009; HISTON, 2012b) and the Prague Basin (MANDA & Kříž, 2006) and shows comparable nautiloid and bivalve assemblages. It therefore has relevance as a biostratigraphical marker within the Silurian. Concluding discussion of the palaeodiversity and palaeobiogeographical implications of the Eggenfeld Section upper Silurian to Lower Devonian nautiloid assemblages will be included in the final paper of this series.

## Systematic Palaeontology

### Introductory Note

The higher taxonomic classification system of the Treatise (MOORE, 1964) has been followed where possible with modifications based on more recent systematic works where appropriate. Synonymies include only the original systematic descriptions of the species in question or publications where new generic combinations have been cited. Sectioning of selected specimens was carried out in order to facilitate identification; however, significant internal features are rarely seen clearly due to recrystallization or the fragmentary and dolomitic nature of the specimens. This has led to some taxa being assigned with doubt. A small percentage of the material from the collection were too badly preserved to be identified to generic level and are referred to here as indeterminate orthocones, but not included below under the systematic descriptions. The first author (K.H.) is solely responsible for the systematic descriptions and taxonomic assignments of the nautiloid faunas, as well as the conclusions drawn regarding

their palaeobiogeographical affinities. The second author (F.M.) carried out the field collection, stratigraphic collocation, preparation of specimens, and all the photography. The Messner Collection of nautiloid cephalopods from the Eggenfeld Section (Graz Palaeozoic, Austria) studied herein is housed in the Universalmuseum Joanneum, Department for Geology & Palaeontology (Graz, Austria) under accession numbers UMJGP 211325–UMJGP 211334 and UMJGP 220093–UMJGP 220145, UMJGP 220156–UMJGP 220191. In some descriptions below several specimens are included as additional material under one single number. The associated fauna of bivalves figured herein is housed under accession numbers UMJGP 220146 to UMJGP 220155.

## Systematics

### Class Cephalopoda CUVIER, 1797

### Subclass Actinoceratoidea TEICHERT, 1933

### Order Actinocerida TEICHERT, 1933

### Family Ormoceratidae SAEMANN, 1853

### Genus *Metarmenoceras* FLOWER, 1940

**Type species:** By original designation *Metarmenoceras bilaterale* FLOWER, 1940. Gaspé, Canada. Lower Devonian.

**Diagnosis:** Small orthoconic conch, armenoceroid siphuncle, compressed central canal, bilateral radial canals branching off at right angles.

### *Metarmenoceras?* sp.

(Pl. 1, Figs. 2–4)

**Material studied:** One specimen – UMJGP 220186. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** The specimen consists of a longitudinally sectioned orthocone measuring 93 mm in length preserved on a polished block of cephalopod-bearing limestone. It is incomplete both apically and adorally with maximum diameter adorally of 13 mm and minimum diameter apically of 7 mm. Conch expands at an angle of 4°. The cross-section of the conch is difficult to determine due to the obliqueness of the section but is assumed to be circular. The body chamber is long being 76 mm in length. Two cameral chambers are preserved with transverse sutures that laterally slope slightly adorally, cameral depth being about 25 %. The position of the siphuncle in the polished sectioned specimen is not clear and is assumed to be subcentral to subventral. Siphuncle globular in form, expanded within the cameral chamber with width greater than length in the ratio 5:4. The siphuncular segment preserved is observed as a globular trace with the darker calcitic remnant of the annulosiphonate deposit showing a medial trace comparable to a central canal and less distinct lateral branching. Septal necks apparently cyrtochoanitic.

**Remarks:** The specimen is very poorly preserved and provides little information for identification except the globular siphuncular segments and remnants of endosiphuncular deposits and a canal system making it comparable to the Actinocerids. It is assigned with doubt to *Metarmenoceras* Flower.

**Silurian occurrence:** Graz Palaeozoic.

**Silurian Range:** Ludfordian.

### Subclass Nautiloidea AGASSIZ, 1847

### Order Orthocerida KUHN, 1940

### Superfamily Orthocerataceae M'COY, 1844

### Family Orthoceratidae M'COY, 1844

### Subfamily Michelinoceratinae FLOWER, 1945

### Genus *Michelinoceras* FOERSTE, 1932

**Type species:** By original designation *Orthoceras michelini* BARRANDE, 1866. Bohemia Faunes Silurien III, etage E (e2), F (f2).

**Diagnosis:** Long, slender, subcylindrical orthocones, circular cross-section, long camerae, long body chamber, siphuncle central to subcentral, cylindrical in form, empty, septal necks orthochoanitic, cameral deposits developed.

### *Michelinoceras* cf. *currens* (BARRANDE, 1866)

(Pl. 1, Figs. 5–9)

1860 *Orthoceras currens* BARRANDE. – BARRANDE, 624 (*nomen nudum*).

1866 *Orthoceras currens* BARRANDE. – BARRANDE, Pls. 221, 222.

1870 *Orthoceras currens* BARRANDE. – BARRANDE, Pls. 407, 411.

1874 *Orthoceras currens* BARRANDE. – BARRANDE, 628.

1962 *Michelinoceras currens* (BARRANDE). – FLOWER, 10.

**Type species:** By original designation *Orthoceras currens* BARRANDE, 1866. Bohemia, Faunes Silurien III, etage E (e2).

**Diagnosis:** As for genus, expansion angle 4–5°, relatively short camerae.

**Material studied:** Three specimens – UMJGP 211331, UMJGP 220187, UMJGP 220188. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** Based on UMJGP 211331. The orthoconic specimen is incomplete apically and adorally and consists of the body chamber and a portion of phragmocone 80.1 mm in length. The cross-section is almost circular with maximum diameter adorally 12 mm and minimum apically 6 mm. Conch expands at an angle of 4–5°. The conch surface is smooth. The junction of the phragmocone and body chamber is directly transverse. Sutures are straight, directly transverse and widely spaced, being more than



four fifths the conch diameter in depth. The siphuncle is central in position and one tenth the conch diameter.

In the sectioned specimens UMJGP 211331 and UMJGP 220188 (Pl. 1, Figs. 7, 9) the septal depth is approximately four fifths the conch diameter. Siphuncle central and cylindrical, however, exposure not always complete in the polished sections studied therefore foramen width approximately between one tenth to one twelfth of conch diameter. The septal necks may be observed even if the siphuncular segments are not clearly exposed and are equal in length to the foramen. No cameral or siphonal deposits preserved.

**Remarks:** The slender conch, narrow siphuncle and chamber length allow the specimens to be assigned to *Michelinoceras currens* (BARRANDE). It differs from *M. michelini* in the greater angle of expansion, shorter camerae and narrower siphuncle.

**Silurian occurrence:** Carnic Alps of Austria and Italy, upper Silurian of SW Sardinia, Bohemia and Middle Asia.

**Silurian Range:** Silurian.

#### ***Michelinoceras cf. michelini* (BARRANDE, 1866)**

(Pl. 1, Figs. 10–12)

- 1866 *Orthoceras michelini* BARRANDE. – BARRANDE, Pl. 221.  
1870 *Orthoceras currens* BARRANDE. – BARRANDE, Pls. 381, 442, 447.  
1874 *Orthoceras currens* BARRANDE. – BARRANDE, 642.  
1932 *Michelinoceras michelini* (BARRANDE). – FOERSTE, 51.  
1962 *Michelinoceras michelini* (BARRANDE). – FLOWER, 10.

**Type species:** By original designation *Orthoceras michelini* BARRANDE, 1866. Bohemia Faunes Silurien III, etage E (e2), F (f2).

**Diagnosis:** as above for genus, elongate, slender slowly expanding conch, long camerae, narrow central siphuncle.

**Material studied:** Three specimens – UMJGP 220189, UMJGP 220190, UMJGP 220191. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** Based on UMJGP 220190. The orthoconic specimen is incomplete apically and adorally and consists of the body chamber and a portion of phragmocone 120.2 mm in length. The cross-section is almost circular with a maximum diameter adorally of 13 mm and minimum apically of 5 mm. Conch expands at an angle of 3°. The conch surface is smooth. The junction of the phragmocone and body chamber is directly transverse. The sutures are straight, directly transverse and widely spaced, their distance apart being more than twice the conch diameter. The siphuncle is central in position and one twelfth of the conch diameter. In the sectioned specimen, the septal depth is approximately 100 % the conch diameter. Siphuncular segments are not preserved. No cameral or siphonal deposits preserved.

**Remarks:** The diagnostic slender conch, long chambers and distinctive small siphon allow these specimens to be compared only with *Michelinoceras michelini* (BARRANDE), however, as the internal morphology is not preserved a definitive assignment is not possible.

**Silurian occurrence:** Cosmopolitan species: Bohemia, Carnic Alps of Austria and Italy, France, Graz Palaeozoic, Morocco, upper Silurian of SW Sardinia, Kazakhstan and Middle Asia, Japan, China, USA.

**Silurian Range:** Silurian.

#### **Genus *Merocycloceras* RISTEDT, 1968**

**Type species:** By original designation *Merocycloceras declivis* RISTEDT, 1968. Rauchkofel Boden, Carnic Alps, Austria. Lower Ludlow.

**Diagnosis:** Slender, orthoconic annulated conch, slowly tapering, annulations slightly oblique more pronounced apically, compressed cross-section, sutures transverse, distant one third conch diameter, siphuncle subcentral, septal necks orthochoanitic.

#### ***Merocycloceras cf. declivis* RISTEDT, 1968**

(Pl. 1, Figs. 13–14)

- 1968 *Merocycloceras declivis* RISTEDT. – RISTEDT, 247, Pl. 1, Figs. 8, 9–11, Text-Fig. 3:3D.

**Type species/Diagnosis:** as above for genus.

**Material studied:** One specimen – UMJGP 211330. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** The specimen is incomplete apically and adorally and consists of a portion of phragmocone 110 mm in length. The cross-section is circular with maximum diameter of 10.6 mm adorally and a minimum 6.1 mm apically. The conch expands slowly at an angle of 4°. The annulations are slightly oblique at c. 8° to the plane normal to the conch axis. Annulations number c. 3–4 per 5 mm adapically. Faint traces of ornament preserved consisting of fine longitudinal striations. Sutures not observed. The siphuncle is central in position apically and one sixth the conch diameter. No internal features observed.

**Remarks:** The specimen has only been studied externally and even if the annulated conch possesses the typical features of the genus, due to the presence of longitudinal ornament and the lack of data regarding internal morphology it is here only compared to *Merocycloceras declivis* RISTEDT.

**Silurian occurrence:** Carnic Alps of Austria and Italy, Graz Palaeozoic, upper Silurian of SW Sardinia, Morocco.

**Silurian Range:** upper Silurian.



## Genus *Kopaninoceras* KISELEV, 1969

**Type species:** By original designation *Orthoceras jucundum* BARRANDE, 1870, Pl. 380. Bohemia, Faunes Silurien III, etage E (e2).

**Diagnosis:** Orthoconic to slightly cyrtoconic longicones, circular or slightly depressed cross-section, ornament of growth lines, long camerae, sutures straight, transverse to slightly oblique, siphuncle central to slightly eccentric, narrow, cylindrical, empty, septal necks long and funnel-shaped, lacking cameral deposits.

### *Kopaninoceras* cf. *jucundum* (BARRANDE, 1870)

(Pl. 2, Figs. 1–8)

- 1870 *Orthoceras jucundum* BARRANDE. – BARRANDE, Pls. 380, 409.  
1874 *Orthoceras jucundum* BARRANDE. – BARRANDE, Texte III, 518.  
1969 *Kopaninoceras jucundum* (BARRANDE, 1870). – KISELEV, 14.  
1977 *Kopaninoceras jucundum* (BARRANDE, 1870). – SERPAGLI & GNOLI, 160–161, Pl. 1, Figs. 1a–1b, Text-Fig. 3.  
2010 *Michelinoceras* sp. – HISTON et al., Pl. 1, Fig. 6.

**Type species:** By original designation *Orthoceras jucundum* BARRANDE, 1870, Pl. 380. Bohemia, Faunes Silurien III, etage E (e2).

**Diagnosis:** As above for genus, expansion rate c. 8°, ornament of numerous fine transverse growth lines, cameral depth two-thirds conch diameter, siphuncle narrow one tenth conch diameter, septal neck long being 2:1 width septal foramen.

**Material studied:** Three specimens – UMJGP 220174–UMJGP 220176. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** Based on UMJGP 220174. This specimen is incomplete apically and adorally and consists of part of the body chamber and a portion of phragmocone 80.2 mm in length. The cross-section is almost circular with a maximum diameter adorally of 17.2 mm and a minimum apically of 8 mm. The conch expands at an angle of 7°. The conch shows transverse striations, numbering c. 2 per mm adapically, and sometimes irregular in outline but present over most of the conch. They become finer adorally, and in some specimens, the ornament is very fine at 5–6 striations per mm. The junction of phragmocone with the body chamber is apparently directly transverse. The sutures are straight, directly transverse and widely spaced, having a cameral depth more than two-thirds the conch diameter where exposed apically. The siphuncle is central in position and narrow at one tenth the conch diameter.

In the sectioned specimens UMJGP 220174 and UMJGP 220176 (Pl. 2, Figs. 3, 4, 7, 8) the sutures are transverse and cameral depth more than half the conch diameter, with septal depth approximately one third conch diameter. The siphuncle is central and cylindrical. As it is not

clear whether the polished sections exactly bisect the siphuncle, it is difficult to ascertain the exact diameter of the septal foramen. Measurements vary from one tenth to one sixteenth of the conch diameter. The long funnel-like septal necks may be observed even if the siphuncular segments are not clearly exposed. The septal necks appear to be equal to or slightly longer than the width of the septal foramen.

**Remarks:** This material is compared with *Kopaninoceras jucundum* (BARRANDE) based on the cameral depth, angle of expansion and length of the funnel-like septal necks. The transverse ornament is not as fine as that given in the diagnosis for the species in some specimens, but the internal morphology is closer to *K. jucundum* than *K. thyrsus* (BARRANDE), and therefore they are placed within the former taxon.

**Silurian occurrence:** Cosmopolitan species with widespread occurrence; Carnic Alps of Austria and Italy, Graz Palaeozoic, upper Silurian of SW Sardinia, Bohemia and Middle Asia, Morocco, Malaysia, Russia, Kirgizistan, Tibet (China), China, Japan.

**Silurian Range:** Silurian, predominantly upper Silurian.

### *Kopaninoceras* cf. *thyrsus* (BARRANDE, 1870)

(Pl. 2, Figs. 9–12)

- 1870 *Orthoceras thyrsus* BARRANDE. – BARRANDE, Pl. 405.  
1874 *Orthoceras thyrsus* BARRANDE. – BARRANDE, Texte III, 555.  
1977 *Kopaninoceras?* *thyrsus* (BARRANDE, 1870). – SERPAGLI & GNOLI, 161, Pl. 1, Figs. 4a–4b.

**Type species:** By original designation *Orthoceras thyrsus* BARRANDE, 1870. Bohemia, Faunes Silurien III, etage E (e2).

**Diagnosis:** As for genus, ornament of fine growth lines numbering 1–2 per mm, cameral depth ranging from minimum 50 % to 100 % conch diameter, siphuncle slightly eccentric, one tenth conch diameter, septal neck long being 1.5 width septal foramen.

**Material studied:** Four specimens – UMJGP 220177–UMJGP 220180. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** Based on UMJGP 220177. The specimen is incomplete apically and adorally and consists of the body chamber and a portion of phragmocone 34.5 mm in length. The cross-section is almost circular with maximum diameter adorally 19.6 mm and minimum apically 17.1 mm. Conch expands at an angle of 4°. The conch shows very fine transverse striations, numbering c. 4–5 per mm, sometimes irregular in outline but present over most of the conch. The junction of phragmocone and body chamber is apparently directly transverse. The position of the siphuncle is observed apically where it is subcentral with a width one tenth of the conch diameter.

In the sectioned specimens (but based mainly on UMJGP 220180), the sutures are transverse and cameral depth approximately two thirds the conch diameter. The septal

depth being one third of diameter. Siphuncle central and narrow, width of septal foramen being 1.5 mm, approximately one twelfth of conch diameter. Septal necks long approximately 2 mm and observed to be funnel-like where the section is fully sagittal.

**Remarks:** The specimens studied possess the diagnostic funnel-like septal necks of *Kopaninoceras* and are compared herein with *K. thyrsus* on the basis of the long cameral chambers and relative length of the septal foramen and septal necks.

**Silurian occurrence:** Carnic Alps of Austria, upper Silurian of SW Sardinia, Bohemia and Middle Asia, Morocco.

**Silurian Range:** upper Silurian.

### Genus *Plagiostomoceras* TEICHERT & GLENISTER, 1952

**Type species:** By original designation *Orthoceras pleurotomum* BARRANDE, 1866.

Bohemia, Faunes Silurien III, etage E.

**Diagnosis:** Long, slender orthocones, circular to slightly depressed cross-section, sutures straight to slightly oblique, development lateral lobes, aperture oblique, sometimes sinuous, ornament of growth lines and weak ridges, siphuncle central to excentric, orthochoanitic.

#### *Plagiostomoceras* cf. *gruenewaldti* (BARRANDE, 1866)

(Pl. 2, Figs. 13–15)

- 1866 *Orthoceras gruenewaldti* BARRANDE. – BARRANDE, Pl. 217.
- 1868 *Orthoceras gruenewaldti* BARRANDE. – BARRANDE, Pl. 315.
- 1874 *Orthoceras gruenewaldti* BARRANDE. – BARRANDE, Texte III, 273.
- 1977 *Plagiostomoceras gruenewaldti* (BARRANDE). – SERPAGLI & GNOLI, 168–169, Pl. 3, Figs. 3–4.
- 2010 *Plagiostomoceras* sp. – HISTON et al., Pl. 1, Fig. 1.

**Type species:** By original designation *Orthoceras gruenewaldti* BARRANDE, 1866. Bohemia, Faunes Silurien III, etage E (e2).

**Diagnosis:** As for genus, expansion rate 4–5°, fine transverse adorally imbricating ridges, numbering c. 3 per mm, shallow dorsal and ventral lobe, camerae short being one third conch diameter, siphuncle subcentral, narrow being one tenth conch diameter.

**Material studied:** Two specimens – UMJGP 220181, UMJGP 220182. Additional material: UMJGP 220183 – 10 specimens. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** UMJGP 220182 is incomplete apically and adorally and consists of the body chamber and a portion of phragmocone 30.5 mm in length. The cross-section is almost circular with maximum diameter adorally 12.8 mm

and minimum apically 9.4 mm. The conch expands at an angle of 6°. The conch shows transverse ridges imbricating adorally, regularly spaced and c. 1 mm in width and present for the full length of the preserved conch. A distinct, but shallow lateral lobe is present and becomes more pronounced adorally. The junction of the phragmocone and body chamber is not exposed.

The sectioned specimen representing UMJGP 220181 is incomplete apically, a long body chamber is present, but due to breakage, the aperture is not preserved. The junction of the phragmocone and the body chamber are apparently directly transverse. The septa are transverse and cameral depth is approximately two fifths the conch diameter. The septal depth is approximately one third of the conch diameter and the septa arch slightly laterally. The siphuncle appears to be central and narrow, its width is difficult to ascertain, but is approximately one tenth of conch diameter adorally.

**Remarks:** All the studied specimens possess the diagnostic ornament of *Plagiostomoceras gruenewaldti* (BARRANDE), to which they have been compared, even if in most of the material the internal features are not preserved. One sectioned specimen possesses the long body chamber typical of the genus and the narrow siphuncle can be seen in apical portions of most specimens exhibiting a transverse section.

**Silurian occurrence:** Carnic Alps of Austria and Italy, upper Silurian of SW Sardinia, Bohemia and Middle Asia, Morocco.

**Silurian Range:** upper Silurian.

### Subfamily Kionoceratinae HYATT in ZITTEL, 1900

#### Genus *Kionoceras* HYATT, 1884

**Type species:** By original designation *Orthoceras doricum* BARRANDE, 1868. Bohemia, Faunes Silurien III, etage E (e2).

**Diagnosis:** Slender to rapidly expanding orthocones, apically curved and sometimes faintly annulated, cross-section circular to subcircular, longitudinally fluted, ornament of prominent longitudinal ribs separated by concave interspaces bearing finer longitudinal and transverse striae. Siphuncle central to subcentral, empty, septal necks suborthochoanitic, segments cylindrical or weakly expanded, annulosiphonate deposits sometimes present.

#### *Kionoceras* cf. *bronni* (BARRANDE, 1868)

(Pl. 3, Fig. 1)

- 1868 *Orthoceras bronni* BARRANDE. – BARRANDE, Pl. 258.
- 1874 *Orthoceras bronni* BARRANDE. – BARRANDE, Texte III, 239–241.

**Type species:** By original designation *Orthoceras bronni* BARRANDE, 1868. Bohemia, Faunes Silurien III, etage E (e2).

**Diagnosis:** As for genus, expansion rate 8°, camera short, 25 % of conch diameter, siphuncle subcentral, one sixth conch diameter, strongly developed longitudinal ribs number c. 50 around conch circumference.

**Material studied:** Two specimens – UMJGP 220156, UMJGP 220164. Additional material: two specimens – UMJGP 220165. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** Specimen UMJGP 220164 is incomplete both apically and adorally and consists of a portion of phragmocone 52.9 mm in length. The cross-section is circular. The maximum diameter adorally is 25.1 mm, minimum apically 19.6 mm. The conch expands at an angle of c. 10°. The surface is somewhat corroded but shows longitudinal ribs, which, where observed number c. five per 5 mm or 27 around the half-circumference of the conch apically, with the intervening flattened spaces measuring c. 1 mm in width. The crests of the ribs appear rounded but become more well defined adorally. Faint transverse striae may be observed in places between the ribs. These number c. 3 per mm. Minor longitudinal ribbing between the main ribs is also observed in places but is poorly preserved. The surface of the conch consists of two layers approximately 0.5 mm in thickness. Four sutures are preserved. They are apparently straight and transverse. Cameral depth is 30 % at a conch diameter of 22 mm. The apical transverse section of the conch shows the siphuncle to be slightly sub-central in position. The diameter of the septal foramen is 3.0 mm at conch diameter 19.6 mm, or approximately one sixth the conch diameter. Internal features not observed.

**Remarks:** These specimens are poorly preserved, but a tentative comparison with *Orthoceras bronni* BARRANDE is based on the ornament, rate of expansion of the conch and position of the siphuncle.

**Silurian occurrence:** Bohemia, Graz Palaeozoic.

**Silurian Range:** upper Silurian.

### ***Kionoceras doricum* (BARRANDE, 1868)**

(Pl. 3, Figs. 2–4)

1868 *Orthoceras doricum* BARRANDE. – BARRANDE, Pl. 269.

1874 *Orthoceras doricum* BARRANDE. – BARRANDE, Texte III, 242–243.

1884 *Kionoceras doricum* (BARRANDE). – HYATT, 275.

**Type species:** By original designation *Orthoceras doricum* BARRANDE, 1868. Bohemia, Faunes Silurien III, etage E (e2).

**Diagnosis:** As for genus, expansion rate 8°, camera short, 20 % of conch diameter, siphuncle slightly excentric from centre, one eighth conch diameter, prominent longitudinal ribs c. 2 mm apart, numbering c. 20–25 around conch circumference, intermediate spaces between ribs show finer longitudinal ribbing and transverse striations.

**Material studied:** Two specimens – UMJGP 220157, UMJGP 220166. Additional material: UMJGP 220167 – 10 specimens. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** Specimen UMJGP 220157 is incomplete both apically and adorally and consists of a portion of phragmocone 25.7 mm in length. The cross-section is circular. The maximum diameter adorally is 17.7 mm, minimum apically 15.2 mm. The conch expands at an angle of c. 7°. The surface shows longitudinal ribs, which number c. 5 per 5 mm and 25 around the half-circumference of conch where preserved. The intervening flattened spaces measuring c. 1 mm. The crests of the ribs are well defined adorally but are not sharp. Faint transverse striae may be observed under oblique light between the ribs numbering c. 3–4 per mm. The four sutures preserved are apparently straight and transverse. The camerae are short and 25 % at a conch diameter of 15 mm. The apical transverse section of the conch shows the siphuncle to be slightly sub-central in position. The diameter of the septal foramen is 2.5 mm at conch diameter 15.2 mm, or approximately one sixth of the conch diameter. Internal features not seen.

**Remarks:** This material is assigned to *Kionoceras doricum* (BARRANDE) based on the typical ornament, rate of expansion of the conch, cameral depth and siphuncle form and position. It differs from the specimens assigned here to *Parakionoceras originale* (BARRANDE) in the presence of flattened spaces between longitudinal ribbing that show transverse striations.

**Silurian occurrence:** Bohemia, British Isles, Carnic Alps of Austria and Italy, France, Graz Palaeozoic, Morocco, Poland, upper Silurian of SW Sardinia, Spain, Kazakhstan and Middle Asia.

**Silurian Range:** Silurian.

### ***Kionoceras* cf. *neptunicum* (BARRANDE, 1868)**

(Pl. 3, Figs. 5–6)

1868 *Orthoceras neptunicum* BARRANDE. – BARRANDE, Pls. 272–274, 322.

1870 *Orthoceras neptunicum* BARRANDE. – BARRANDE, Pls. 401, 443, 452.

1874 *Orthoceras neptunicum* BARRANDE. – BARRANDE, Texte III, 247–249.

**Type species:** By original designation *Orthoceras neptunicum* BARRANDE, 1868. Bohemia, Faunes Silurien III, etage E (e2).

**Diagnosis:** As for genus, expansion rate 7–10°, camerae short, 20 % of conch diameter, siphuncle slightly eccentric in position, one seventh conch diameter, longitudinal ribs closely spaced numbering c. 2–3 per mm, intermediate longitudinal finer ribbing numbering 3, with fine transverse striae.

**Material studied:** Three specimens – UMJGP 220158, UMJGP 220168, UMJGP 220169. Additional material: UMJGP 220170 – five specimens. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** UMJGP 220158 is incomplete both apically and adorally and consists of a portion of phragmocone and body chamber 21.8 mm in length. The cross-section is



circular. The maximum diameter adorally is 12.3 mm, minimum apically 9.7 mm. Conch expands slowly at an angle of c. 7°. The surface is poorly preserved, and the ornament is best observed under shadow. Longitudinal ribs are observed numbering c. 1 per mm, however, it was not possible to count the number within the half-circumference of the conch due to corrosion. The crest of the ribs appears rounded and the intervening flattened spaces measure c. 1 mm. A finer longitudinal ribbing is observed midway between the main ribs and faint transverse striae may be observed between these, numbering c. 3 per mm. Seven sutures are preserved, apparently straight and directly transverse, short camerae c. 20 % at conch diameter 12 mm. The apical transverse section of the conch shows the siphuncle to be slightly subcentral in position. Diameter of the septal foramen is 1.5 mm at conch diameter 9.7 mm, or approximately one sixth the conch diameter. Internal features not observed.

**Remarks:** Although the material studied is poorly preserved a tentative comparison with *Kionoceras neptunicum* (BARRANDE) is made based on the typical finely developed ornament and short camerae.

**Silurian occurrence:** Bohemia, Carnic Alps of Austria, Graz Palaeozoic.

**Silurian Range:** upper Silurian.

### Genus *Parakionoceras* FOERSTE, 1928

**Type species:** By original designation *Orthoceras originale* BARRANDE, 1868. Bohemia, Faunes Silurien III, etage E, F (f1).

**Diagnosis:** Faintly curved, uncompressed, exogastric longicones, sometimes annulated apically, long camerae, straight transverse sutures, ornament of sharp-edged longitudinal ribs separated by broad concave interspaces or grooves, siphuncle slightly excentric, empty, septal necks short, loxochonitic, connecting rings cylindrical but slightly inflated at septal neck.

#### *Parakionoceras originale* (BARRANDE, 1868)

(Pl. 3, Figs. 7–10)

- 1868 *Orthoceras originale* BARRANDE. – BARRANDE, Pl. 267.
- 1874 *Orthoceras originale* BARRANDE. – BARRANDE, texte III, p. 206–209.
- 1928 *Parakionoceras originale* (BARRANDE). – FOERSTE, 313
- 2010 *Parakionoceras* sp. – HISTON et al., Pl. 1, Fig. 3.

**Type species:** By original designation *Orthoceras originale* BARRANDE, 1868. Bohemia, Faunes Silurien III, etage E, F (f1).

**Diagnosis:** As above for genus, expansion rate 10–14°, cameral depth one third conch diameter, siphuncle subcentral, one tenth conch diameter.

**Material studied:** Four specimens – UMJGP 211328, UMJGP 220159–UMJGP 220161. Additional material: UMJGP 220171 – 10 specimens. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** UMJGP 220160 is incomplete both apically and adorally and consists of a portion of phragmocone and body chamber 70.4 mm in length. The cross-section is circular. The maximum diameter adorally is 25.5 mm, minimum apically 8.4 mm. The conch expands at an angle of c. 13°. The conch surface is well preserved on most specimens and the typical ornament is easily observed. Longitudinal ribs number c. 1 per mm, with c. 50–60 present around the circumference of the conch. The crests of the ribs are sharply defined, and the intervening grooves concave and apparently smooth with a width of c. 1 mm. Sutures appear straight and directly transverse. Cameral depth is c. 30 % at a conch diameter of 24 mm. The apical transverse section of the conch shows the siphuncle to be slightly subcentral in position. Diameter of the septal foramen is 1.5 mm at conch diameter 15 mm, or approximately one tenth the conch diameter. Internal features not observed.

**Remarks:** The specimens possess the diagnostic ornament of *Parakionoceras* FOERSTE and are assigned specifically to *Parakionoceras originale* (BARRANDE) on the basis of the position and size of the siphuncle, apical angle and cameral depth. One juvenile specimen (UMJGP 220171) though poorly preserved shows slight annulations, however, the distinctive longitudinal ribs and grooves leave no doubt that it belongs to *Parakionoceras* and is differentiated by these features from other annulated taxa showing longitudinal ornament described herein. These include *Calorthoceras*, *Metaspyroceras* and specimens assigned below within the KIONOCERATINAE as Gen. and sp. indet.

**Silurian occurrence:** Bohemia, British Isles, Carnic Alps of Austria and Italy, France, Germany, Graz Palaeozoic, Morocco, Poland, upper Silurian of SW Sardinia, Spain, Kazakhstan and Middle Asia.

**Silurian Range:** Silurian.

#### *Parakionoceras* cf. *striatopunctatum* (MÜNSTER, 1840)

(Pl. 3, Figs. 11–13)

- 1840 *Orthoceratites striato-punctatus* MÜNSTER, 101–102, Pl. 20, Figs. 1–3.
- 1972 *Parakionoceras striatopunctatum* (MÜNSTER). – BARSKOV, 47.
- 2010 *Parakionoceras* sp. – HISTON et al., Pl. 1, Fig. 10.

**Type species:** By original designation *Orthoceratites striato-punctatus* MÜNSTER, 1840. Elbersreuth, Frankenwald (Germany), upper Silurian.

**Diagnosis:** As above for genus, longitudinal ribs show transverse markings or cavities, grooves smooth, expansion rate 14–17°, cameral depth one fourth conch diameter, siphuncle central, one tenth conch diameter.

**Material studied:** Four specimens – UMJGP 211329, UMJGP 220162, UMJGP 220163, UMJGP 220172. Additional material: UMJGP 220173 – two specimens. Eggenfeld Section, Graz Palaeozoic.



**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** UMJGP 220172 is incomplete apically and adorally and consists of a portion of phragmocone and body chamber 49.8 mm in length. The cross-section is circular. The maximum diameter adorally is 16.6 mm, minimum apically 9.4 mm. Conch expands at an angle of c. 12°. Although the surface is poorly preserved on most specimens, the typical ornament may be distinguished. Longitudinal ribs are observed numbering c. 7 per 5 mm, and number c. 60 around the circumference of the conch. The crests of the ribs are sharply defined, and the intervening grooves concave and apparently smooth, measuring slightly less than 1 mm in width. Faint transverse regularly spaced markings are observed along the crest of the longitudinal ribs, numbering c. 3 per mm. The sutures appear straight and directly transverse, cameral depth c. 35 % at conch diameter 8.4 mm. Septal depth approximately two fifths of conch diameter. The apical transverse section of the conch shows the siphuncle to be slightly subcentral in position. In the sectioned specimen UMJGP 220162 diameter of the septal foramen is 0.9 mm at conch diameter 8.3 mm, approximately one tenth the conch diameter. Siphuncle cylindrical, slight expansion of connecting rings adorally. The septal necks are short and loxochoanitic in form. Siphonal or cameral deposits not preserved.

**Remarks:** The specimens possess the diagnostic ornament of *Parakionoceras* FOERSTE and may be compared specifically to *Parakionoceras striatopunctatum* (MÜNSTER) on the basis of the transverse ornamentation of the longitudinal ribs. In this, they differ from *P. originale* (BARRANDE), as they do also in the smoothness of the interspaces between the ribs.

**Silurian occurrence:** Bohemia, Carnic Alps of Austria, Graz Palaeozoic, Germany, Kazakhstan and Middle Asia.

**Silurian Range:** upper Silurian.

#### ***Kionoceratinae* gen. et sp. indet.**

(Pl. 5, Figs. 8–16)

**Material studied:** Five specimens – UMJGP 220124–UMJGP 220128. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** Based on UMJGP 220127. The slightly cyrtoconic specimen is incomplete both apically and adorally and consists of an apical portion of phragmocone 34.7 mm in length. The cross-section is circular with maximum diameter 7.4 mm adorally and minimum 4.4 mm apically. Conch expands slowly at an angle of 5°. The conch is annulated: these are slightly obliquely angled at c. 5° to the plane normal to the conch axis. Annulations number c. 8 per 10 mm adorally. Ornament consisting of fine densely developed longitudinal striations numbering six per mm. Sutures not well exposed but adorally cameral depth estimated at 1.7 mm, being one fifth conch diameter. The siphuncle is subcentral in position adorally, with septal foramen 1 mm, being approximately one seventh conch diameter.

**Remarks:** These annulated slightly cyrtoconic forms showing only longitudinal striae are assigned herein with doubt to the *Kionoceratinae*. The specimens from the Graz Palaeozoic are not well enough preserved to allow them to be determined at specific level or to merit designation of a new taxa. Many of the longitudinally densely ribbed, more apical annulated specimens within the assemblage have been assigned herein to *Parakionoceras* (see above) as the more “tubular-like” ornament seems to justify this distinction. However, the specimens described herein do not show affinities either to *Kionoceras* or *Parakionoceras* as the longitudinal ornament is much finer and more filiform. They also differ from *Vericeras* KOLEBABA (1977) in the presence of annulations. They differ from *Gaspocyrtoceras* FOERSTE (1936) in their more elongate form and subcentral siphuncle. No comparative taxa have been found within the various studies of annulated orthoconic nautiloids (FLOWER, 1943; KRÖGER & ISAKAR, 2006) and of longitudinally ornamented orthoconic nautiloids (KOLEBABA, 1977) therefore, pending further study it is preferred herein to leave the material in open nomenclature within the *Kionoceratinae*.

**Silurian occurrence:** Graz Palaeozoic.

**Silurian Range:** Ludfordian.

#### **Subfamily Leurocycloceratinae SWEET, 1964**

##### **Genus *Metaspyroceras* FOERSTE, 1932**

**Type species:** By original designation *Spyroceras ruedemanni* FOERSTE, 1932.

**Diagnosis:** Transversely to obliquely annulated orthoconic conch, longitudinal striae with subordinate transverse ornament, sutures oblique sloping adorally on opposite side of annulations.

##### ***Metaspyroceras venustum* (BARRANDE, 1868)**

(Pl. 4, Figs. 1–3)

1868 *Orthoceras venustum* BARRANDE. – BARRANDE, Pls. 279, 286.

1874 *Orthoceras venustum* BARRANDE. – BARRANDE, Texte III, 604–605.

2010 *Orthocycloceras* sp. – HISTON et al., Pl. 1, Fig. 11.

**Type species:** By original designation *Orthoceras venustum* BARRANDE, 1868. Bohemia, Faunes Siluriennes III, etage E (e1).

**Diagnosis:** Obliquely annulated orthocone, distinguished by finely developed longitudinal ornament and faint transverse striations, slow rate of expansion, central siphuncle.

**Material studied:** Two specimens – UMJGP 220096, UMJGP 220111. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** UMJGP 220096 consists of an apically and adorally incomplete portion of phragmocone 37.4 mm in length. The cross-section is circular. Maximum diameter

7.9 mm and minimum 7.7 mm apically with maximum of 10.7 mm and minimum of 10.3 mm adorally. The conch expands slowly at an angle of 4°. The conch is annulated: these are obliquely angled at c. 10° to the plane normal to the conch axis, sloping apically ventrally. The crests of the annulations are rounded, but asymmetric resembling a smoothed sawtooth series of waves. Annulations number c. 4 per 5 mm apically, measuring 2 mm between crests adorally with an intervening area of c. 1.0 mm. The conch ornament consists of longitudinal and transverse striations. The longitudinal striations are sometimes difficult to discern, but where seen, they are sharply defined, occasionally sinuous, and number c. 4–5 per mm at a conch diameter of 9.4 mm. The intervening furrows are twice as wide as the striations. The transverse ornament is faint and visible only as a consequence of the nodes formed where the transverse striae intersect the longitudinal striation, giving a distinct “pocked” appearance to the surface of the annulations. Nodes number c. 4 per mm. Suture apparently straight and transverse, numbering one with respect to two annulations apically. Two cameral chambers are exposed apically. Cameral depth 2.8 mm at a conch diameter of 7.9 mm and is estimated c. 35 % of the conch diameter. The siphuncle is seen to be central in position apically. Diameter of the septal foramen is 1.5 mm at conch diameter 7.9 mm, or approximately one fifth the conch diameter. The form of the siphuncle appears to be slightly expanded within the apical cameral chamber, however, the section is not central. Septal necks not observed.

**Remarks:** The specimen described herein has been compared with specimens figured by BARRANDE (1868) and has been assigned to the species *Orthoceras venustulum* BARRANDE as it possesses finely developed longitudinal striations which form typical nodes with the transverse striae and placed in *Metaspyroceras* FOERSTE on the basis of the longitudinal and transverse ornament and oblique annulations. It differs from *Pseudocycloceras* BARSKOV 1959 and *Orthocycloceras fluminese* (MENEHINI) in the presence of fine longitudinal ornament and the degree of expansion. It differs from *Calorthoceras* CHEN 1981 in the presence of oblique annulations and the finer longitudinal ornamentation.

**Silurian occurrence:** Carnic Alps of Austria, Bohemia and Graz Palaeozoic.

**Silurian Range:** upper Silurian.

### ***Metaspyroceras* sp.**

(Pl. 4, Figs. 4–5)

**Material studied:** One specimen – UMJGP 220097. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** This specimen is incomplete apically and adorally and consists of a portion of mould of phragmocone 31.4 mm long. The cross-section is slightly compressed apically with maximum diameter 7.4 mm and minimum 7.1 mm and circular adorally with a maximum diameter of 9.7 mm. Conch expands slowly at an angle of 4°. The annulations are slightly oblique at c. 8° to the normal of the

conch axis but are difficult to discern except adorally due to poor preservation. Annulations number c. 5 per 7 mm adorally. Faint traces of ornament preserved adorally consist of fine longitudinal striations that are sometimes difficult to discern except in low angle light. They are intersected by a transverse ornament. Sutures not observed. The siphuncle apparently central in position apically but obscured by calcite.

**Remarks:** The specimen is poorly preserved but is assigned to *Metaspyroceras* on the basis of the oblique annulations and presence, even if faint, of both longitudinal and transverse ornament. Lack of diagnostic features does not allow comparison at species level.

**Silurian occurrence:** Graz Palaeozoic.

**Silurian Range:** upper Silurian, Ludfordian.

## **Genus *Orthocycloceras* BARSKOV, 1972**

**Type species:** By original designation *Orthocycloceras alayense* BARSKOV, 1972. Kazakhstan, upper Silurian.

**Diagnosis:** Orthoconic to slightly cyrtconic transversely or slightly obliquely annulated conch, ornament of transverse striations, sutures straight, siphuncle central to slightly excentric, septal necks orthochoanitic, no endosiphuncular or cameral deposits.

### ***Orthocycloceras* aff. *fluminese* (MENEHINI, 1857)**

(Pl. 5, Figs. 1–2)

- 1855 *Orthoceras bohemicum* BARRANDE. – BARRANDE, 450 (*nomen nudum*).
- 1857 *Orthoceras* (*Cameroceras*) *fluminese*. – MENEHINI, 188–189, Pl. C, Figs. 3a–c.
- 1977 *Orthocycloceras?* *fluminese* (MENEHINI). – SERPAGLI & GNOLI, 178, Pl. 5, Figs. 2a, b; Text-Fig. 9.

**Holotype:** By original designation *Orthoceras* (*Cameroceras*) *fluminese* MENEHINI, 1857. Fluminimaggiore, SW Sardinia (Italy). Upper Silurian.

**Diagnosis:** Orthoconic conch, circular cross-section, rate of expansion 5–6°, oblique rounded annulations sloping approximately 8° to horizontal, ornament of transverse striations, suture transverse, cameral depth one third conch diameter, siphuncle subcentral, one tenth conch diameter, orthochoanitic septal necks, cylindrical segments.

**Material studied:** Three specimens – UMJGP 220113, UMJGP 220118, UMJGP 220119. Additional 13 specimens – UMJGP 220120. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** The specimens consist mainly of fragments of phragmocone or body chambers ranging in length from 13 mm to 39 mm. The rate of expansion is c. 4–5°. Annulations are rounded, numbering usually four per 10 mm, width c. 3 mm between crests, interspaces concave and broader than crest. They are oblique and slope more pro-

nouncedly on the venter, seemingly transverse dorsally. Ornamentation not preserved, recrystallization and dolomitization on the surface of the internal mould gives an erroneous impression of striae. Sutures apparently straight and directly transverse where exposed but depth of chambers cannot be determined. Siphuncle subcentral and small when observed, approximately one tenth conch diameter. No internal features observed.

**Remarks:** The specimens are fragmented and badly preserved and either lack ornamentation or it is difficult to discern due to the dolomitic nature of the material. Nevertheless, they show affinities to *Orthocycloceras fluminese* (MENEGHINI) due to the orthoconic conch form with circular cross-section and sloping rounded annulations showing broad concave interspaces that are distinctive features of the species. Even if badly preserved they constitute one of the most numerous of the annulated forms in the assemblage.

**Silurian occurrence:** Carnic Alps of Austria and Italy, upper Silurian of SW Sardinia, Bohemia, France, Morocco, Spain.

**Silurian Range:** middle to upper Silurian.

#### *Orthocycloceras* cf. *lynx* (BARRANDE, 1868)

(Pl. 1, Fig. 1; Pl. 5, Figs. 3–6)

1868 *Orthoceras lynx* BARRANDE. – BARRANDE, Pl. 336.

1874 *Orthoceras lynx* BARRANDE. – BARRANDE, Texte III, 333–334.

1977 *Orthocycloceras*? cf. *lynx* (BARRANDE, 1868). SERPAGLI & GNOLI, 179, Pl. 5, Figs. 1a, b.

**Type species:** By original designation *Orthoceras lynx* BARRANDE, 1868. Faunes Siluriennes III, stage E (e2). Lochkovian.

**Diagnosis:** Orthoconic annulated conch, circular cross-section, annulations transverse and rounded numbering c. 10 per 10 mm, ornament of transverse striations numbering ten between crests of annulations, sutures transverse corresponding to annulations.

**Material studied:** Four specimens – UMJGP 220121–UMJGP 220123, UMJGP 220184. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** UMJGP 220123 is an apically and adorally incomplete phragmocone 22.1 mm long. The cross-section is circular. The maximum diameter adorally is 9.9 mm, minimum adorally 9.0 mm. Conch expands slowly at an angle of c. 5°. The surface is somewhat corroded but shows rounded transverse annulations, numbering c. 5 per 5 mm, measuring 1.0–1.5 mm between crests, the crest width being c. 1.0 mm with intervening concave areas of 1.5 mm. The crest of the annulation coincides apically where observed with the position of the suture. Cameral depth is 30 % that of the conch diameter. Ornament is poorly preserved in this specimen but well preserved in the more juvenile portion of phragmocone represented by UMJGP 220121 that exhibits sharply defined, transverse striations numbering c. 8 between crests. Sutures apparently

straight and directly transverse. The apical transverse section of the conch shows the siphuncle to be central in position. The diameter of the septal foramen is 1.0 mm at a conch diameter of 9.1 mm, or approximately one ninth of the conch diameter. Internal features are observed in a longitudinal section of specimen UMJGP 220122 (Pl. 5, Fig. 6), where however, recrystallization renders interpretation of these features somewhat ambiguous. It is difficult to discern the septal necks. The trace of the siphuncular segments would suggest that they are cylindrical with a slight expansion from the septal neck. No cameral or siphonal deposits observed.

**Remarks:** These specimens all show the distinctive transversely ornamented orthoconic, closely annulated conch that allows comparison with *Orthocycloceras lynx* (BARRANDE). They differ from *O. fluminese* (MENEGHINI) in the more closely spaced and transverse annulations, and from *Columenoceras agassizi* (BARRANDE) in the smaller siphuncle and more rounded annulations.

**Silurian occurrence:** Carnic Alps of Austria and Italy, upper Silurian of SW Sardinia, Bohemia, Graz Palaeozoic.

**Silurian Range:** middle Silurian to Lower Devonian.

#### **Family Anaspyroceratidae CHEN in CHEN, LIU & CHEN 1981**

#### **Genus *Calorthoceras* CHEN in CHEN, LIU & CHEN 1981**

**Type species:** By original designation *Orthoceras pseudocalamiteum* BARRANDE, in QUENSTEDT, 1851.

**Diagnosis:** as below for type species.

#### *Calorthoceras* cf. *pseudocalamiteum* (BARRANDE in QUENSTEDT, 1851)

(Pl. 4, Figs. 6–10)

1851 *Orthoceratites pseudo-calamiteum*. – BARRANDE in QUENSTEDT, 342, Pl. 26, Fig. 8.

1866 *Orthoceras pseudo-calamiteum* BARRANDE. – BARRANDE, Pls. 217, 222.

1868 *Orthoceras pseudo-calamiteum* BARRANDE. – BARRANDE, Pls. 278, 286.

1870 *Orthoceras pseudo-calamiteum* BARRANDE. – BARRANDE, Pls. 361.

1874 *Orthoceras pseudo-calamiteum* BARRANDE. – BARRANDE, 261–264.

1968 *Anaspyroceras pseudocalamiteum* (BARRANDE). – RISTEDT, 249–250, Pl. 1, Fig. 3, Text-Fig. 3: Fig. 4c)

1981 *Calorthoceras pseudocalamiteum* (BARRANDE). – in CHEN, LIU & CHEN 1981, 98, Text-Fig. 36, Pl. 25, Figs. 1–8.

**Lectotype:** By subsequent designation *Orthoceras pseudocalamiteum* BARRANDE (1868, specimen figured Pl. 278, Fig. 5), in RISTEDT (1968: 249). Koněprusy near Beroun, Prague, Czech Republic. Faunes Siluriennes III, stage E, F, G. Upper Koněprusy Limestone, Lower Devonian.



**Paralectotypes:** By subsequent designation *Orthoceras pseudocalamiteum* BARRANDE (1868, specimens figured Pl. 278, Figs. 16–20, 24–26; Pl. 286, Fig. 16), in RISTEDT (1968: 249).

**Diagnosis:** Orthoconic, transversely annulated conch, annulation rounded and wide, intervening space concave, ornamentation longitudinal ridges and transverse striae, expansion angle 4–5°, circular cross-section, simple transverse sutures, cameral depth one fifth conch diameter, siphuncle central and suborthochoanitic, septal foramen one sixth conch diameter.

**Material studied:** Four specimens – UMJGP 220114a, UMJGP 220114b, UMJGP 220115, UMJGP 220117. Additional material: UMJGP 220116 – 14 specimens. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** UMJGP 220117 is incomplete apically and adorally, consisting of a portion of phragmocone 39.3 mm in length. The cross-section is slightly subcircular due to breakage and compression. The maximum diameter apically is 9.3 mm, minimum apically 6.8 mm. The maximum diameter adorally is 12.6 mm, minimum adorally 11.7 mm. Conch expands slowly at an angle of 4.5°. The conch shows rounded transverse annulations, numbering c. five per 10 mm, measuring 2–3 mm between crests, crest width being c. 1.0 mm with intervening concave area 1.5 mm. The crest of the annulation is observed to coincide with the suture at the apical end of the conch being only exposed there, cameral depth 20 % conch diameter. The ornament, which is poorly preserved in most specimens due to corrosion of the conch surface and dolomitic nature of the sediment, consists of longitudinal and transverse striations, the former more sharply defined, the latter faint. Adorally longitudinal striations number c. 5 per mm, stronger longitudinal ribbing not preserved. Sutures apparently straight and transverse. The apical transverse section of the conch shows the siphuncle to be central in position. Diameter of the septal foramen is 1.7 mm at conch diameter 9.3 mm, or approximately one sixth the conch diameter. Internal features not observed.

**Remarks:** The material studied is compared with *Calorthoceras pseudocalamiteum* (BARRANDE) on the basis of the orthoconic annulated form showing both longitudinal and transverse ornament. However, this material is assigned to the species with some reservation due to the density of the longitudinal ribbing and faintness of the transverse striae, so that the classical reticulate ornamentation of *C. pseudocalamiteum* consisting of a set of stronger longitudinal ribbing with intermediate finer ribbing is not always evident but this may be an effect of the dolomitic host sediment which has led to corrosion of the external ornament in most of the material. On the other hand, it can be easily differentiated from juvenile *Parakionoceras* FOERSTE specimens present in the assemblage (see above) through the distinct orthoconic conch form. It differs from *Metaspyroceras venustulum* (BARRANDE) in the transverse annulations. The species has a range from upper Silurian to Lower Devonian, and even if the type specimen of the species is Devonian in age, it also commonly occurs in the upper Silurian.

**Silurian occurrence:** Bohemia, Carnic Alps of Austria and Italy, China, Graz Palaeozoic, SW Sardinia.

**Silurian Range:** upper Silurian.

## Family Arionoceratidae DŽIK, 1984

### Genus *Arionoceras* BARSKOV, 1966

**Type species:** By subsequent designation *Orthoceras affine* MENEHINI, 1857 in SERPAGLI & GNOLI (1977). Fluminimaggiore, SW Sardinia (Italy). Silurian.

**Diagnosis:** Orthoconic with slight apical curvature, expansion rate 6–10°. Circular cross-section, surface smooth or with transverse growth lines, large protoconch ogival in shape, suture transverse, camera short approximately one half conch diameter, septa deeply concave, arched laterally, siphuncle central, cylindrical, varying from one sixth apically to one ninth adorally of conch diameter, septal necks suborthochoanitic, cameral deposits developed.

### *Arionoceras* cf. *affine* (MENEHINI, 1857)

(Pl. 6, Figs. 6–9)

1857 *Orthoceras affine*. – MENEHINI, 217–218, Pl. C, Fig. 16.

1977 *Arionoceras affine* (MENEHINI). – SERPAGLI & GNOLI, 182–183, Pl. 6, Figs. 2a–7, Text-Fig. 10b.

**Type species:** By original designation *Orthoceras affine* MENEHINI, 1857. Fluminimaggiore, SW Sardinia (Italy). Silurian.

**Diagnosis:** As for genus with shell surface showing fine transverse growth lines, siphuncle subcentral, one sixth conch diameter.

**Material studied:** Three specimens – UMJGP 220136, UMJGP 220137, UMJGP 220138. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** The specimen UMJGP 220136 consists of an apically and adorally incomplete portion of body chamber and phragmocone 170 mm in long. The cross-section is almost circular with maximum diameter adorally 31 mm and minimum apically 12 mm. The conch expands at an angle of 6°. The conch shows faint transverse striations, better preserved apically numbering c. 2 per mm in width, sometimes irregular in outline but present over most of the conch. The junction of the phragmocone and body chamber is apparently directly transverse.

In the sectioned specimens UMJGP 220137 and UMJGP 220138 (Pl. 6, Figs. 8, 9) the sutures are transverse and cameral depth approximately half the conch diameter. The septa are deeply concave with depth one third of diameter and arch typically laterally. Siphuncle apparently central from trace and narrow, width difficult to ascertain, but approximately one ninth of conch diameter adorally in one specimen, the other polished section is at an oblique angle however, the trace in the most adoral septa is about one tenth the conch diameter. Cameral deposits are present.



**Remarks:** The specimens possess the specific characters of *Arionoceras affine* (MENEHINI) with the conch form and external diagnostic features being well preserved, however, as the internal morphology is not clearly observed it is preferred to only compare the material studied to *A. affine*.

**Silurian occurrence:** Bohemia, Carnic Alps of Austria and Italy, Graz Palaeozoic, Kazakhstan, Morocco, upper Silurian of SW Sardinia.

**Silurian Range:** Silurian.

***Arionoceras cf. capillosum* (BARRANDE, 1868)**

(Pl. 6, Figs. 10–11)

- 1868 *Orthoceras capillosum* BARRANDE – BARRANDE, Pl. 325.  
1870 *Orthoceras capillosum* BARRANDE. – BARRANDE, Pls. 357, 394.  
1874 *Orthoceras capillosum* BARRANDE. – BARRANDE, Texte III, 486.  
1998 *Arionoceras capillosum* (BARRANDE). – GNOLI & HISTON, 325.

**Type species:** By original designation *Orthoceras capillosum* BARRANDE, 1868. Bohemia, Faunes Silurien III, etage E to H. Silurian to Devonian.

**Diagnosis:** As for genus with shell surface showing distinct transverse growth lines with shallow sinus, siphuncle central, one tenth conch diameter.

**Material studied:** Two specimens – UMJGP 220139, UMJGP 220140. Additional material: Five specimens – UMJGP 220144. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** Based on UMJGP 220139. The orthoconic specimen is incomplete apically and adorally and consists of a portion of phragmocone 43.3 mm in length. The cross-section is almost circular with maximum diameter adorally 14.6 mm and minimum apically 10 mm. Conch expands at an angle of 5°. The conch shows distinct transverse striations of c. 2–3 per mm in width over the length of the conch and a shallow lobe is developed but it is difficult to determine if this is on the dorsum or venter. Sutures transverse with cameral depth varying from one third to half the conch diameter. Adorally septa deeply concave arching laterally with depth almost 50 % of conch diameter. The siphuncle is central in position and narrow. The diameter of the septal foramen is c. 2 mm at a conch diameter 14.6 mm, or less than one eighth of the conch diameter. No internal features preserved.

**Remarks:** The external diagnostic features in the studied material are well preserved, however, as the internal morphology of the siphuncle is not observed it is preferred to only compare this material to *A. capillosum*. This material differs from *A. affine* in the more marked transverse growth lines showing a shallow sinus and in the narrower siphuncle.

**Silurian occurrence:** Bohemia, Carnic Alps of Austria and Italy, Graz Palaeozoic, Kazakhstan, Morocco, upper Silurian of SW Sardinia.

**Silurian Range:** Silurian.

***Arionoceras cf. submoniliforme* (MENEHINI, 1857)**

(Pl. 6, Figs. 12–14)

- 1857 *Orthoceras submoniliforme*. – MENEHINI, 217–218, Pl. C, Fig. 16.  
1977 *Arionoceras submoniliforme* (MENEHINI). – SERPAGLI & GNOLI, 183–186, Pl. 6, Figs. 9a–b, Pl. 7, Figs. 1–3, Text-Figs. 10a, 11.

**Type species:** By original designation *Orthoceras submoniliforme* MENEHINI, 1857. Fluminimaggiore, SW Sardinia (Italy). Silurian.

**Diagnosis:** As for genus with shell surface apparently smooth, siphuncle slightly excentric, one fifth conch diameter.

**Material studied:** Three specimens – UMJGP 220141, UMJGP 220142, UMJGP 220143. Additional material: three specimens – UMJGP 220145. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** Based on UMJGP 220141. The specimen is incomplete apically and adorally and consists of the body chamber and a portion of phragmocone 41.7 mm in length. The cross-section is subcircular due to compression with maximum diameter adorally 15.3 mm and minimum 12.6 mm. More circular apically with maximum 7.1 mm, minimum 6.8 mm. Conch expands at an angle of 11° but is variable in other specimens from 7–8°. The conch is apparently smooth. Junction of phragmocone and body chamber not observed. Sutures are transverse to slightly oblique, this may be a consequence of the compression, and cameral depth approximately one third conch diameter. Siphuncle slightly excentric of center and wide, septal foramen c. 1.5 mm at conch diameter 7.1 mm, or about one fifth of the conch diameter. No internal features preserved.

**Remarks:** The specimens are compared with *Arionoceras submoniliforme* (MENEHINI) as the specific characters of smooth evenly tapering conch with deeply concave septa and larger siphuncle may be recognized, however, the external and internal features are not well preserved.

**Silurian occurrence:** Bohemia, Carnic Alps of Austria and Italy, Graz Palaeozoic, Kazakhstan, Morocco, upper Silurian of SW Sardinia.

**Silurian Range:** Silurian.

## Family Geisonoceratidae ZHURAVLEVA, 1959

### Genus *Geisonoceras* HYATT, 1884

### *Geisonoceras* sp.

(Pl. 6, Fig. 5)

**Type species:** By original designation *Orthoceras rivale* BARRANDE, 1866. Bohemia, Faunes Silurien III, etage E (e2).

**Diagnosis:** Orthoconic to cyrtoconic conch, subcircular cross-section, ornament of broad transverse bands with occasionally developed intermediate transverse growth lines, suture straight to slightly oblique, siphuncle subcentral, septal necks short and suborthochoanitic, connecting rings slightly expanded, annulosiphonate and cameral deposits developed.

#### *Geisonoceras* cf. *rivale* (BARRANDE, 1866)

(Pl. 6, Figs. 1–4)

1866 *Orthoceras rivale* BARRANDE. – BARRANDE, Pls. 209, 216.

1870 *Orthoceras rivale* BARRANDE. – BARRANDE, Pls. 374, 387, 406.

1874 *Orthoceras rivale* BARRANDE. – BARRANDE, 383.

1884 *Geisonoceras rivale* (BARRANDE). – HYATT, 369.

**Type species:** By original designation *Orthoceras rivale* BARRANDE, 1866. Bohemia, Faunes Silurien III, etage E (e2).

**Diagnosis:** As above for genus, conch slowly tapering c. 4°, siphuncle subcentral, bands broad and transverse.

**Material studied:** Two specimens – UMJGP 220132, UMJGP 220133. Additional material: two portions of external moulds showing banded ornament – UMJGP 220134. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** Based on UMJGP 220132. The specimen is incomplete apically and adorally and consists of the body chamber and a portion of phragmocone 46.3 mm in length. The cross-section is almost circular with maximum diameter adorally 17.3 mm and minimum apically 14.6 mm. Conch expands at an angle of 4°. The conch shows broad transverse bands c. 2 mm in width over most of its length, and a shallow lobe is also developed. The junction of the phragmocone with the body chamber is slightly oblique to the normal of the conch axis. Sutures not observed. The siphuncle lies just off-center and is wide, with a septal foramen c. 4 mm at a conch diameter of 14.6 mm, or less than one third of the conch diameter. No internal features preserved.

**Remarks:** The material studied possesses the transverse banded ornament typical of *Geisonoceras* HYATT and it compares with *Orthoceras rivale* BARRANDE in its ornament, the tapering of the conch and siphuncle position.

**Silurian occurrence:** Bohemia and Graz Palaeozoic.

**Silurian Range:** middle to upper Silurian.

**Material studied:** One specimen – UMJGP 220135. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** The specimen is incomplete apically and adorally and consists mostly of the body chamber and a small portion of phragmocone with overall length of 105 mm. The cross-section is circular with maximum diameter adorally 36 mm and minimum apically 25 mm. Conch expands at an angle of c. 5°. The conch surface is poorly preserved but fragmentary traces of transverse bands of c. 4 mm in width are visible. Subordinate transverse striations numbering c. 4–5 are present in the intervening spaces. The junction of the phragmocone and body chamber is apparently transverse. Sutures not observed. Siphuncle apparently just off centre, septal foramen not well exposed but c. 4 mm at a conch diameter of 25 mm, or almost one fifth of the conch diameter. No internal features are preserved.

**Remarks:** The specimen described is badly preserved but the surface shows traces of transverse banding and striations, the broad siphuncle is subcentral. These features are sufficient to allow this specimen to be assigned to *Geisonoceras* HYATT.

**Silurian occurrence:** Graz Palaeozoic.

**Silurian Range:** Ludfordian.

### Genus *Murchisoniceras* BABIN, 1966

**Type species:** By original designation *Orthoceras murchisoni* BARRANDE, 1868. Bohemia, Faunes Silurien III, etage E (e2).

**Diagnosis:** Conch orthoconic or slightly cyrtoconic, circular cross-section, ornamentation of very fine sinuous growth lines transverse to slightly oblique, and slightly serrated, suture transverse, siphuncle subcentral towards venter, slightly expanded, septal necks orthochoanitic, cameral deposits developed.

#### *Murchisoniceras* sp.

(Pl. 6, Figs. 15–16)

**Material studied:** One specimen – UMJGP 220131. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** This specimen is incomplete apically and consists of the body chamber and a portion of phragmocone 87 mm long. The cross-section is subcircular with a maximum diameter adorally of 23 mm and minimum apically of 11 mm. The conch expands at an angle of 9°. The conch shows broad transverse bands c. 2 mm in width over most of the conch, which narrow to fine transverse

striations numbering 3–4 per mm adorally. The striations develop a distinct sigmoidal curvature adorally that appears to follow the line of the aperture. The sutures and siphuncle have not been observed. No internal features are preserved.

**Remarks:** The specimen is assigned to this genus on the basis of the orthoconic conch form and typical sigmoidal transverse ornament. Although few other features are preserved, the similarity to *Murchisonoceras* BABIN is quite marked.

**Silurian occurrence:** Graz Palaeozoic.

**Silurian Range:** upper Silurian.

### Genus *Columenoceras* BARSKOV, 1960

**Type species:** By original designation *Orthoceras columen* BARRANDE, 1868. Bohemia, Faunes Silurien III, etage E (e2).

**Diagnosis:** Large cylindrical in form orthoconic conch, column-like with narrow angle of expansion, deep camerae, narrow siphuncle, orthochoanitic septal necks, “biscuit-like” endosiphuncular deposits.

#### *Columenoceras agassizi* (BARRANDE, 1866)

(Pl. 7, Figs. 1–5)

- 1866 *Orthoceras Agassizi* BARRANDE – BARRANDE, Pls. 227, 228.
- 1868 *Orthoceras Agassizi* BARRANDE. – BARRANDE, Pls. 280, 281, 282.
- 1870 *Orthoceras Agassizi* BARRANDE. – BARRANDE, Pls. 353, 399, 424, 446.
- 1874 *Orthoceras Agassizi* BARRANDE. – BARRANDE, Texte III, 299–302.
- 1984 *Columenoceras agassizi* (BARRANDE, 1866). – DŽIK, 98, Text-Fig. 36, Pl. 25, Figs. 1–8.

**Type species:** By original designation *Orthoceras Agassizi* BARRANDE, 1866. Bohemia, Faunes silurien III, etage E (e2), G.

**Diagnosis:** Orthoconic, slowly tapering, annulations apically, slightly oblique transverse ornament, long cameral chambers, wide subcentral siphuncle.

**Material studied:** Three specimens – UMJGP 220098, UMJGP 220099, UMJGP 220102. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** Based on UMJGP 220098. The orthoconic specimen is incomplete both apically and adorally and consists of a portion of phragmocone and body chamber 63.9 mm in length. The cross-section is slightly subcircular. The maximum diameter apically is 9.5 mm, and the minimum apically 8.1 mm. The maximum diameter adorally is 13.7 mm, and minimum adorally 13.5 mm. The conch expands slowly at an angle of 5°. The conch shows low transverse annulations, obliquely angled at c. 8° to the plane normal to the conch axis; these fade adorally. An-

nullations number c. 4 per 10 mm, measuring 3–4 mm between crests, the width of the crest being c. 1.0–1.5 mm, with the intervening area being almost the same width. The crest of the annulation does not coincide with the position of the suture and number four per cameral chamber. Ornament consists of transverse striations, sharply defined, numbering c. 8 between crests apically and 2–3 per mm in density. Adorally, striations number c. 4 per mm. Suture apparently straight and transverse. The junction of the phragmocone with the body chamber is directly transverse. Six cameral chambers preserved with depth apically of 11.1 mm at a diameter of 11 mm with a ratio c. 1:1 and 10.5 mm at a diameter of 12.3 mm adorally, or c. 85 % of the conch diameter. The apical transverse section of the conch shows the siphuncle to be subcentral in position. Diameter of the septal foramen is 2.6 mm at a conch diameter of 12.1 mm, or approximately one fifth the conch diameter. Internal features are observed in a longitudinal section of specimen UMJGP 220102 showing the cyclindrical form of the siphuncle. Septal necks not exposed but presumed to be orthochoanitic as the connecting rings are not expanded within the cameral chamber. Mural cameral deposits preserved apically.

**Remarks:** The wide subcentral siphuncle and well-defined, slightly oblique to directly transverse striae with sloping annulations that fade adorally allow these specimens, which compare well with those figured by BARRANDE, to be assigned to *Columenoceras agassizi* (BARRANDE). They differ from *C. subannulare* (MÜNSTER) in the greater rate of taper and degree of slope of the annulations. The relatively long cameral chambers allow comparison with *C. grande* (MENEHINI, 1957) and *C. columen* (BARRANDE, 1868), however, the ornament differs in the former and the rate of taper is less in the latter.

**Silurian occurrence:** Bohemia, Carnic Alps of Austria and Italy, upper Silurian of SW Sardinia, Poland, Graz Palaeozoic.

**Silurian Range:** upper Silurian.

#### *Columenoceras grande* (MENEHINI, 1857)

(Pl. 7, Figs. 6–7)

- 1857 *Orthoceras grande* MENEHINI. – MENEHINI, 189–191, Pl. C, Figs. 4A, a, a’.
- non 1977 *Michelinoceras grande* (MENEHINI). – SERPAGLI & GNOLI, 162–165, Pl. 2, Figs. 1–4, Text-Fig. 7a.
- 1987 *Columenoceras grande* (MENEHINI). – GNOLI, 245–250, Pl. 1.

**Type species:** By original designation *Orthoceras grande* MENEHINI, 1857. Fluminimaggiore, SW Sardinia, upper Wenlock.

**Diagnosis:** Orthoconic, slowly tapering, smooth, long cameral chambers, wide subcentral siphuncle.

**Material studied:** Two specimens – UMJGP 220101, 220112. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** UMJGP 220101 is an apically and adorally incomplete portion of phragmocone 51.7 mm in length. The cross-section is slightly subcircular. The maximum diameter apically is 12.8 mm, minimum apically 11.7 mm. The maximum diameter adorally is 13.1 mm, minimum adorally 12.3 mm. The conch expands slowly at an angle of 3°. The conch is apparently smooth where the conch wall is preserved. Suture apparently straight and transverse, but showing a broad and shallow ventral lobe. Six cameral chambers preserved with depth apically 7.7 mm at diameter 12.8 mm, decreasing adorally to 6.4 mm at a diameter of 13.1 mm, ranging from 60–48 % of the conch diameter. Septal depth shallow 2 mm at conch diameter 12.6 mm and is estimated at 15 % of the conch diameter. Shallow broad lobe developed ventrally. The apical transverse section of the conch shows the siphuncle to be central in position. Diameter of the septal foramen is not clear due to breakage, c. 2.7 mm at a conch diameter of 12.8 mm apically, or approximately one fifth the conch diameter. The dolomitic nature of the material did not allow for sectioning to expose the siphuncle. Thus, no internal features are observed.

**Remarks:** The columnar form, smooth conch, long cameral chambers, wide subcentral siphuncle compare well with specimens figured by GNOLI (1987) and allow the specimen to be assigned to *Columenoceras grande* (MENEHINI). It differs in the slower rate of taper and lack of annulations and transverse ornament from *C. subannulare* (MÜNSTER) and *C. agassizi* (BARRANDE).

**Silurian occurrence:** Bohemia, Carnic Alps of Austria and Italy, upper Silurian of SW Sardinia, Poland, Graz Palaeozoic.

**Silurian Range:** Silurian.

***Columenoceras subannulare* (MÜNSTER, 1840)  
comb. nov.**

(Pl. 7, Figs. 8–9; Text-Fig. 3)

- 1840 *Orthoceratites subannulare* MÜNSTER, 99, Pl. 19, Fig. 3.
- 1866 *Orthoceras subannulare* MÜNSTER. – BARRANDE, Pls. 210, 212.
- 1868 *Orthoceras subannulare* MÜNSTER. – BARRANDE, Pls. 253, 283, 323, 336.
- 1870 *Orthoceras subannulare* MÜNSTER. – BARRANDE, Pls. 399, 445, 451, 460.
- 1874 *Orthoceras subannulare* MÜNSTER. – BARRANDE, Texte III, 343–346.
- 1925 *Orthoceras subannulare* MÜNSTER. – HELLER, 246–247, Pl. IV, Figs. 3a–d.
- 1964 *Leurocycloceras subannulare* (MÜNSTER). – TEICHERT, K20, Fig. 3.
- 1968 *Orthoceras subannulare* BARRANDE [sic]. – RISTEDT, Fig. 3: 5b
- Non 1972 *Metaspyroceras subannulare* (MÜNSTER). – ZHURAVLEVA, 69.
- 2010 *Orthocycloceras* sp. – HISTON et al., Pl. 1, Fig. 12.

**Lectotype:** Designated herein *Orthoceratites subannulare* MÜNSTER, specimen figured by MÜNSTER (1840: Pl. 19,

Fig. 3). Elbersreuth, Frankenwald, Germany. Upper Silurian in age. Specimen also figured by HELLER (1925: Pl. IV, Figs. 3c, 3d). Housed in the Bavarian State Collection for Palaeontology and Geology in Munich (Bavaria, Germany) under accession number SNSB-BSPG AS VII 941. Reasons for selection of lectotype are outlined below under Remarks.

**Paralectotypes:** The type series of specimens of *Orthoceratites subannulare* described by MÜNSTER in his 1840 monograph are housed in the Bavarian State Collection for Palaeontology and Geology in Munich (Bavaria, Germany) under accession numbers SNSB-BSPG AS VII 942–43.

**Additional reference material from the Elbersreuth type locality:** Specimens described and figured by HELLER (1925) as *Orthoceras subannulare* MÜNSTER are housed in the Bavarian State Collection for Palaeontology and Geology, Munich, (Bavaria, Germany) under accession number SNSB-BSPG AS VII 986–988. Other topotype material from the collections of MÜNSTER and referred to by HELLER is housed in the Museum für Naturkunde (Berlin, Germany) under accession numbers MB.C.10740 and MB.C.10743. It has been confirmed (LINHART, pers. comm., 2020) that specimens stated by HELLER (1925: 247) as being in the Sammlung der geognostischen Landesuntersuchung von Bayern and the Bayreuther Kreisnaturaliensammlung have been transferred to the Urwelt-Museum in Bayreuth.

**Additional comparative material:** specimens of *Orthoceras subannulare* MÜNSTER figured by BARRANDE on Plate 210 (published 1866), Plates 253, 283, 323, 336 (published 1868), Plates 399, 445, 451, 460 (published 1870) housed in the National Museum of Prague (Czech Republic). Bohemia, upper Silurian to earliest Devonian in age (after BARRANDE 1870: 45: Faunes siluriennes II and III, stage D (d5), E and F).

**Diagnosis emended after BARRANDE (1874: 343–346) and Ristedt (1968: Fig. 3: 5b):** Slender annulated orthocone, slight curvature apically and showing geisonoceratidae-type ontogenetic development, circular cross-section, apical angle 4–6°, annulations low and broad and slightly oblique from venter at c. 10–12° to plane normal to conch axis, numbering c. 5 per 10 mm, and fading adorally, ornament variable along length of conch, mainly of transverse striations imbricating adorally numbering c. 10 between the crests of annulations, very slight lateral sinus, aperture oblique at c. 10–12° to the plane normal to the conch axis with a slight constriction, body chamber one third total length, suture straight, the distance between sutures approximately two thirds of the conch diameter, septal depth approximately one third conch diameter, siphuncle slightly subcentral, septal foramen one sixth the conch diameter, orthochoanitic septal necks, connecting rings cyclindrical to weakly expanded, annulosiphonate deposits as simple annuli within septal foramen, episeptal, hyposeptal and mural cameral deposits assymmetrically developed.

**Material studied:** One specimen – UMJGP 211334. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** The specimen UMJGP 211334 consists of an apically and adorally incomplete portion of phragmocone



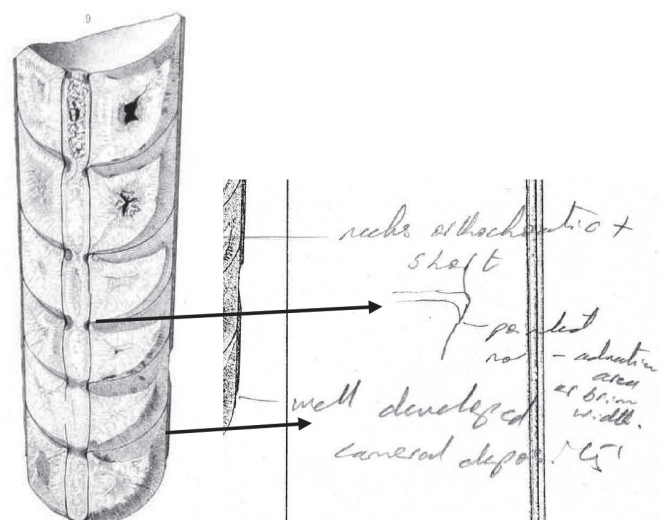
and body chamber 36 mm in length. The cross-section is circular. The maximum diameter adorally is 7.5 mm, and the minimum apically 5.4 mm. The conch expands slowly at an angle of 3.3°. The external ornament consists of low broad transverse annulations, angled at c. 12° to the plane normal to the conch axis. The annulations fade adorally to become flattened broad bands 2 mm in width that imbricate adorally. Annulations number c. 5 per 10 mm, measuring 2 mm from crest to crest. The width of the crests is c. 1.4 mm, and the intervening area c. 0.5 mm. Where the sutures are visible, they are seen to coincide with the crests of the annulations. The ornament consists of transverse striations that imbricate adorally, are sharply defined, occasionally wavy, and number c. five between crests. Adorally the striations number c. 7 per corresponding transverse band. Suture apparently straight and transverse. The junction of the phragmocone with the body chamber is not seen. Only one cameral chamber exposed apically. The depth of the camera is 1.8 mm at a conch diameter of 6.4 mm, or 28 % of the conch diameter. The apical transverse section is at an oblique angle to the conch, but the siphuncle is seen to be subcentral in position. The diameter of the septal foramen is 1.1 mm at a conch diameter of 6.4 mm, or approximately one sixth the conch diameter. The dolomitic nature of the material made it unsuitable for sectioning in order to expose the siphuncle. No internal features are observed.

**Remarks:** The material described from the Eggenfeld locality compares well with the original description by MÜNSTER (1840) and topotype material figured by HELLER (1925) as well as with the specimens of *Orthoceras subannulare* MÜNSTER illustrated by BARRANDE (1868) on Plate 283 with regard to the distinctive oblique ornamentation and low broad annulations on the slender conch form and slightly subcentral position of the siphuncle. There is therefore, no doubt regarding the specific assignment. However, the higher taxonomy of this species remains somewhat problematic, as the type material figured and described by MÜNSTER (1840) from the Elbersreuth locality in the Frankenwald area of Germany is quite fragmentary and preserves only external features. Topotype material of *Orthoceras subannulare* described and illustrated by HELLER (1925) from the same upper Silurian *Orthoceras* limestone level at the Elbersreuth locality also does not display internal features. HELLER in his monograph of these Silurian faunas included and revised the *Orthoceras* specimens from the collections made by MÜNSTER. Much confusion has resulted from the lack of internal morphological details, leading to specimens being assigned with doubt to this species on the basis of ornament only, and then being placed provisionally within a variety of genera possessing annulated conchs. In addition, it was reported erroneously that the type material had been lost during WWII (see GNOLI et al., 2000: 10). Here it is confirmed that the type material of both MÜNSTER (1840) and HELLER (1925) is housed at the Bavarian State Collection for Palaeontology and Geology in Munich (see above). As this species is common within the upper Silurian of Europe and can prove stratigraphically useful, the current situation is unsatisfactory. Consideration of a variety of criteria may help stabilise the classification of this species.

Firstly, as stated above the type material of *Orthoceras subannulare* MÜNSTER (1840) is not lost. Therefore, selection of a lectotype specimen is both possible and essen-

tial. Regarding this selection it is considered herein that the specimen originally figured by MÜNSTER (1840: Pl. 19, Fig. 3) is the best choice, even if it is obviously a more apical view of the conch and the annulations appear more pronounced than stated in the description by the original author.

Secondly, BARRANDE in his descriptions of the Silurian faunas from Bohemia dedicated four pages of text (1874) and numerous figures on 10 plates (1866, 1868, 1870) in order to describe in detail the variety of both external and internal features, which differentiate *Orthoceras subannulare*, listing its affinities and differences with comparable species. The stratigraphical horizons are clearly stated for the localities of the specimens. The best illustrations of the specific characteristics are shown on plates 283 and 336 (1868). In addition, the stratigraphical horizons of the Bohemian localities within the Silurian Faunas III, etage E are comparable in age with that of the original material from the upper Silurian Elbersreuth locality (refer to stratigraphical and geographical distribution in BARRANDE, 1870: 45 and 64 respectively). HELLER (1925) confirms that the horizon from the Elbersreuth locality is the same stratigraphic level as those from the upper Silurian of Bohemia and that the faunas are comparable with the material described by BARRANDE. Therefore, description of the internal morphology for this species is herein based on specimens from the BARRANDE collection housed in the National Museum of Prague. The first author (K.H.) personally examined many of the specimens of *Orthoceras subannulare* MÜNSTER from the BARRANDE collections in 1998 and confirms from her notes that they are comparable with the original description and illustration of the taxa by MÜNSTER (1840). A drawing made at this time from a longitudinal section of a specimen illustrated by BARRANDE (1866: Pl. 210, Fig. 9) confirms the septal neck is orthochoanitic (Text-Fig. 3). The BARRANDE collection is easily accessible in the National Museum of Prague where excellent facilities are provided, therefore the series of specimens described and illustrated by BARRANDE as *Orthoceras subannulare* MÜNSTER (1840) are available for further study. RISTEDT (1968: Fig. 3: 5b) uses one



Text-Fig. 3. *Columenoceras subannulare* (MÜNSTER, 1840), after BARRANDE, 1866: Pl. 210, Fig. 9 (image on plate reversed representation of longitudinal section of specimen). Drawing of orthochoanitic septal neck at fourth septum (not to scale). First author's (K.H.) sketch notes: necks orthochoanitic and short, pointed, no adnation area or brim width, well-developed cameral deposits.

of BARRANDE's figures of *Orthoceras subannulare* as an example of the geisonoceratidae-type ontogenetic development in his study of juvenile faunas. The original specific diagnosis of *Orthoceras subannulare* MÜNSTER is consequently emended herein based on the additional information provided in the extensive study by BARRANDE, the data regarding the juvenile specimen by RISTEDT and the first author's (K.H.) own studies of this material.

MÜNSTER (1840) compared his new taxa with *Orthocera annulata* SOWERBY and his own species of *O. cinctus* MÜNSTER. The affinities of the species and comparison with other taxa were discussed at length in a number of publications based mainly on similarity of the ornament. BARRANDE (1874: 346) compared it with his own species of *Orthoceras nobile*, *O. inchoatum*, *O. Le Honi* and *O. Duponti* but most closely to *O. vicarians*. He did not compare it with *Orthoceras lynx*, as has been done by recent authors, despite figuring both species on the same plate (1868: Pl. 336). WHIDBOURNE in his studies of the Devonian of southern England (1892: 138–140) shed doubt on whether the Devonian and Silurian material belong to the same species (see comments below), FOORD (1888: 59–61) confirmed the distinct character of the species in his comparison of material from the Silurian of the British Isles and elsewhere with the type material.

The generic classification of this species has undergone a multitude of changes. The transverse striations have prompted some authors in the past to compare the species with *Dawsonoceras annulatum* (SOWERBY) and place it within that genus, however, the ornament and annulations of the latter are more pronounced than in *subannulare* (HE-RITSCH, 1943; HISTON, 1999) and the internal morphology differs considerably. It has been assigned with doubt to *Orthocycloceras* BARSKOV 1972 (emended by ZHURAVLEVA, 1978 to include oblique annulations) as was originally the specimen described herein from the Eggenfeld Section (HISTON et al., 2010: Pl. 1, Fig. 12), placed in synonymy by various authors with *Orthocycloceras lynx* (BARRANDE) (see SERPAGLI & GNOLI, 1977; GNOLI & HISTON, 1998), or compared with *Orthocycloceras fluminese* (MENEHINI) due to the oblique annulations. The species differs from *Orthocycloceras* in the less pronounced form of the annulations and the presence of siphonal deposits. Specimens described by WHIDBOURNE (1892: Pl. XIV, Figs. 7, 8) from the Devonian of Wolbournagh (Southern England) as *Orthoceras subannulare* subsequently assigned to *Metaspyroceras* FOERSTE 1932 by ZHURAVLEVA (1978: 69) clearly do not belong to *subannulare* as they possess both longitudinal and transverse ornamentation. It should be made clear that only the British Devonian specimens figured by WHIDBOURNE (1892: Pl. XIV, Figs. 7, 8) were reassigned to *Metaspyroceras* by ZHURAVLEVA (1978), but failure to correctly interpret Zhuravleva's publication (in Russian) led to confusion, with the combination of *Metaspyroceras subannulare* (MÜNSTER) being subsequently reported in the literature (GNOLI, 2003).

Finally, a specimen figured by BARRANDE (1868: Pl. 283, Figs. 2, 3, 17) from the BARRANDE series of *Orthoceras subannulare* MÜNSTER (1840) was also illustrated in the Treatise (TEICHERT, 1964: K20, Fig. 3) as *Leurocycloceras* FOERSTE 1928. Specimens of *Orthoceras subannulare* MÜNSTER from Bohemia contained in the Shary Collection in the Museum of Comparative Zoology (USA) were also assigned to *Leurocycloceras* by WESTERMANN (1985) as was Silurian material

from the Italian Carnic Alps assigned with doubt by SERVENTI (2011), however, this genus has an empty siphuncle. Comparison with the genus *Pseudocycloceras* BARSKOV 1959 highlights the more pronounced rounded annulations with respect to the present species and differs in that the septal necks are suborthochoanitic. It differs from *Geisonoceras* HYATT 1884 in the presence of annulations.

The species *Orthoceras subannulare* MÜNSTER 1840 is therefore assigned herein to *Columenoceras* BARSKOV 1960 based on the presence of an orthoconic conch with annulations that fade adorally, transverse ornament, orthochoanitic septal necks, presence of siphonal deposits in the form of annuli and cameral deposits.

It differs from other species of *Columenoceras* such as *C. agassizi* (BARRANDE) and *C. columen* (BARRANDE) in the inclination of the annulations, and from *C. degener* (BARRANDE), *C. dupontii* (BARRANDE) and *C. grande* (MENEHINI) in the position and size of the siphuncle and ornamentation.

**Silurian occurrence:** Bohemia, Carnic Alps of Austria and Italy, France, Germany, Graz Palaeozoic, British Isles.

**Silurian Range:** upper Silurian.

### *Columenoceras* sp.

(Pl. 7, Figs. 10–11)

**Material studied:** One specimen – UMJGP 220100. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** This specimen comprises an apically and adorally incomplete portion of phragmocone 29.7 mm in length. The cross-section is circular. The maximum diameter adorally is 8.4 mm, minimum apically 7.2 mm. The conch expands slowly at an angle of 2.3°. The external ornament is of low transverse annulations, obliquely angled at c. 30° to the plane normal to the conch axis, fading to broad bands adorally. Annulations number c. 8 per 10 mm, measuring c. 2 mm between crests. Finer ornament consists of transverse striations, sharply defined, numbering c. 4 per mm. Sutures not observed. The apical transverse section shows the siphuncle, which appears to be central in position. Diameter of the septal foramen is c. 2 mm apically, or approximately one fourth the conch diameter. The dolomitic nature of the material would not facilitate sectioning to expose the siphuncle. No internal features are observed.

**Remarks:** The features preserved allow the specimen to be assigned to *Columenoceras* BARSKOV on the basis of the expansion rate and obliquely annulated conch with transverse striations. It has not been given a specific determination. It compares with *C. subannulare* (MÜNSTER) in the degree of inclination to plane normal to conch axis and frequency of the annulations, however, the direction of inclination is from the dorsum unlike that of *C. subannulare*, which is oblique from the venter.

**Silurian occurrence:** Graz Palaeozoic.

**Silurian Range:** Ludfordian.

## Genus *Temperoceras* BARSKOV, 1960

**Type species:** By subsequent designation *Orthoceras ludense* SOWERBY in MURCHISON, 1839, HOLLAND, 2000. Ludlow, Shropshire, England, "Lower Ludlow Rock", Gorstian.

**Diagnosis:** as below for type species.

### *Temperoceras ludense* (SOWERBY in MURCHISON, 1839)

(Pl. 7, Figs. 12–13)

1839 *Orthoceras ludense* SOWERBY. – MURCHISON, 619, Pl. 9, Figs. 1a, 1b.

2000 *Temperoceras ludense* (SOWERBY in MURCHISON, 1839). – HOLLAND, 120, Text-Fig. 1, Pl. 1, Figs. 3–4, 6–7.

**Type species:** By original designation *Orthoceras ludense* (SOWERBY in MURCHISON, 1839). Ludlow, Shropshire, England, "Lower Ludlow Rock", Gorstian.

**Diagnosis:** Orthoconic, smooth, slowly tapering, circular cross-section, cameral chambers one third conch diameter, wide subcentral siphuncle ranging from 12–25 % of conch diameter, siphonal segments slightly convex, cameral and annulosiphonate deposits.

**Material studied:** Five specimens – UMJGP 220104 to UMJGP 220108. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** Specimen UMJGP 220106 is a portion of phragmocone 25.7 mm in length comprising of two incompletely preserved camerae. Cross-section circular. The maximum diameter is 49 mm, and the minimum 47.5 mm. Rate of expansion approximately 6°. Smooth conch; thickness of conch wall 2 mm. Sutures transverse and straight, distant 16.7 mm but not completely preserved, being approximately 35 % of conch diameter. Septal depth 22.5 mm at diameter 49 mm. Siphuncle subcentral, diameter of septal foramen 5.6 mm, or 11 % of conch diameter. No internal features observed on any of the studied specimens.

**Remarks:** Most of the material is fragmentary with just a few cameral chambers preserved. However, the diagnostic features of slowly tapering large smooth conch, circular cross-section and short cameral chambers with subcentral wide siphuncle are present and confirm assignment to *Temperoceras ludense* (SOWERBY in MURCHISON, 1839). It is a cosmopolitan nektonic longiconic form and occurs within the Ludfordian all along the North Gondwana area, sometimes forming a distinctive layer of aligned specimens on the bedding plane often referred to in the literature as the *Temperoceras* beds, horizons or limestone (HISTON, 2012a, b). It is widespread in the Wenlock but particularly the Ludlow strata of England and the Welsh Borderlands. It has been noted for the great length of the slender conch both in the Ludfordian of England (HOLLAND, 2000), the Carnic Alps (HISTON, 2012b) and Morocco (KRÖGER, 2008; POHLE & KLUG, 2018). The species *Orthoceras temperans* BARRANDE common in the Ludlow of Bohemia has been placed in synonymy with *T. ludense* (SOWERBY in MURCHISON, 1839)

by HOLLAND (2000), thus extending the palaeogeographical range to Bohemia. Therefore, its occurrence within the Graz Palaeozoic assemblage indicates that this is comparable with a stratigraphically distinct cephalopod biofacies interval.

**Silurian occurrence:** Bohemia, British Isles, Carnic Alps of Austria, Ludlow of Gotland, Graz Palaeozoic, Morocco, upper Silurian of SW Sardinia, Kazakhstan and Middle Asia.

**Silurian Range:** Silurian, predominantly Ludlow.

### *Temperoceras migrans* (BARRANDE, 1866)

(Pl. 7, Fig. 14)

1866 *Orthoceras migrans* BARRANDE – BARRANDE, Pls. 212, 222.

1868 *Orthoceras migrans* BARRANDE. – BARRANDE, Pls. 309, 348.

1870 *Orthoceras migrans* BARRANDE. – BARRANDE, Pl. 377.

1874 *Orthoceras migrans* BARRANDE. – BARRANDE, Texte III, 643.

1972 *Temperoceras migrans* (BARRANDE, 1866). – BARSKOV, 49–50, Pl. 4, Fig. 1.

**Type species:** By original designation *Orthoceras migrans* BARRANDE, 1866. Bohemia. Faunes Siluriennes III, stage E.

**Diagnosis:** Slender, slowly tapering smooth conch, circular cross-section, cameral chambers relatively long at 50 % of conch diameter, siphuncle central to subcentral, c. 10 % of conch diameter.

**Material studied:** One specimen – UMJGP 220103. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** The slender elongate orthoconic specimen is incomplete both apically and adorally and consists of a portion of phragmocone 165.3 mm in length. The cross-section is slightly subcircular adorally and conch diameter incomplete apically due to breakage. The conch has apparently undergone compression. The maximum diameter apically is 29.9 mm. The maximum diameter adorally is 32.1 mm, minimum adorally 26.3 mm. Conch expands slowly at an angle of 1°. The conch surface is well preserved and smooth. Suture straight and transverse adorally, slightly sloped apically due to compression, being 14.8 mm apart at diameter 29 mm, cameral depth c. 50 % of conch diameter. The adoral transverse section of the conch shows the siphuncle to be central in position. Diameter of the septal foramen c. 3.3 mm at conch diameter 32.1 mm apically, approximately one tenth the conch diameter. No internal features are observed.

**Remarks:** The specimen is assigned to *Temperoceras migrans* (BARRANDE) on the basis of the elongate slowly expanding smooth conch, chamber length and central siphon. This species has been assigned in the past to *Michelinoceras* FOERSTE, however, the studied specimen resembles more the characteristics of *Temperoceras* BARSKOV and therefore herein the combination of BARSKOV (1972) is preferred.



**Silurian occurrence:** Bohemia, Carnic Alps of Austria, Graz Palaeozoic, Morocco, upper Silurian of SW Sardinia, Kazakhstan and Middle Asia.

**Silurian Range:** upper Silurian.

***Temperoceras* sp.**

(Pl. 7, Fig. 15)

**Material studied:** one specimen – UMJGP 220110; additional material: nine specimens – UMJGP 220109. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** These specimens are fragmentary, incomplete both apically and adorally, consisting of lengths of phragmocone and body chamber ranging from 45–98 mm in length. The cross-section is slightly subcircular. The maximum diameter apically ranges from 32–45 mm, minimum apically 29–32 mm. The maximum diameter adorally ranges from 39–44 mm, minimum adorally ranges from 33–35 mm. Conchs show some compression and expand slowly at an angle of 4–5°. The conch is apparently smooth where the conch wall is preserved. Suture apparently straight and transverse. Cameral depth cannot be estimated. One specimen shows a centrally positioned siphuncle in the apical transverse section of the conch, but it is not clear enough to facilitate measurement of the diameter of the septal foramen. No internal features are observed.

**Remarks:** This material is badly preserved, and the only distinct features are the smooth conch surface and large size of the slowly tapering conchs. However, as they are numerous within the studied assemblage and can be compared with *Temperoceras* BARSKOV it is preferred to assign them herein to this genus rather than leave them in open nomenclature as indeterminate orthocones.

**Silurian occurrence:** Graz Palaeozoic.

**Silurian Range:** Ludfordian.

**Family Paraphragmitidae FLOWER in FLOWER & KUMMEL, 1950**

**Genus *Cyrtocycloceras* FOERSTE, 1936**

**Type species:** By original designation *Cyrtoceras urbanum* BARRANDE. Bohemia, Faunes Siluriennes III, Stage E (e2), Ludlow.

**Diagnosis:** Annulated cyrtocone, exogastric, subcircular cross-section, ornament of transverse striations, siphuncle subcentral.

***Cyrtocycloceras* aff. *urbanum* (BARRANDE, 1866)**

(Pl. 5, Fig. 7)

1866 *Cyrtoceras urbanum* BARRANDE – BARRANDE, Pl. 198.

1874 *Cyrtoceras urbanum* BARRANDE. – BARRANDE, Texte III, 699.

1936 *Cyrtocycloceras urbanum* (BARRANDE). – FOERSTE, 58.

**Material studied:** One specimen – UMJGP 220129. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** The slightly cyrtoconic specimen is incomplete both apically and adorally and consists of an apical portion of phragmocone 20.1 mm in length. The cross-section is circular with diameter 7.2 mm and expands slowly at an angle of 5.5°. The conch is annulated: these are slightly obliquely angled at c. 8° to the plane normal to the conch axis. Annulations number c. 5 per 10 mm adorally. Faint traces of ornament are preserved adorally. These consist of fine transverse striations sometimes difficult to discern except in low angle light. Sutures not observed. The siphuncle is apparently subcentral in position apically.

**Remarks:** The specimen is poorly preserved but shows affinities with the type species of *Cyrtocycloceras* FOERSTE in the cyrtoconic form, circular cross-section, transverse ornament and annulations and subcentral siphuncle.

**Silurian occurrence:** Bohemia, Graz Palaeozoic.

**Silurian Range:** middle to upper Silurian.

**Superfamily Pseudorthocerataceae FLOWER & CASTER, 1935**

**Family Pseudorthoceratidae FLOWER & CASTER, 1935**

**Subfamily Spyroceratinae SHIMIZU & OBATA, 1935**

**Genus *Pseudocycloceras* BARSKOV, 1959**

**Type species:** By original designation *Pseudocycloceras karglense* BARSKOV, 1959. USSR (Southern Ferghana), middle Silurian.

**Diagnosis:** Annulated orthocones, ornament of transverse bands and or ridges, siphuncle subcentral and subcylindrical, septal necks orthochoanitic, siphonal and cameral deposits developed.

***Pseudocycloceras* cf. *transiens* (BARRANDE, 1866)**

(Pl. 4, Figs. 11–12)

1866 *Orthoceras transiens* BARRANDE. – BARRANDE, Pls. 218, 224.

1868 *Orthoceras transiens* BARRANDE. – BARRANDE, Pls. 292, 293.

1870 *Orthoceras transiens* BARRANDE. – BARRANDE, Pls. 402, 442.



- 1874 *Orthoceras transiens* BARRANDE. – BARRANDE, Texte III, 88–90.
- 1987 *Pseudocycloceras transiens* (BARRANDE). – KISELEV & STARSHININ, 86.

**Type species:** By original designation *Orthoceras transiens* BARRANDE, 1866. Bohemia, Faunes Siluriennes III, Stage E, upper Silurian.

**Diagnosis:** Orthoconic, annulated, circular cross-section, ornament of transverse to slightly oblique bands and secondary transverse striae, suture transverse to slightly oblique, siphuncle central.

**Material studied:** One specimen – UMJGP 220130. Eggenfeld Section, Graz Palaeozoic.

**Stratigraphical horizon:** Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic. *Polygnathoides siluricus* conodont biozone, Ludfordian.

**Description:** This specimen is incomplete apically and ad-orally and consists of a portion of phragmocone 47 mm in length. The cross-section is circular with maximum diameter ad-orally 23.8 mm and minimum apically 16.6 mm. Conch expands rapidly at an angle of 12°. The conch shows broad transverse bands 3–4 mm in width with an intermediate ornament of fine transverse striations numbering 8–10 per band. Sutures not observed. The siphuncle apparently central in position apically. No internal features observed.

**Remarks:** The specimen can be compared with *Pseudocycloceras transiens* (BARRANDE) in the rapidly tapering form, circular cross-section, transverse banded ornament and sub-central siphuncle.

**Silurian occurrence:** Bohemia, Carnic Alps of Austria, Graz Palaeozoic, Morocco, upper Silurian of SW Sardinia, Kazakhstan and Middle Asia.

**Silurian Range:** middle to upper Silurian.

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# Plates

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## Plate 1

Locality: Eggenfeld Section, NW of Graz (Styria, Austria).  
Horizon: Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic.  
Stratigraphic age: *Polygnathoides siluricus* conodont biozone, Ludfordian, upper Silurian.

### *Orthocycloceras* cf. *lynx* (BARRANDE, 1868)

Fig. 1: UMJGP 220184. Longitudinal section showing trilobite remains within conch, x 2.

### *Metarmenoceras?* sp.

Fig. 2: UMJGP 220186. Longitudinal section showing globular siphuncle and cameral chambers, x 2.

Fig. 3: UMJGP 220186. Detail of siphuncular segments, x 3.5.

Fig. 4: UMJGP 220186. Transverse view showing cross-section and siphuncle (arrow), x 3.5.

### *Michelinoceras* cf. *currens* (BARRANDE, 1866)

Fig. 5: UMJGP 211331. Longitudinal overview of elongate smooth conch, x 2.

Fig. 6: UMJGP 211331. Transverse view showing circular cross-section and central siphuncle, x 2.5.

Fig. 7: UMJGP 211331. Longitudinal section showing narrow cylindrical siphuncle and long cameral chambers, x 3.5.

Fig. 8: UMJGP 220187. Longitudinal overview of elongate smooth conch, x 2.

Fig. 9: UMJGP 220188. Longitudinal section showing long cameral chambers, x 2.

### *Michelinoceras* cf. *micelini* (BARRANDE, 1866)

Fig. 10: UMJGP 220189. Longitudinal overview of slender elongate smooth conch, x 4.

Fig. 11: UMJGP 220190. Longitudinal overview of slender elongate smooth conch, x 2.

Fig. 12: UMJGP 220190. Transverse view showing circular cross-section and central siphuncle, x 2.5.

### *Merocycloceras* cf. *declivis* (RISTEDT, 1968)

Fig. 13: UMJGP 211330. Longitudinal overview of annulated conch, x 2.

Fig. 14: UMJGP 211330. Transverse view showing circular cross-section and central siphuncle, x 2.

All photos by Fritz Messner, Graz.







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## Plate 2

Locality: Eggenfeld Section, NW of Graz (Styria, Austria).  
Horizon: Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic.  
Stratigraphic age: *Polygnathoides siluricus* conodont biozone, Ludfordian, upper Silurian.

### *Kopaninoceras* cf. *jucundum* (BARRANDE, 1870)

- Fig. 1: UMJGP 220174. Longitudinal overview conch showing transverse ornament, x 2.  
Fig. 2: UMJGP 220174. Transverse view showing circular cross-section and subcentral siphuncle, x 2.5.  
Fig. 3: UMJGP 220174. Longitudinal section showing cylindrical siphuncle and cameral chambers, x 2.  
Fig. 4: UMJGP 220174. Detail of funnel-like septal necks, x 5.  
Fig. 5: UMJGP 220175. Longitudinal overview conch showing transverse ornament, x 2.  
Fig. 6: UMJGP 220175. Transverse view showing circular cross-section and subcentral siphuncle, x 2.  
Fig. 7: UMJGP 220176. Longitudinal section showing narrow cylindrical siphuncle and cameral chambers, x 3.  
Fig. 8: UMJGP 220176. Detail of funnel-like septal necks, x 5.

### *Kopaninoceras* cf. *thyrsus* (BARRANDE, 1870)

- Fig. 9: UMJGP 220177. Longitudinal overview conch showing transverse ornament, x 2.5.  
Fig. 10: UMJGP 220178. Longitudinal section showing cylindrical siphuncle and cameral chambers, x 3.  
Fig. 11: UMJGP 220179. Longitudinal section showing cylindrical siphuncle and cameral chambers, x 3.  
Fig. 12: UMJGP 220180. Longitudinal section showing cylindrical siphuncle and cameral chambers, x 2.

### *Plagiostomoceras* cf. *gruenewaldti* (BARRANDE, 1866)

- Fig. 13: UMJGP 220181. Longitudinal section showing long body chamber and cameral chambers, x 2.  
Fig. 14: UMJGP 220182. Longitudinal overview conch showing transverse ornament, x 2.  
Fig. 15: UMJGP 220182. Detail of transverse ornaments, x 4.

All photos by Fritz Messner, Graz.







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## Plate 3

Locality: Eggenfeld Section, NW of Graz (Styria, Austria).  
Horizon: Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic.  
Stratigraphic age: *Polygnathoides siluricus* conodont biozone, Ludfordian, upper Silurian.

***Kionoceras cf. bronni* (BARRANDE, 1868)**

Fig. 1: UMJGP 220156. Longitudinal overview of conch showing fine longitudinal ornament, x 2.

***Kionoceras doricum* (BARRANDE, 1868)**

Fig. 2: UMJGP 220157. Longitudinal overview conch showing fine longitudinal ornament, x 2.

Fig. 3: UMJGP 220157. Transverse view showing circular cross section and subcentral siphuncle, x 2.

Fig. 4: UMJGP 220157. Longitudinal overview conch showing cameral chambers, x 2.

***Kionoceras cf. neptunicum* (BARRANDE, 1868)**

Fig. 5: UMJGP 220158. Longitudinal overview of conch showing fine longitudinal ornament, x 2.5.

Fig. 6: UMJGP 220158. Transverse view showing circular cross section and subcentral siphuncle, x 2.5.

***Parakionoceras originale* (BARRANDE, 1868)**

Fig. 7: UMJGP 220160. Longitudinal overview of conch showing longitudinal ornament, x 1.8.

Fig. 8: UMJGP 220159. Detail of longitudinal ornament showing grooves and ridges, x 4.

Fig. 9: UMJGP 220161. Transverse view of circular cross section and subcentral siphuncle, x 1.8.

Fig. 10: UMJGP 211328. Longitudinal overview conch showing cameral chambers, x 1.8.

***Parakionoceras cf. striatopunctatum* (MÜNSTER, 1840)**

Fig. 11: UMJGP 220163. Longitudinal overview of conch showing longitudinal ornament, x 1.8.

Fig. 12: UMJGP 211329. Detail of longitudinal ornament showing grooves and punctuated ridges, x 4.

Fig. 13: UMJGP 220162. Longitudinal section showing narrow cylindrical siphuncle and septal necks, c. x 3.

All photos by Fritz Messner, Graz.







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## Plate 4

Locality: Eggenfeld Section, NW of Graz (Styria, Austria).  
Horizon: Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic.  
Stratigraphic age: *Polygnathoides siluricus* conodont biozone, Ludfordian, upper Silurian.

***Metaspyroceras venustulum* (BARRANDE, 1868)**

- Fig. 1: UMJGP 220096. Longitudinal overview showing oblique annulations, x 2.5.  
Fig. 2: UMJGP 220111. Longitudinal overview showing oblique annulations, x 2.5.  
Fig. 3: UMJGP 220111. Detail of ornament showing fine longitudinal striations, x 10.

***Metaspyroceras* sp.**

- Fig. 4: UMJGP 220097. Longitudinal overview showing oblique annulations, x 2.  
Fig. 5: UMJGP 220097. Fine detail of ornament, x 10.

***Calorthoceras* cf. *pseudocalamiteum* (BARRANDE in QUENSTEDT, 1851)**

- Fig. 6: UMJGP 220114a. Longitudinal overview of annulated conch, x 2.5.  
Fig. 7: UMJGP 220114a. Detail of longitudinal and transverse ornament, x 5.  
Fig. 8: UMJGP 220114a. Fine detail of ornament, x 10.  
Fig. 9: UMJGP 220115. Longitudinal overview of annulated conch, x 2.5.  
Fig. 10: UMJGP 220115. Transverse circular cross-section, x 2.5.

***Pseudocycloceras* cf. *transiens* (BARRANDE, 1866)**

- Fig. 11: UMJGP 220130. Longitudinal overview showing banded transverse ornament, x 2.  
Fig. 12: UMJGP 220130. Detail of intervening transverse finer striations, x 4.

All photos by Fritz Messner, Graz.







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## Plate 5

Locality: Eggenfeld Section, NW of Graz (Styria, Austria).  
Horizon: Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic.  
Stratigraphic age: *Polygnathoides siluricus* conodont biozone, Ludfordian, upper Silurian.

***Orthocycloceras* aff. *fluminense* (MENEHINI, 1857)**

- Fig. 1: UMJGP 220113. Longitudinal overview showing oblique annulations, x 2.5.  
Fig. 2: UMJGP 220119. Longitudinal overview showing oblique annulations, x 2.5.

***Orthocycloceras* cf. *lynx* (BARRANDE, 1868)**

- Fig. 3: UMJGP 220121. Longitudinal overview showing annulations, x 2.5.  
Fig. 4: UMJGP 220121. Detail of ornament showing transverse striations, x 4.  
Fig. 5: UMJGP 220121. Longitudinal natural section of most apical cameral chambers, x 5.  
Fig. 6: UMJGP 220122. Longitudinal section showing siphuncle trace and cameral chambers, x 2.5.

***Cyrtocycloceras* aff. *urbanum* (BARRANDE, 1866)**

- Fig. 7: UMJGP 220129. Longitudinal overview of annulated cyrtconic conch, x 2.5.

***Kionoceratinae* gen. et sp. indet.**

- Fig. 8: UMJGP 220124. Longitudinal overview of annulated conch, x 2.5.  
Fig. 9: UMJGP 220124. Fine detail of longitudinal ornament, x 10.  
Fig. 10: UMJGP 220124. Transverse circular cross-section, x 2.5.  
Fig. 11: UMJGP 220125. Longitudinal overview of annulated conch, x 2.5.  
Fig. 12: UMJGP 220126. Longitudinal overview of annulated conch, x 2.5.  
Fig. 13: UMJGP 220127. Longitudinal overview of annulated conch, x 2.5.  
Fig. 14: UMJGP 220127. Fine detail of longitudinal ornament, x 10.  
Fig. 15: UMJGP 220127. Transverse circular cross-section, x 2.5.  
Fig. 16: UMJGP 220128. Longitudinal overview of annulated conch, x 2.5.

All photos by Fritz Messner, Graz.

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## Plate 6

Locality: Eggenfeld Section, NW of Graz (Styria, Austria).  
Horizon: Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic.  
Stratigraphic age: *Polygnathoides siluricus* conodont biozone, Ludfordian, upper Silurian.

***Geisonoceras* cf. *rivale* (BARRANDE, 1866)**

- Fig. 1: UMJGP 220132. Longitudinal conch overview showing transverse ornament, x 1.5.  
Fig. 2: UMJGP 220133. Longitudinal conch overview showing transverse ornament, x 1.3.  
Fig. 3: UMJGP 220133. Transverse view of central siphuncle, x 1.3.  
Fig. 4: UMJGP 220133. Detail of transverse banded ornament, x 3.

***Geisonoceras* sp.**

- Fig. 5: UMJGP 220135. Longitudinal overview of conch showing ornament, 1:1.

***Arionoceras* cf. *affine* (MENEHINI, 1857)**

- Fig. 6: UMJGP 220136. Longitudinal overview of conch, 1:1.  
Fig. 7: UMJGP 220136. Detail of fine transverse striations on apical part of conch, x 3.  
Fig. 8: UMJGP 220137. Longitudinal overview showing deeply concave septa, 1:1.  
Fig. 9: UMJGP 220138. Polished section showing cameral chambers, x 1.5.

***Arionoceras* cf. *capillosum* (BARRANDE, 1868)**

- Fig. 10: UMJGP 220139. Longitudinal overview showing transverse ornament, x 2.  
Fig. 11: UMJGP 220139. Transverse view of circular cross section of conch, x 1.5.

***Arionoceras* cf. *submoniliforme* (MENEHINI, 1857)**

- Fig. 12: UMJGP 220141. Longitudinal overview showing smooth conch, x 1.5.  
Fig. 13: UMJGP 220142. Longitudinal overview showing deeply concave septa, x 1.5.  
Fig. 14: UMJGP 220143. Polished section showing cameral chambers, x 1.5.

***Murchisoniceras* sp.**

- Fig. 15: UMJGP 220131. Longitudinal overview showing sigmoidal ornament towards the aperture, x 2.  
Fig. 16: UMJGP 220131. Detail of sigmoidal striations, x 4.

All photos by Fritz Messner, Graz.







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## Plate 7

Locality: Eggenfeld Section, NW of Graz (Styria, Austria).  
Horizon: Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic.  
Stratigraphic age: *Polygnathoides siluricus* conodont biozone, Ludfordian, upper Silurian.

### *Columenoceras agassizi* (BARRANDE, 1866)

- Fig. 1: UMJGP 220098. Longitudinal overview showing annulations and transverse ornament, x 2.  
Fig. 2: UMJGP 220098. Longitudinal overview of long cameral chambers, x 2.  
Fig. 3: UMJGP 220098. Detail of transverse striations, x 4.  
Fig. 4: UMJGP 220098. Transverse view of subcentral siphuncle, x 2.  
Fig. 5: UMJGP 220102. Longitudinal section showing cylindrical form of siphuncle and camera, x 2.

### *Columenoceras grande* (MENEHINI, 1857)

- Fig. 6: UMJGP 220101. Longitudinal overview of sutures with shallow lobe, x 0.5.  
Fig. 7: UMJGP 220101. Longitudinal overview showing columnar form and cameral chambers, x 0.5.

### *Columenoceras subannulare* (MÜNSTER, 1840)

- Fig. 8: UMJGP 211334. Longitudinal overview showing slightly oblique broad annulations and transverse ornament, x 2.  
Fig. 9: UMJGP 211334. Detail of fine transverse striations, x 4.

### *Columenoceras* sp.

- Fig. 10: UMJGP 220100. Longitudinal overview showing oblique annulations and transverse ornament, x 2.  
Fig. 11: UMJGP 220100. Detail of fine transverse striations, x 4.

### *Temperoceras ludense* (SOWERBY in MURCHISON, 1839)

- Fig. 12: UMJGP 220106. Lateral view of short cameral chambers, 1:1.  
Fig. 13: UMJGP 220106. Transverse view of circular cross-section and subcentral siphuncle, 1:1.

### *Temperoceras migrans* (BARRANDE, 1866)

- Fig. 14: UMJGP 220103. Longitudinal overview of elongate smooth conch, 1:1.

### *Temperoceras* sp.

- Fig. 15: UMJGP 220110. Longitudinal overview elongate conch, 1:1.

All photos by Fritz Messner, Graz.

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## Plate 8

All figures x 2

Locality: Eggenfeld Section, NW of Graz (Styria, Austria).

Horizon: Level K1, Eggenfeld Member, Kötschberg Formation, Graz Palaeozoic.

Stratigraphic age: *Polygnathoides siluricus* conodont biozone, Ludfordian, upper Silurian.

### *Cardiola* cf. *alata* BARRANDE, 1881

Fig. 1: UMJGP 220146. Internal mould, left valve (?), dorso-lateral view.

Fig. 2: UMJGP 220146. Digital negative inversion of the same photo.

### *Cardiola* cf. *conformis* BARRANDE, 1881

Fig. 3: UMJGP 220147. Left valve, lateral view.

Fig. 4: UMJGP 220147. Left valve, postero-lateral view.

Fig. 5: UMJGP 220147. Left valve, dorso-lateral view.

Fig. 6: UMJGP 220148. Right valve, lateral view.

Fig. 7: UMJGP 220148. Right valve, antero-lateral view.

Fig. 8: UMJGP 220148. Right valve, antero-lateral view, more oblique.

Fig. 9: UMJGP 220148. Right valve, dorso-lateral view.

### *Cardiola* sp.

Fig. 10: UMJGP 220149. Mould inside a calyx of a rugose coral.

Fig. 11: UMJGP 220149. Digital negative inversion of the same photo.

### *Cardiolinka* cf. *bohémica* (BARRANDE, 1881)

Fig. 12: UMJGP 220150. Right valve, lateral view.

Fig. 13: UMJGP 220150. Right valve, antero-lateral view.

Fig. 14: UMJGP 220150. Right valve, postero-lateral view.

Fig. 15: UMJGP 220150. Right valve, dorso-lateral view.

Fig. 16: UMJGP 220151. Left valve, lateral view.

Fig. 17: UMJGP 220151. Left valve, antero-lateral view.

### *Dualina?* sp. 1

Fig. 18: UMJGP 220152. Part of a right (?) valve, lateral view.

Fig. 19: UMJGP 220152. Part of a right (?) valve, oblique dorsal view.

### *Dualina?* sp. 2

Fig. 20: UMJGP 220153. Dorsal part of a right valve, lateral view.

Fig. 21: UMJGP 220153. Dorsal part of a right valve, dorso-lateral view.

### *Dualina?* sp. 3

Fig. 22: UMJGP 220154. Left (?) valve, lateral view.

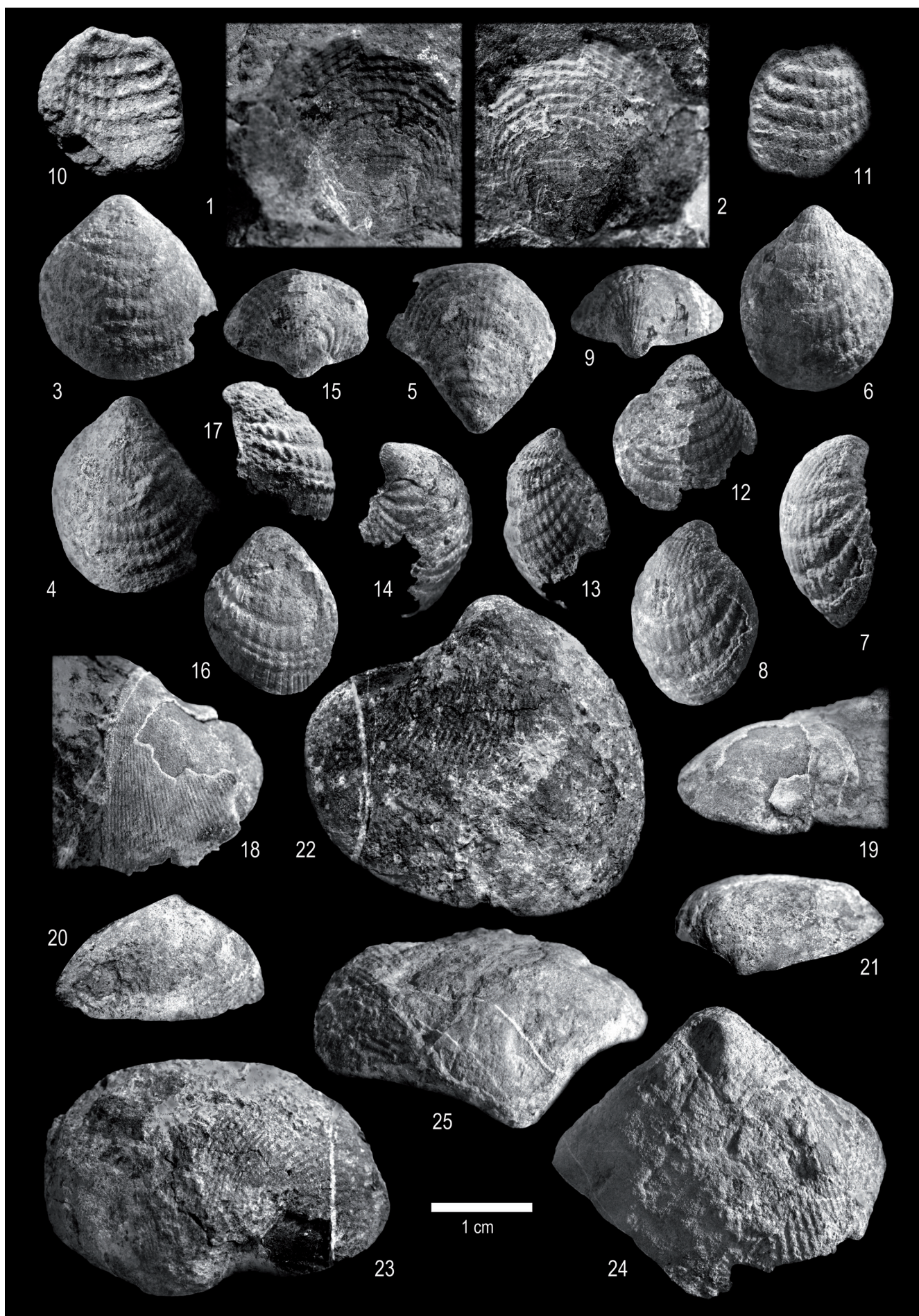
Fig. 23: UMJGP 220154. Left (?) valve, dorso-lateral view.

### *Dualina?* sp. 4

Fig. 24: UMJGP 220155. Left valve, lateral view.

Fig. 25: UMJGP 220155. Left valve, dorso-lateral view.

All photos by Fritz Messner, Graz.





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Zoologisch-Botanische Datenbank/Zoological-Botanical Database

Digitale Literatur/Digital Literature

Zeitschrift/Journal: [Jahrbuch der Geologischen Bundesanstalt](#)

Jahr/Year: 2020

Band/Volume: [160](#)

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