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# **Silurian nautiloid cephalopods from Sardinia: the state of the art**

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**ABSTRACT** - The complete faunal list of nautiloid cephalopods from the Silurian of Sardinia has been compiled herein. A history leading to the present state of knowledge on this fossil group, achieved after forty years of extensive study, is reviewed.

A total of 61 species assigned to 38 genera are known from the Wenlock-Pridoli of southern Sardinia. The fauna strongly supports links with coeval associations of Bohemia and, to a lesser extent, with the Carnic Alps.

**KEY WORDS** - Silurian, Sardinia, Cephalopods, Palaeogeography.

## **INTRODUCTION**

This paper represents the nautiloid cephalopod sum up of more than forty years of scientific activity within the informal International Group on the Palaeozoic Palaeontology headed by Prof. Enrico Serpagli, who devoted most of his research to the Italian Palaeozoic outcrops mainly in two areas, the Carnic Alps and southern Sardinia. During these years, many field trips have been carried out in Sardinia allowing the collection of an enormous amount of samples studied in detail in their palaeontological (either taxonomic or biostratigraphical) content by Italian, German, English, Irish, Spanish, Swedish and Czech members of the research team. Such a multidisciplinary approach involved also a formal definition of the lithostratigraphical units in the post-Sardic Ordovician (Leone et al., 1991) and in the Silurian-Lower Devonian of southwestern Sardinia (Gnoli et al., 1990). The aim of this paper is to report the present knowledge on the Sardinian Silurian nautiloid cephalopods.

## **NAUTILOID CEPHALOPOD FAUNA**

The first description and illustration of these fossils in Sardinia is that of Meneghini (1857) who published the palaeontological part of La Marmora's "Voyage en Sardaigne". Twenty nautiloid species were described from outcrops in the Fluminimaggiore and San Nicolò Gerrei areas. Meneghini's original fauna (Fig. 1) has been later restudied by Gnoli & Serpagli (1977) and its updated list is reported in Tab. 1.

Later on, after the publication of Meneghini's pioneering contribution, some other mainly geological papers (Canavari, 1899; Novarese, 1922; Novarese & Taricco, 1923) mentioned the occurrence of orthoconic nautiloids (a summary of these old studies,

including faunal lists, was published by Comaschi-Caria, 1949, 1974). In the sixties, Ristedt (1968) described and illustrated several juvenile stages of Sardinian Silurian nautiloids from the Fluminese area.

Along with the revision of Meneghini's original fauna by Gnoli & Serpagli (1977) and the collection of new material from the Fluminimaggiore area, Serpagli & Gnoli (1977) published a large monograph with 9 plates on Silurian cephalopods from southwestern Sardinia. In that paper, still representing a milestone in our knowledge of the Silurian of Sardinia, 38 species of 21 genera were described and illustrated. New taxa were introduced and important systematic emendations were suggested. Furthermore, representatives of actinoceroid and cyrthoceraconic genera were mentioned in the Mediterranean area for the first time (Serpagli & Gnoli, 1977). As a whole, a strong affinity with the Barrandian nautiloid fauna was highlighted.

Gnoli (1987) revised "*Orthoceras*" *grande* Meneghini, 1857 as a true *Columenoceras* because of its inner features, and included it in the Family Geisonoceratidae Zhuravleva, 1959. Further contributions to a refinement of previous taxonomic knowledge were

	Meneghini (1857) determinations	revised determinations
figs. 1a, b	<i>Orthoceras</i> sp. ind.	Unidentifiable fragment
fig. 2	<i>Orthoceras</i> sp. ind.	Unidentifiable fragment
figs. 3a-c	<i>Orthoceras fluminese</i> nov. sp.	<i>Orthocycloceras?</i> <i>fluminese</i> (Meneghini, 1857)
figs. 4A, 4a-a'	<i>Orthoceras grande</i> nov. sp.	<i>Columenoceras grande</i> (Meneghini, 1857)
figs. 4Ab, 4b'	<i>Orthoceras subconoideum</i> nov. sp.	<i>Michelinoceras subconoideum</i> (Meneghini, 1957)
figs. 4b''-b'''	<i>Orthoceras simplex</i> Desnoy	<i>Arionoceras canonicum</i> (Meneghini, 1857)
figs. 4Ac-c''	<i>Orthoceras simplex</i> Desnoy	<i>Arionoceras canonicum</i> (Meneghini, 1857)
figs. 4Ad	<i>Orthoceras simplex</i> Desnoy	Unidentifiable fragments
figs. 5a-c	<i>Orthoceras simplex</i> Desnoy	<i>Michelinoceras currens</i> (Barrande, 1866)
figs. 6A, 6a-a'	<i>Orthoceras bohemicum</i> Barrande	<i>Orthocycloceras?</i> <i>fluminese</i> (Meneghini, 1857)
figs. 7a-a'''	<i>Orthoceras canonicum</i> nov. sp.	<i>Arionoceras affine</i> (Meneghini, 1857).
figs. 8a-a'	<i>Orthoceras</i> sp. ind.	Unidentifiable specimen
fig. 9a	<i>Orthoceras submoniliforme</i> nov. sp.	<i>Michelinoceras currens</i> (Barrande, 1866)
figs. 9b-b'	<i>Orthoceras submoniliforme</i> nov. sp.	<i>Arionoceras submoniliforme</i> (Meneghini, 1857)
figs. 10A (inside the block)	<i>Orthoceras subtrocleatum</i> Münster?	<i>Michelinoceras currens</i> (Barrande, 1870)
figs. 10Aa-a''	<i>Orthoceras subtrocleatum</i> Münster?	Unidentifiable specimens
fig. 10Ab	<i>Orthoceras subannulare</i> Münster	<i>Orthocycloceras?</i> cf. <i>lynx</i> (Barrande, 1868)
fig. 10 Ac	<i>Orthoceras subcyprium</i> nov. sp.	Unidentifiable specimens
fig. 10 Ad	<i>Orthoceras canonicum</i> nov. sp.	Unidentifiable specimens
fig. 10Ae	<i>Orthoceras</i> sp. ind.	Unidentifiable specimens
figs. 11a-a'	<i>Orthoceras</i> sp. ind.	Unidentifiable specimens
figs. 12a-d	<i>Orthoceras</i> sp. ind.	<i>Plagiostomoceas gruenewaldti</i> (Barrande, 1867)
figs. 13a-a', b-b'	<i>Orthoceras subcyprium</i> nov. sp.	" <i>Parashaerorthoceras?</i> " <i>subcyprium</i> (Meneghini, 1857)
figs. 14a-a'	<i>Orthoceras</i> sp. ind.	Unidentifiable specimen
fig. 15	<i>Orthoceras</i> sp. ind.	<i>Arionoceras submoniliforme</i> (Meneghini, 1857)
fig. 16	<i>Orthoceras affine</i> nov. sp.	<i>Arionoceras canonicum</i> (Meneghini, 1857)

Tab. 1 - Revision of specimens figured by Meneghini (1857).

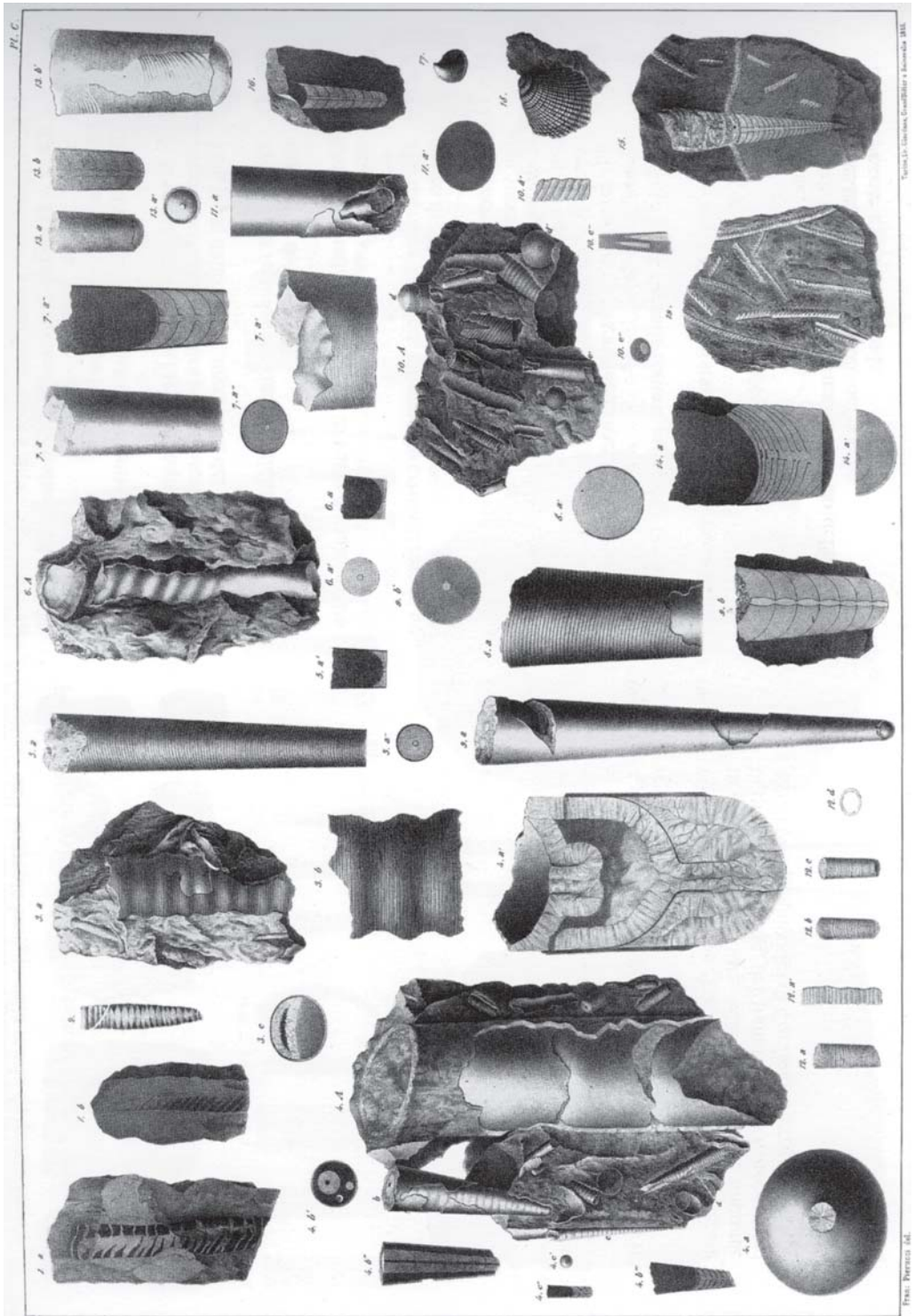


Fig. 1 - Reproduction of Plate C of Meneghini (1857), reduced at 48% of the original size (after Gnoli & Serpagli, 1977, mod.).

submitted by Gnoli (1990, 1994, 1996, 1998), Kiselev & Gnoli (1992), Gnoli & Kiselev (1994), Holland (2000) and Gnoli & Serventi (2006). At the same time, *O. pseudocalamiteum* Barrande was regarded as a type species of the new genus *Calorthoceras* (Chen et al., 1981).

At present the complete Nautiloidea faunal content of the Sardinian Silurian is listed below. In all, 61 taxa are identified at the species level, belonging to 12 higher taxa at family or subfamily level, belonging in turn to the orders Orthocerida, Actinocerida and Oncocerida. No Pseudorthocerida have been identified till now.

The systematic scheme adopted by the Treatise Part K Mollusca 3 (1964) is here followed, with integrations by T. Engeser's Data Retrieval System Nautiloidea. Dzik's 1984 "Phylogeny of Nautiloidea" was also taken in account.

Phylum MOLLUSCA Linnaeus, 1758  
Class CEPHALOPODA Couvier, 1797  
Subclass Nautiloidea Agassiz, 1847

Order Orthocerida Kuhn, 1940

Fam. Orthoceratidae M'Coy, 1844

Subfam. Michelinoceratinae Flower, 1945 amend. Kiselev & Gnoli, 1992

*Hemicosmorthoceras laterculum* Ristedt, 1968

*Hemicosmorthoceras semiannulatum* (Barrande, 1870)

*Hemicosmorthoceras* aff. *serratulum* (Barrande, 1867)

*Hemicosmorthoceras* sp. *sensu* Serpagli & Gnoli, 1977

*Kopaninoceras jucundum* (Barrande, 1870)

*Kopaninoceras?* *thyrsus* (Barrande, 1870)

*Mericoceras?* cf. *sericatum* (Barrande, 1868)

*Mericoceras?* cf. *simois* (Barrande, 1867)

*Michelinoceras* (*Michelinoceras*) *currens* (Barrande, 1866)

*Michelinoceras* (*Michelinoceras*) *michelini* (Barrande, 1866)

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Plate 1

Fig. 1 - *Michelinoceras* (*Michelinoceras*) *michelini* (Barrande, 1866), young specimen in lateral view (IPUM 18987); Fluminimaggiore area, upper Silurian; x2.

Fig. 2 - *Arionoceras submoniliforme* (Meneghini, 1857), lateral view of a juvenile specimen (IPUM 19066); Fluminimaggiore area, upper Silurian; x10.

Fig. 3 - *Orthocycloceras?* *fluminense* (Meneghini, 1857), lateral view (IPUM 19046); Fluminimaggiore area, upper Silurian; x1.

Fig. 4 - *Hemicosmorthoceras* sp., lateral view (IPUM 18977); Fluminimaggiore area, upper Silurian; x5.

Fig. 5 - *Pseudocycloceras transiens* (Barrande, 1866), lateral view (IPUM 21655)✕ "Sentiero Flumini" locality, lower Ludlow; x2.

Fig. 6 - *Columenoceras?* *degener* (Barrande, 1870), lateral view (IPUM 21661); "Mason Porcus" section, Pridoli; x1.

Fig. 7 - *Columenoceras* cf. *columen* (Barrande, 1867), dorsoventral section to show inner features (IPUM 19074); Fluminimaggiore area, upper Silurian; x1.

Fig. 8 - *Geisonoceras* cf. *socium* (Barrande, 1859), lateral view (IPUM 21665); "Galemmu" locality, lower Ludlow; x1.





*Michelinoceras (Michelinoceras) subconoideum* (Meneghini, 1857)  
*Michelinoceras (Michelinoceras) sp. 1 sensu* Serpagli & Gnoli, 1977  
*Michelinoceras (Michelinoceras) sp. 2 sensu* Serpagli & Gnoli, 1977  
*Michelinoceras (Michelinoceras) sp. 3 sensu* Serpagli & Gnoli, 1977  
*Michelinoceras (Sphaerorthoceras) beatum* (Ristedt, 1968)  
*Michelinoceras (Sphaerorthoceras) curvum* (Ristedt, 1968)  
*Michelinoceras (Sphaerorthoceras) teichertii* (Ristedt, 1968)  
*Michelinoceras (Sphaerorthoceras) sp. sensu* Serpagli & Gnoli, 1977  
«*Parasphaerorthoceras*» sp. B *sensu* Ristedt, 1968  
«*Parasphaerorthoceras*» sp. H *sensu* Ristedt, 1968  
«*Parasphaerorthoceras*» sp. J *sensu* Ristedt, 1968  
«*Parasphaerorthoceras*» sp. K *sensu* Ristedt, 1968

Subfam. Protobactritinae Chen, 1981

*Plagiostomoceras gruenewaldti* (Barrande)  
*Plagiostomoceras cf. pleurotomum* (Barrande)  
*Protobactrites?* sp. *sensu* Serpagli & Gnoli, 1977

Subfam. Leurocycloceratinae Sweet, 1964

*Akrosphaerorthoceras gregale* Ristedt, 1968  
*Calorthoceras pseudocalamiteum* (Barrande in Quenstedt, 1851)  
*Orthocycloceras fluminense* (Meneghini, 1857)  
*Orthocycloceras cf. lynx* (Barrande)  
*Merocycloceras declive* Ristedt, 1968  
*Pseudocycloceras transiens* (Barrande, 1866)

Subfam. Kionoceratinae Hyatt in Zittel, 1900

*Kionoceras doricum* (Barrande, 1868)  
*Parakionoceras originale* (Barrande, 1868)  
*Vericeras ambigena* (Barrande)

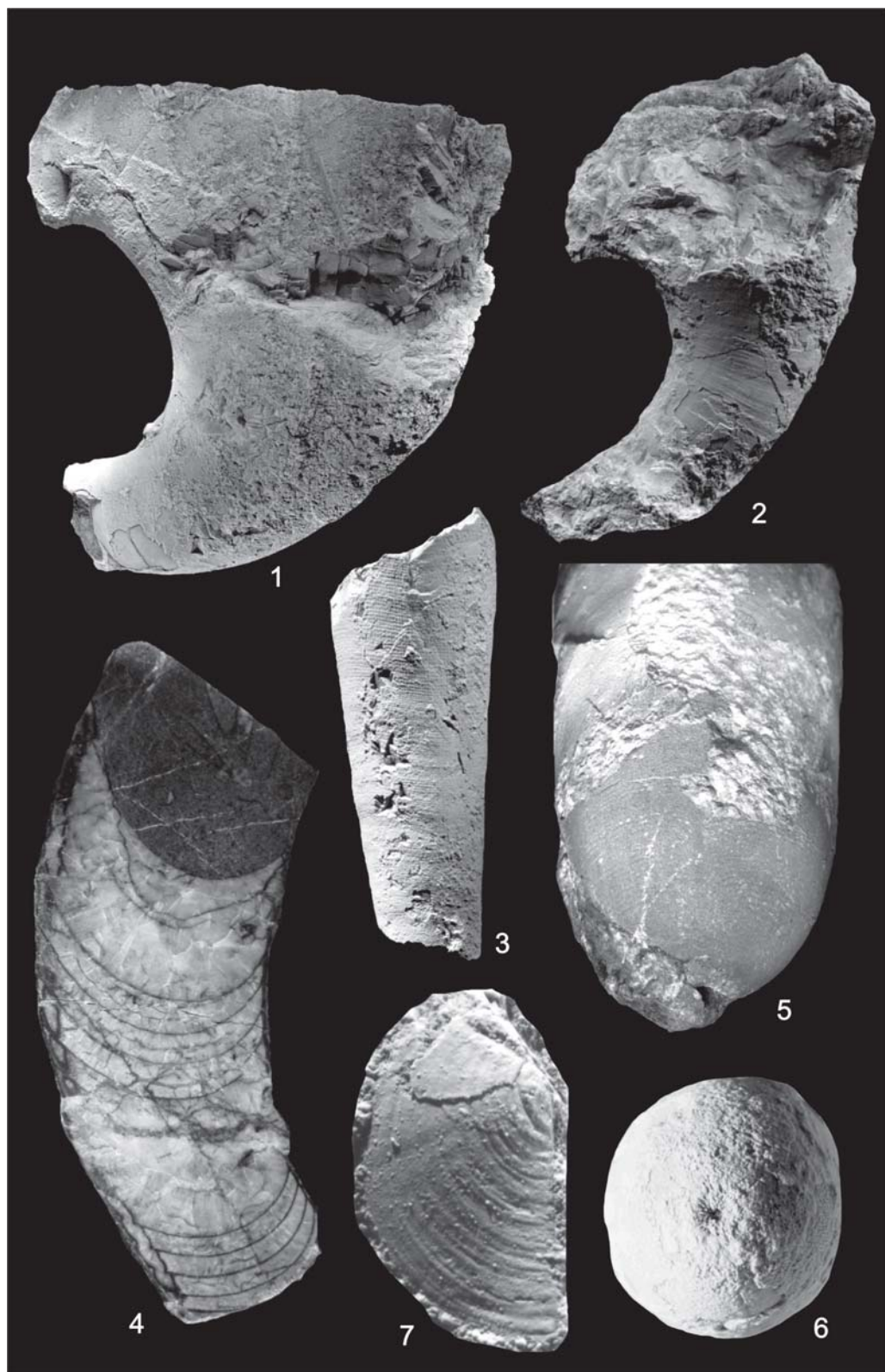
Fam. Geisonoceratidae Zhuravleva, 1959

*Arionoceras canonicum* (Meneghini, 1857)  
*Arionoceras? repetitum* (Barrande, 1866)

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Plate 2

- Fig. 1 - *Phragmoceras broderipi subleve* (Barrande, 1865), lateral view (IPUM 21677); "Sentiero Flumini" locality, upper Wenlock; x0,75.  
Fig. 2 - *Protophragmoceras minus* (Barrande, 1865), lateral view (IPUM 21678); "Galemmu" locality, lower Ludlow; x1.  
Fig. 3 - *Mericoceras?* cf. *sericatum* (Barrande, 1868), ventral view (IPUM 21653); "Sentiero Flumini" locality, lower Wenlock; x2.  
Fig. 4 - *Oonoceras acinaces elongatum* (Barrande, 1866), view of the polished longitudinal middle section (IPUM 33100); "Argiola" locality, Pridoli; x1,5.  
Figs. 5-6 - *Sphooceras truncatum* (Barrande, 1860).  
5. ventral view enlarged to show "finger print" type ornament of the outer truncature callus (IPUM 21672); Fluminimaggiore area, lower Ludlow; x1;  
6. terminal view to show siphuncle position and radial arrangement of intermediate callus (IPUM 21674); Fluminimaggiore area, lower Ludlow; x5.  
Fig. 7 - *Aptychopsis prima* Barrande, 1872 (IPUM 21661); "Sentiero Flumini" locality, lower Wenlock; x5.





*Arionoceras submoniliforme* (Meneghini, 1857)  
*Columenoceras agassizi* (Barrande, 1866)  
*Columenoceras cf. columen* (Barrande, 1867)  
*Columenoceras? degener* (Barrande, 1870)  
*Columenoceras grande* (Meneghini, 1857)  
*Columenoceras? intermixtum* (Barrande, 1867)  
*Cryptocycloceras? cf. deludens* (Barrande, 1870)  
*Geisonoceras? cf. socium* (Barrande, 1859)  
*Geisonoceras sp. sensu* Gnoli, 1990  
*Harrisoceras vibrayei* (Barrande, 1859)  
*Murchisoniceras? calamoides* (Barrande, 1867)  
*Temperoceras temperans* (Barrande, 1867) = *Temperoceras ludense*  
(Sowerby in Murchison, 1839) *fide* Holland, 2000.

Fam. Sphooceratidae Flower, 1962

Subfam. Sphooceratinae Flower, 1962 amend. Gnoli & Kiselev, 1994  
*Sphooceras truncatum* (Barrande, 1860)

Subfam. Disjunctoceratinae Gnoli & Kiselev, 1994  
*Disjunctoceras disjunctum* (Barrande, 1868)

Fam. Lechritrochoceratidae Flower, 1950

*Kosovoceras sandbergeri* (Barrande, 1865)

Fam. Phragmocerotidae Hyatt, 1900

*Phragmoceras broderipi subleve* (Barrande, 1865)  
*Phragmoceras cf. labiosum* (Barrande, 1865)  
*Protophragmoceras minus* (Barrande, 1865)

Order Actinocerida Teichert, 1933

Fam. Ormoceratidae Saemann, 1853

*Metarmenoceras? meneghinii* Serpagli & Gnoli, 1977  
*Sactoceras richteri* (Barrande, 1866)

Order Oncocerida Flower in Flower & Kummel, 1950

Fam. Oncoceratidae Hyatt, 1884

*Oocerina abdita* (Barrande, 1877)  
*Oonoceras plebeium* (Barrande, 1866)  
*Oonoceras acinaces elongatum* (Barrande, 1866)

Fam. Acleistoceratidae Flower in Flower & Kummel, 1950

*Galtoceras? sardous* Serpagli & Gnoli, 1977

Order and Family uncertain

*Aptychopsis prima* Barrande, 1872 (see remarks below)

For two decades *Aptychopsis*, has been considered, even if with some doubts, to be an opercular nautiloid device (Holland et al., 1978; Turek, 1978; Stridsberg, 1984; Holland, 1996). Its final interpretation, however, is far from accepted. *Aptychopsis prima* was recorded and identified years ago, though never published, by one of us (MG) from two levels in the Wenlock of Fluminimaggiore area. Such a fossil is listed here as part of the Sardinian Silurian cephalopod assemblage for the first time (Pl. 3, fig. 7).

## OTHER CONSIDERATIONS

The material collected in the last 40 years allowed not only to better define the composition of the nautiloid cephalopod fauna, but also to interpret its palaeoenvironmental and palaeogeographical significance as well as to test the biostratigraphical implication of respective nautiloid assemblages.

In general, the Late Wenlock-Pridoli cephalopod fauna represents the “*Orthoceras*” Limestone Community (Ferretti et al., 1999), a high to medium diversity community in which nautiloids are associated with bivalves, conodonts, graptolites, crinoidal fragments, crustaceans (ostracodes and phyllocarids), gastropods, and rare brachiopods (Gnoli et al., 1988, 1990). Bathymetric studies on about thirty species of nautiloids from the upper Silurian “*Orthoceras limestone*” of southwestern Sardinia has implied a water depth of <350m, based on those septa that have imploded as they exceeded their calculated hydrostatic limits (Histon & Gnoli, 1994, 1999).

Gnoli & Serpagli (1991) identified three successive assemblages of nautiloid cephalopods from the Fluminimaggiore Formation and tested their biostratigraphical significance by means of conodonts recovered from the same samples. The *Pseudocycloceras transiens-Columenoceras grande* Assemblage characterizes Wenlock sediments. It represents a quite widespread fauna, also known from Central Bohemia, Podolia, Poland and Northern Urals (Gnoli & Serpagli, 1991). The *Merocycloceras declive-Cryptocycloceras? deludens* Assemblage occurs in Ludlow strata, and its representatives are also reported from Central Bohemia, Armorican Massif, the Carnic Alps, Podolia and Poland. The *Kopaninoceras? thyrus-Orthocycloceras? fluminense* Assemblage spans from the Pridoli to the earliest Lochkovian and is known also from Central Bohemia, Armorican Massif, the Urals, the Russian Platform, Podolia and Poland.

The strong faunal link between Sardinia and the Barrandian of Central Bohemia during the Silurian times, already stressed by many of the previous works, was later confirmed by Holland et al. (1994). Worldwide distribution of cephalopod limestone biofacies distribution was used by Gnoli (2003) to assess the reconstruction of the North Gondwana margin during the Silurian-Early Devonian. A Q-mode cluster analysis on a matrix of faunal similarities, estimated by means of the Jacard coefficient, revealed the greatest faunal similarity between southwestern Sardinia and the Prague Basin (0.89), followed by similarity between the Carnic Alps and the two areas just mentioned (0.70).

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