A preliminary study of the upper Silurian nautiloid cephalopods from the Eggenfeld section (Graz Paleozoic, Austria)

Kathleen Histon, Bernhard Hubmann & Fritz Messner

ABSTRACT - The preliminary results of a systematic investigation of the nautiloid faunas from the upper Silurian (Pridoli) Eggenfeld section of the Graz Paleozoic are presented. A faunal list of the seven genera recognized to date, representing the families Oonoceratidae and Lechrirochoceratidae and subfamilies Michelinoceratinae, Kionoceratinae, Leurocycloceratinae is given and selected taxa illustrated. These genera document faunal exchange between the Graz Paleozoic, central Bohemia, the Carnic Alps, Sardinia, France (Montagne Noire), Spain (the Ossa Morena Zone) and Morocco during the late Silurian. The study adds a further contribution to the ongoing systematic description by diverse research groups of Silurian nautiloid cephalopods from the North Gondwana sector within a well defined biostratigraphic framework in order to elaborate their use as a tool for biostratigraphic correlation and paleobiogeographic reconstructions.

KEY WORDS - Nautiloid cephalopods, upper Silurian, Austria, paleobiogeography, biostratigraphy.

INTRODUCTION

In recent years there has been an increase in systematic studies of Silurian nautiloid cephalopods from a variety of geographical settings and the observed temporal and spatial data from these faunas may now be considered a reliable tool for paleobiogeographic reconstruction and tracing of migrational pathways of pelagic organisms. Concentrated efforts have been made to improve the knowledge of the distribution and taxonomy of Silurian nautiloid cephalopod faunas and many existing collections have been revised using up to date taxonomic criteria as well as collection of new material from horizons with precise biostratigraphic data. In Europe the main work has been done in the British Isles (Evans, 1994; Evans & Holland, 1995; Holland, 1998, 1999, 2000a, 2000b, 2000c, 2002, 2003, 2004, 2007; Holland & Stridsberg, 2004), Sweden (Stridsberg, 1985), Prague Basin (Marek, 1971; Kolebaba, 1975, 1977, 1999, 2002; Turek, 1975; Marek & Turek, 1986; Manda, 1996, 2008; Gnoli, 1997; Stridsberg & Turek, 1997; Manda & Kriz, 2006, 2007; Manda & Turek, 2009a, 2009b, 2009c), South West Sardinia (Gnoli & Serpagli, 1977, 1991; Serpagli & Gnoli, 1977, 1990; Gnoli & Serventi, 2006, 2009 and references therein), Spain (Bogolepova, 1998b), France (Ristedt, 1968; Serventi & Feist, 2009) and the Carnic Alps (Ristedt, 1968; Histon, 1997, 1998, 1999, 1998, 2002, 2002; Bogolepova, 1998a; Gnoli & Histon, 1998; Gnoli et al., 2000; Serventi & Gnoli, 2001; Serventi et al., 2006, 2010; Gnoli & Serventi, 2008). Tentative correlations are now possible between Avalonia (British faunas) and North Gondwana (Carnic Alps, Sardinia, France and Spain) and Bohemia and Baltica, although problems still exist in recognition of faunas at both generic and specific level due to poor preservation and lack of precise taxonomic diagnoses.
Detailed study of Silurian-Devonian nautiloid faunas from Morocco (Kröger, 2008) presented together with precise stratigraphic and lithofacies data for the collection localities has highlighted further that correlation is feasible between the Peri-Gondwana Terranes and that nautiloid cephalopods are reliable paleobiogeographic indicators.

This is the first detailed systematic study of the nautiloid fauna from the upper Silurian sections of the Graz Paleozoic area to be carried out even though nautiloids are to be found in abundance there (Ebner, 1976a; Hiden, 1995). It is hoped that the results of the systematic investigation in progress will be of importance for placing the nautiloid faunas from the Graz Silurian within a global scenario both with regard to the implications from the faunal assemblage present for paleobiographical reconstruction and patterns of faunal exchange along the North Gondwana margin but also with regard to their paleoecological and paleoenvironmental settings which in some ways are similar to those in some areas of the Prague Basin (Manda & Kriz, 2006).

GEOLOGICAL SETTING

The Graz Paleozoic located in eastern Austria (Fig. 1) extends over approximately 1250 km² and is isolated from other low metamorphic Paleozoic occurrences by tectonic borders to the north, east and west as well as by its younger overlays in the south (Fig. 2). The northwestern and western parts of the Graz Paleozoic are bordered by polycrystalline units of the Austroalpine Crystalline Zone, whereas in the south, Paleozoic successions are transgressively overlain by Neogene sediments of the “Styrian Basin”. The southwestern parts are unconformably covered by Upper Cretaceous sediments of the Kainach Gosau.

The Graz Paleozoic is divided into a basal, an intermediate and an upper nappe group (Fritz & Neubauer, 1990) based on lithological similarities, the tectonic position as well as the metamorphic superimposition of successions.

- The Basal Nappe System (“Schöckl-Hochschlag Nappe”; upper Silurian to Middle Devonian) was deformed under upper greenschist facies conditions. Volcaniclastics dominate the late Silurian to Early Devonian interval, and carbonates the Middle Devonian time span.
- The Intermediate Nappe System (“Laufenitzdorf Nappe and Kalkschiefer Nappes”; lower Silurian to Upper Devonian) contains pelagic limestones, shales, volcaniclastics as well as siliciclastics.
- The Upper Nappe System (“Rannach-Hochlantsch Nappe”; upper Silurian to Upper Carboniferous) is characterised by Lower to Middle Devonian volcaniclastic rocks, Lower to Middle Devonian siliciclastics and fossil-rich carbonates of near-shore environment followed by the pelagic sequences of late Givetian to Bashkirian age with shallow marine sediments at the top.

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 (Fritz et al., 1992). During Pragian to Givetian time deposition changed from near-shore facies to open platform environments, during the Frasnian the carbonate platform was drowned and limestones were deposited. The “Variscan event” is indicated by mixed conodont faunas, stratigraphic gaps and karstification (Ebner, 1976b).

STRATIGRAPHY AND ENVIRONMENTAL ARCHITECTURE OF THE RANNACH NAPPE (UPPER NAPPE GROUP)

Volcaniclastics characterise the basal parts of all nappe groups of the Graz Paleozoic. The sequence of the
The Rannach Nappe starts with predominantly alkaline subordinately acidic metavolcanites (tuffs, lavas) of the Kehr Fm. (Fig. 3). A single finding of the graptolite *Bohemograptus bohemicus tenuis* (Boucek, 1936) within a tuffitic layer at the very top of the formation indicates an age not younger than Ludfordian (*Neocucullograptus kozlowskii* graptolite Biozone). The following Kötschberg Fm. comprises predominantly dolostones, argillaceous shales and silty shales of Ludlow to Lochkovian age (Ebner, 1976a; Hiden, 1995). Following the basal sequences dominated by volcaniclastics to fine-grained clastics sedimentation changes to platy crinoidal limestones intercalated with sandy marls and sand/siltstones of the Pragian age Parmasegg Fm. (Fritz, 1991). During Emsian times the peritidal Flösserkogel Fm. with monotonous light grey late diagenetic dolostones, reddish-purple to green volcanoclastics, pure quartz sandstones, marly dolomites and biolaminated dolomites of varying colours was formed (Fenninger & Holzer, 1978).

A sea level rise resulted in the deposition of highly fossiliferous dark marly bioclastic limestones with reefal structures (coral-stromatoporoid-carpets), the Eifelian Plabutsch Fm. (Hubmann, 1993, 2003). This phase is terminated by a repetition of tidal flat deposits similar to the Flösserkogel Fm. and obviously caused by an eustatic sea level fall.

During the Givetian renewed transgression resulted in sequences with sharp (bio)facial contrasts between patch-reefs and monotonous mudstones (Kollererkogel Fm., Tynaueralm Fm., and Zachenspitz Fm.). During the uppermost Givetian to lower Frasnian the sedimentation of shallow platform carbonates was replaced by micritic cephalopod limestones (Steinberg Fm.). This sedimentation continued up to the Bashkirian (Sanzenkogel Fm., Forstkogel Group) with some interruptions caused by uplifting during the Variscan collision (Ebner, 1976b, 1978). Finally the sequence is terminated by shallow marine shales and limestones with birdseye structures (Hahng raben Fm.) (Hubmann & Messner, 2007).

### The Eggenfeld Section

The Eggenfeld section belongs to the Eggenfeld Member (Flügel, 2000) of the Kötschberg Fm. (Ludfordian - Lochkovian). The Silurian succession of the section (Fig. 4) at Eggenberg (hill north of the village of Eggenfeld) consists of greenish, massive diabase (V) at the base, which is followed by approximately a 2 m
thickness of violet and greenish-grey unlayered tuffs, as well as thin bedded ash tuffs (Ebner, 1976a). Some concretionary horizons with haematite occur. A moderately well preserved specimen of *Bohemograptus bohemicus tenuis* was recorded (Hiden, 1995) from one of the ash tuff horizons. Above the volcanoclastic horizon which marks the boundary between the Kehr Fm. and the overlying Kötschberg Fm. (Eggenfeld Member) a layer of haematite (R) is developed at the contact between the diabase and dolomite. This haematite layer passes into a 1 m thick succession of bedded dark grey dolostones which is overlain by fossil free tuffaceous schists and claystones (S). Carbonate rocks K1, K2 and K3 of the section are dark grey, bedded dolomites and/or dolomitic limestones that are locally rich in fossils. They can be differentiated on the basis of their microfacies into: bioclastic dolosparites to biodolosparites, biodolosparites and biomicrites (microsparites). The bioclastic content (mainly crinoids, orthocerids, brachiopods, rare solitary rugose corals) is subject to strong fluctuations, however, generally amounts are up to 15%. The fossil content of the biodolosparites likewise reaches 15% but comprises exclusively crinoidal remains. Biomicrites contain up to 20% shell fragments, brachiopods, crinoids, trilobites and subordinate orthoconic nautiloids. The brachiopods are mostly preserved with both valves. The occurrence of macrofossils varies throughout the carbonate horizons (Ebner, 1976a):

- K2 - crinoids, orthocerids, *Septatrypa subsecrreta*, *Syringaxon* frame.

Preservation of conodonts is excellent within the dolomites (see Ebner, 1976a) and these indicate a range from the *P. siluricus* conodont Zone (upper Ludlow) to the *I. woschmidti* conodont Zone (Lochkovian).

**NAUTILOID FAUNAS**

The collection of nautiloid fauna being studied is housed at the University of Graz under the accession number series E.I-001-399. The material which to date includes over 400 specimens, was collected from the K, horizon at the Eggenfeld section locality and is being prepared and photographed at the University of Graz. The specimens have to date been divided into 16 distinct taxa

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**EXPLANATION OF PLATE 1**

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<td>Fig. 1</td>
<td><em>Plagiostomoceras</em> sp. Coll. n. E.I–329, external view of the specimen, showing fine, transverse ornament, Pridoli, level K2, Eggenfeld section (Graz Paleozoic), scale bar 1 cm.</td>
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<td>Figs. 2, 9</td>
<td><em>Lechritrochoceras</em> sp. 2 - Coll. n. E.I–109, external view of the specimen, showing transverse ornament, prominent annulations and deep hyponomic sinus, Pridoli, level K2, Eggenfeld section (Graz Paleozoic), scale bar 1 cm. 9 - Coll. n. E.I–077, external view of the specimen, showing fine, transverse and longitudinal ornament and oblique annulations, Pridoli, level K2, Eggenfeld section (Graz Paleozoic), scale bar 1 cm.</td>
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<td>80</td>
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<td><em>Parakionoceras</em> sp. 3 - Coll. n. E.I–311, external view of the specimen, showing longitudinal ornament, Pridoli, level K2, Eggenfeld section (Graz Paleozoic), scale bar 1 cm. 10 - Coll. n. E.I–122, external view of the specimen, showing longitudinal ornament, Pridoli, level K2, Eggenfeld section (Graz Paleozoic), scale bar 1 cm.</td>
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<td><em>Oonoceras</em> sp. Coll. n. E.I–079, external view of the specimen, showing slender cyrtoconic form and oblique septa, Pridoli, level K2, Eggenfeld section (Graz Paleozoic), scale bar 1 cm.</td>
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<td>Figs. 11-12</td>
<td><em>Orthocycloceras</em> sp. 11 - Coll. n. E.I–165, external view of the specimen, showing fine, transverse ornament and transverse annulations, Pridoli, level K2, Eggenfeld section (Graz Paleozoic), scale bar 1 cm. 12 - Coll. n. E.I–165, external view of the specimen, showing fine, transverse ornament and slightly oblique annulations, Pridoli, level K2, Eggenfeld section (Graz Paleozoic), scale bar 1 cm.</td>
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however, this preliminary classification is based solely on external features, mainly ornament and conch form, and requires further verification based on internal features after sectioning of specimens has been completed. The preliminary data presented here includes a faunal list of the seven genera which have been ascertained to date and illustration of a selection of these specimens (Pl. 1, figs. 1-12). The higher taxonomic classification system of the Treatise (Moore, 1964) has been followed where possible with modifications from more recent systematic works when appropriate.

FAUNAL LIST

**Class CEPHALOPODA Cuvier, 1797**
**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
  (Pl. 1, figs. 5-7)
- **Genus Merocycloceras** Ristedt, 1968
  (Pl. 1, fig. 4)
- **Genus Plagiostomoceras** Teichert & Glenister, 1952
  (Pl. 1, fig. 1)
**Subfamily KIONOCERATINAE Hyatt, in Zittel, 1900**
- **Genus Parakionoceras** Foerste, 1928
  (Pl. 1, figs. 3, 10)
**Subfamily LEUROCYCLOCERATINAE Sweet, 1964**
- **Genus Orthocycloceras** Barskov, 1972
  (Pl. 1, figs. 11, 12)
**Order ONCOCERIDA Flower, in Flower & Kummel, 1950**
**Family OONOCERATIDAE Hyatt, 1884**
- **Genus Oonoceras** Hyatt, 1884
  (Pl. 1, fig. 8)
**Family LECHRITROCHOCERATIDAE Flower, in Flower & Kummel, 1950**
- **Genus Lechritrochoceras** Foerste, 1926
  (Pl. 1, figs. 2, 9)

PALEOBIOGEOGRAPHY

The importance of nautiloid cephalopods for biostratigraphy and paleobiogeography was highlighted by Crick (1990, 1993) who noted that Paleozoic nautiloid distribution was controlled by water depth, distance separating adjacent shelf seas, and water temperature. Nautiloid cephalopods were also not subject to extensive post-mortem drift, the latter being a reason that this group has been considered in the past as unreliable as paleobiogeographic markers (Westermann, 1998). Crick emphasized that much more detailed systematic work on nautiloid faunas with precise stratigraphic data was needed to facilitate their use for reliable paleobiogeographic reconstructions and as stated above the array of studies emerging in recent years has shown this to be feasible. The Silurian Cephalopod Limestone Biofacies (Kriz, 1998) is well developed in Spain, France, Sardinia, the Carnic Alps and Bohemia and has been famous since the last century for its abundance of macrofossils, particularly of nautiloid cephalopods. Hence the name ‘Orthoceras’ limestone was widely used in the literature on these areas. A detailed multidisciplinary study of the occurrence of the Silurian Cephalopod Limestone Biofacies at various sections in the Carnic Alps which, focused on obtaining data concerning the paleogeographical setting of the Carnic Alps during the Silurian (Ferretti & Histon, in press), has shown that these horizons with rich nautiloid faunas may be traced all along the northern Gondwana margin from Morocco, the Ossa Morena Zone (South West Spain), Montagne Noire (France), West South Sardinia, the Carnic Alps to the Prague Basin. Kriz (1998) and Bogolepova (1996c) have outlined the distribution of cephalopod limestones during the Silurian along the North Gondwana margin, Perunica and North Asia and Ferretti & Kriz (1995) did a detailed microfacies study of diverse horizons of this biofacies in the Prague Basin identifying two distinct depositional environments: one by surface currents and one within a shallower setting affected by storm action. The cephalopod bearing limestone beds from the section being studied in the Graz Paleozoic also show diverse orientation of the nautiloid conchs on the bedding surface and taphonomic features which may be indicative of small scale depositional cycles within this succession (Figs. 5-8). Uni-directional orientation of conchs (Figs. 6-7) may indicate deposition by surface currents while the perpendicular orientation of conchs (Fig. 5) and distinct time-rich taphonomic features such as dissolution of shell material and disarticulation of septal chambers on the bedding surface (Fig. 8) may indicate deposition.
within a shallower setting and periods of non-deposition.

The presence of the common Circum Mediterranean ‘Orthoceras’ Limestone and Scyphocrinites Communities (Vai, 1999) and the Dualina nigra-Patrocardia bivalve subcommunity (Kriz, 1999) within the latest Pridoli of the Carnic Alps sections demonstrates that faunal exchange was taking place during this interval between the Peri Gondwana terranes and Baltica (Histon, 2002). This may also be the case for the faunas of the Graz Paleozoic.

Unfortunately there are few age comparable faunas described for considering exchange of the nautiloid faunas between the North Gondwana terranes during the Pridoli as systematic revision, particularly of the Bohemian fauna, is still lacking. As outlined above many authors have shown links between the Sardinian (Gnoli & Serpagli, 1977, 1991; Serpagli & Gnoli, 1977; Gnoli, 1990; Gnoli & Serventi, 2006, 2009 and references therein) and Bohemian (Marek, 1971; Kolebaba, 1975, 1977, 1999, 2002; Turek, 1975; Marek & Turek, 1986; Manda, 1996, 2008; Gnoli, 1997; Stridsberg & Turek, 1997; Manda & Kriz, 2006, 2007; Manda & Turek, 2009a, 2009b, 2009c) Silurian nautiloid faunas within a broad stratigraphic framework while close relationships between the nautiloids of the Carnic Alps (Ristedt, 1968; Histon, 1997, 1998, 1999a, 1999b, 2002; Bogolepova, 1998a; Gnoli & Histon, 1998; Gnoli et al., 2000; Serventi & Gnoli, 2001; Serventi et al., 2006, 2010; Gnoli & Serventi, 2008) and both the latter areas has also been suggested. Histon (2002) contributed additional data to support the idea of faunal exchange between the Carnic Alps, in particular with Bohemia and Baltica during the late Silurian. The conclusion of the study was that the more shallow water, facies restricted, nautiloid species described were common to both areas possibly reflecting the closeness of the Carnic Alps to Bohemia where these forms are common in the Ludlow and/or Pridoli series (Marek & Turek, 1986; Manda & Turek, 2009c; Storch pers. comm.) while the more pelagic faunas in common reflected the exchange between the various North Gondwana terranes, Baltica and the Urals due to currents.

The preliminary results of the present study further support this hypothesis as genera common to both the Carnic Alps, Sardinia, Spain (Ossa Morena Zone), France (Montagne Noire), Morocco (Tafilalt, Anti-Atlas) and Bohemia (Prague Basin) are found at the Eggenfeld locality of the Graz Paleozoic (Table 1). These in part represent the more pelagic component of the fauna and probably are the result of surface current transport. However, some more benthonic elements may also reflect the closeness of these terranes during this time slice. Further study of the faunas and precise classification at species level should shed more light on this aspect.

DISCUSSION

It is hoped that the results of the systematic investigation:

![Fig. 6](image1.png)
![Fig. 7](image2.png)
![Fig. 8](image3.png)
(1) will increase and add to the existing documentation of the Silurian nautiloid fauna on a global scale and thus make a further contribution towards the paleobiogeographic knowledge of the position of this fragment of the North Gondwana terranes at a precise stratigraphic interval, the latest Pridoli;

(2) will add more data to support the idea of faunal exchange between North Gondwana terranes such as Morocco, the Ossa Morena Zone, Montagne Noire, Sardinia, the Carnic Alps and Baltica and the documentation of distinct nautiloid communities within precise stratigraphic intervals;

(3) will be of great importance for placing the nautiloid faunas from the Graz Silurian successions within a global scenario. The results of the study of the systematics and paleobiogeography of the fossil nautiloids will provide important information on regional paleogeography and possible migrational pathways for pelagic organisms. This will yield further insights into the positioning of paleocontinents and seaways and mechanisms of paleooceanography during the Silurian.

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