



Paolo Serventi
Carlo Corradini
Luca Simonetto

FIRST DESCRIPTION OF THE GENUS *NUCLEOCERAS* KOLEBABA FROM THE SILURIAN OF THE CARNIC ALPS, N.E. ITALY

PRIMA DESCRIZIONE DEL GENERE *NUCLEOCERAS* KOLEBABA
DAL SILURIANO DELLE ALPI CARNICHE,
ITALIA NORDORIENTALE

Riassunto breve - Vengono descritti in dettaglio il genere *Nucleoceras* e la specie *Nucleoceras* cf. *obelus* trovato per la prima volta al di fuori dell'area tipo, la Boemia. I caratteri interni tipici del genere, vale a dire gli anelli di connessione aperti sul lato dorsale e i depositi camerali ipo/episettali ben sviluppati e dalla conformazione caratteristica, consentono un buon riconoscimento sistematico. Il campione studiato proviene dal Siluriano del versante italiano delle Alpi Carniche ed è stato rinvenuto lungo il Costone Lambertenghi presso Passo Volaja.

Parole chiave: Nautiloidi, Siluriano, *Nucleoceras*, Italia, Alpi Carniche.

Abstract - *The genus Nucleoceras and the species Nucleoceras cf. obelus are here described for the first time outside of Bohemia, its type-area. Critical internal features of the genus, such as the open connecting rings on dorsal side and well developed hyposeptal and episeptal cameral deposits, are well preserved in the studied material, which were collected from the Silurian of the Carnic Alps (Italian side).*

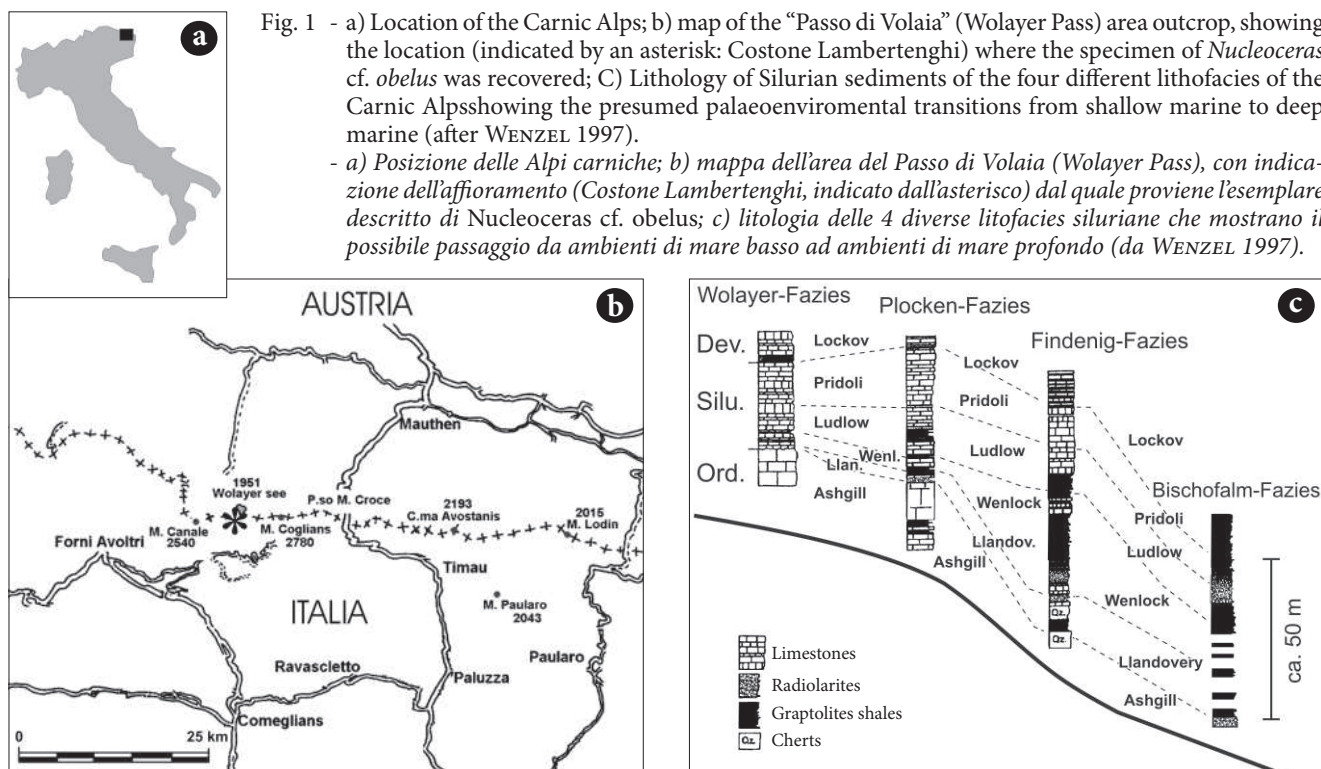
Key words: Nautiloids, Silurian, *Nucleoceras*, Italy, Carnic Alps.

Introduction

Many Palaeozoic nautiloids have orthoconic longi-conic conchs and, although, some of the genera are similar in external features, there are many differences in their internal morphologies. These differences are evolutionarily and taxonomically important, and they have important implications in how they solved buoyancy and equilibrium problems (i.e. to balance the shell into the horizontal position with venter down). Some important internal features are represented by carbonate deposits in the chambers and within the siphon in the adapical part of the phragmocone (e.g., see Fig. 2, TEICHERT et al. 1964). Today, specialists generally accept the purpose of the cameral deposits as controls of buoyancy and equilibrium.

The organic origin of siphuncular and cameral deposits was recognized for the first time by BARRANDE (1855, 1859, 1877). Debate as if and how these mineral deposits were organically deposited within the phragmocone chambers and within the siphuncle is still unresolved. More than 75 years ago TEICHERT (1933) proposed the presence of a tissue inside the gas chambers that was able to secrete cameral deposits. A

few years later FLOWER (1939, 1941, 1955, 1962, 1964) introduced the term “cameral mantle” for this tissue. Later studies (for examples see HOLLAND 1965, FISCHER & TEICHERT 1969, KOLEBABA 1974) accepted the idea of cameral deposit secretion by a mantle tissue; however, other cephalopod specialists reject the “cameral tissue” hypothesis in favour of inorganic precipitation of the mineral deposits inside the phragmocone. For MUTVEI (1956, and repropose later in 2002a, 2002b) is adamant that these structures are inorganic and that the “cameral mantle” does not exist because no openings are present in the connecting ring that would allow a tissue connection between the siphuncle and the interior of the cameral opening where cameral deposits are found. In 1969, FISCHER & TEICHERT attempted to resolve this debate using exceptionally preserved aragonite material from the famous Buckhorn Asphalt (Carboniferous) of Oklahoma. However, resolution of this controversy remains with DZIK (1984) and CRICK (1988) supporting inorganic deposition and KOLEBABA (1999a, 1999b) supporting the “mantle tissue” hypothesis by demonstrating the presence of dorsally open connecting rings (troughs) enabling the possible connection of the siphuncle and cameral tissues.



We support the concept of the presence of a cameral mantle rather than inorganic precipitation for the origin of cameral deposits, and therefore, we utilize that hypothesis in the following discussion and analysis.

TEICHERT (1961) erected the Family Lamellorthoceratidae for cephalopods with “original presence of a cameral mantle which consisted of a system of radially arranged lamellae with respect to the axis of septal foramina” and again “connecting rings in most of the genera unknown, supposedly open dorsally to form connecting troughs...”. Later, MAREK (1998: p. 181) established the Order Pallioceratida, with “longiconic or subcyrtoconic shells with a soft tissue in the gas chambers. Connecting rings are not a closed structure, but open so that their internal space is joined with cameral one”. Furthermore, MAREK (1998) indicates that the cameral deposits in the adapical part of the shell are well developed but some space of the chambers remains open. The order Pallioceratida includes cephalopods in which the morphological features indicating the presence of an internal cameral mantle has been detected. According to MAREK (1998) it is possible to recognize two different groups on the basis of the morphology of the cameral mantle: if it is “like a pouch” then the specimen should be placed in the Family Leurocyloceratidae SWEET, 1964, and if it is in radially arranged lamellae, more or less longitudinal, then the specimen should be placed in the Family Lamellorthoceratidae TEICHERT, 1961. KOLEBABA (2002) emended the ordinal diagnosis of MAREK (1998), pointing out that “...at least in the adapical part of the phragmocone” the connecting rings are not closed structure.

However, the debate on the validity of order Pallioceratida is still debated: KRÖGER & ISAKAR (2006: p. 142) pointed out that the use of the shape of endosiphuncular deposits is problematic and the deposit development depends on the growth age, and KRÖGER (2008: p. 52) noted that the presence of a cameral mantle is only a “physiological hypothesis”, and concluded that the order is not valid because all the different genera “that have been assigned to the Pallioceratida display strong differences in conch morphology”.

Considering that we do not have enough material to contribute to the discussion on the high taxonomic attribution of genus *Nucleoceras*, in this paper we follow the classification proposed by KOLEBABA (2002), who first described the genus.

In the Carnic Alps the presence of *Nucleoceras* have been reported by SERVENTI (2002), but the specimen was not described. In this paper the specimen collected from the Kok Formation at Costone Lambertenghi (Passo di Volaja [Wolayer Pass] area; Fig. 1b) is discussed and illustrated; also this study increases the knowledge on nautiloid faunas of the Carnic Alps area and the paleobiogeographic links between the terranes of the northern Gondwana margin during Silurian times.

Geological settings

The Carnic Alps are located across the Italian-Austrian border. One of the best exposed and most complete Palaeozoic succession in the world, ranging from Upper Ordovician to Upper Permian, occurs.

Silurian outcrops are irregularly distributed in the region. The main types of rocks exposed here include shallow water bioclastic limestones, nautiloid-bearing limestones, limestones interbedded with shales, and black graptolitic shales and cherts (“lydites”). The overall thickness of Silurian strata does not exceed 60m. Four main lithofacies (Fig. 1c), representing different depths and hydraulic conditions of deposition, have been described in the Silurian of the Carnic Alps (WENZEL 1997). The Wolayer-facies is characterised by proximal sediments, the Bischofalm-facies by deep water euxinic deposits; the Plöcken-facies and the Findenig-facies are intermediate between these two. In rough approximation, the four facies seem to replace each other from north-west to south-east in the western and central sectors of the Carnic Alps. The depositional features suggest an overall transgressional regime from Llandovery to Ludlow. The formation of uniform calcareous deposits in the Prídoli indicates that stable conditions were developed in the region at that time (SCHÖNLAUB 1997).

In terms of the recently established new, still unpublished, lithostratigraphical subdivisions, three units follow each other in the succession in the proximal (calcareous) parts of the basin: the Kok Fm. (Llandovery-lower Ludlow), the Cardiola Fm. (Ludlow) and the Alticola Fm. (upper Ludlow-Prídoli). The last unit corresponds to the former Alticola Limestone and Megerella Limestone. All three units are represented mainly by “*Orthoceras* limestone”, a wackestone-packstone with high bioclastic content. Nautiloid cephalopods are very abundant; trilobites, bivalves and conodonts are common; crinoids,

gastropods and rarer ostracods, brachiopods, chitinozoans, graptolites are also present (SCHÖNLAUB 1997; HISTON & SCHÖNLAUB 1999; SCHÖNLAUB & HISTON 2000; CORRADINI et al. 2010, 2014).

In the deeper part of the basin, the Silurian corresponds to the up to 60 m thick Bischofalm Fm. It consists of black siliceous shales with interbeds of chert and clayish alum slate, mainly deposited in a euxinic environment. Graptolites are generally abundant in these rocks (SCHÖNLAUB 1997). Alternating black graptolitic shales, marls and limestones of the Nölbling Fm. were deposited in conditions intermediate between calcareous and shaley facies, (SCHÖNLAUB 1997).

Systematic part

Class Cephalopoda CUVIER, 1798
 Order Pallioceratida MAREK, 1998 (= *Lituitina* DZIK, 1984, partim) (emended KOLEBABA 2002)
 Family Lamellorthoceratidae TEICHERT, 1961 (emended KOLEBABA 1999b)
 Genus *Nucleoceras* KOLEBABA, 1999a
 Type species: *Orthoceras obelus* BARRANDE, 1870 (partim)

Diagnosis (after KOLEBABA 1999a): longiconic orthoconic shell with compressed in cross-section; surface lacking ornamentation except for growth lines and fine lirae or striae. Connecting troughs well developed; intrasiphonal deposits confined to ventral part of the conch.

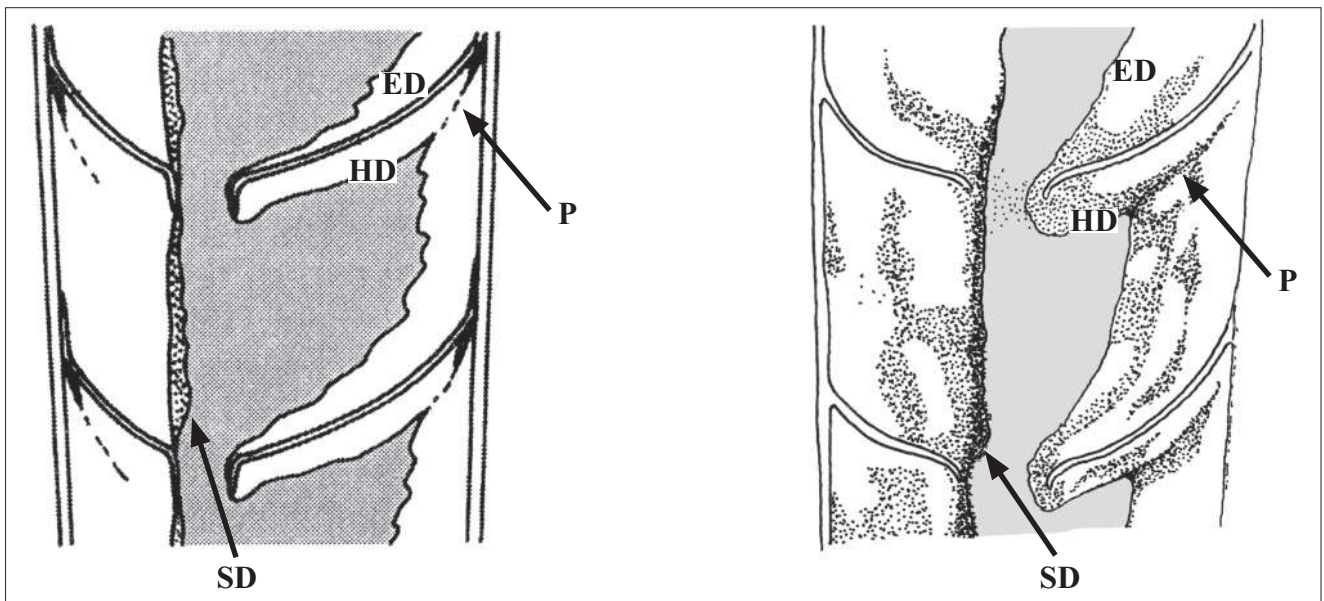


Fig. 2 - Schematic drawings of *Nucleoceras obelus*, *N.?* sp. A and *N.?* sp. B (after KOLEBABA 1999a) comparing with *N. cf. obelus* in this paper (right). Used symbol: ED - episeptal deposit; HD - hyposeptal deposit; P - pseudoseptum; SD - siphonal deposit.

- Disegno schematico di *Nucleoceras obelus*, *N.?* sp. A e *N.?* sp. B (da KOLEBABA 1999a) in confronto con *N. cf. obelus* qui descritto (a destra). Abbreviazioni: ED - deposito episetale; HD - deposito iposetale; P - pseudosetto; SD - deposito sifonale.



Fig. 3 - Specimen MFSNgp 20824: a) polished longitudinal section view, x3; b) enlarged detail of the first 6 chambers, showing the inner features, x7; c) enlarged detail of the second chamber showing the orthoconitic septal necks.
 - Esemplare MFSNgp 20824; a) sezione longitudinale lucida, x3; b) dettaglio delle prime 6 camere che mostra le caratteristiche interne, x7; c) dettaglio della seconda camera che mostra il colletto settale ortocoanitico.

Species included: *Nucleoceras obelus* (BARRANDE, 1870); *Nucleoceras* ? sp. A KOLEBABA, 1999a; *Nucleoceras* ? sp. B KOLEBABA, 1999a; *Nucleoceras hollandi* KOLEBABA, 1999b.

Occurrence: Silurian, Barrandian Area, Czech Republic; Carnic Alps, Italy.

Nucleoceras cf. *obelus* (BARRANDE, 1870)

Fig. 2, Fig. 3

1870 *Orthoceras obelus* BARRANDE, Pl. 366, fig. 16-17

1999a *Nucleoceras obelus* (BARRANDE, 1870) - KOLEBABA, Pl 4, figs. 1-4; Pl. 5, figs. 1-8; Fig. 5c

2002 *Nucleoceras* sp. - SERVENTI, fig. 1

Material: one fragment of phragmocone, deposited in the geo-palaeontological collections of Museo Friu-

lano di Storia Naturale, under catalog number MFSNgp 20824.

Description: the specimen is an orthoconic and longiconic nautiloid fragment 42mm long, bearing 18 chambers, only eight of which are completely intact. The apical part of the conch is broken. Diameters of the conch are 3 mm apicad reaching a maximum diameter of 4.5 mm orad. The angle of expansion of the shell is close to 4.5 degrees. The depth of the chambers is about 2/3 their own diameter. Siphuncle has a sub-central position and the septal foramen (Fig. 2) is shifted ventrally by about 37% (calculated at first camera). Septal necks are orthoconitic and reach about 4% of the height of the corresponding gas chamber. Connecting rings are open on the dorsal side, and there is a dark (organic?) line marking the position of the connecting rings along the ventral side of the conch. Hyposeptal and episeptal cameral deposits are well developed (Fig. 2, HD and

	<i>Nucleoceras obelus</i> (Kolebaba, 1999a)	<i>Nucleoceras?</i> sp. A (Kolebaba, 1999a)	<i>Nucleoceras?</i> sp. B (Kolebaba, 1999a)	<i>Nucleoceras hollandi</i> (Kolebaba, 1999b)	<i>Nucleoceras</i> cf. <i>obelus</i> This paper
Compressed shell	15-30%	Not available	Not available	20%	Not available
Apical angle	From 5-7° to 3°	Not available	Not available	4,5°	4,5°
Septal foramens shifting	30-42%	24-29%	27%	29%	37%
$\varnothing SF/\varnothing Sd$	12-15%	18%	20%	Not available	Not available
$LS/\varnothing Sd$	From 18 to 25%	Not available	10%	Not available	Not available
Septal necks	Orthochoanitic	Not available	Suborthochoanitic	Not available	Orthochoanitic
Average height gas chambers	Not available	Not available	Not available	36%	Not available

Tab. I - List of species belonging to the genus *Nucleoceras* KOLEBABA; $\varnothing SF/\varnothing Sd$ = Septal Foramen diameter/Shell diameter; $LS/\varnothing Sd$ = Length of the Septal necks/Shell diameter.

- *Elenco delle specie appartenenti al genere Nucleoceras KOLEBABA; $\varnothing SF/\varnothing Sd$ = diametro del forame settale/diametro della conchiglia; $LS/\varnothing Sd$ = lunghezza del colletto settale/diametro della conchiglia.*

ED); the presence of a pseudoseptum (P in Fig. 2) is outlined by darker material. The internal surface of the connecting trough is ventrally marked by a continuous lining of dark endosiphonal deposits (Fig. 2, SD).

Discussion: since the only available surface of the specimen is the longitudinal section. Therefore it is not possible to see the ornamentation on the external surface of the shell. Nevertheless the longitudinal section permits to study some aspects of the inner morphology. The studied specimen has been attributed to *Nucleoceras* cf. *obelus* on the basis of the presence of orthochoanitic septal neck configuration and similar degree of septal foramen shifting (Tab. I) and by close morphology of deposits (Figg. 2, 3). Additional details on differences in morphology are provided in Table I. It should be noted that many features are not comparable across taxa because of differences in preservation.

Stratigraphy: it is not possible give a precise age for the studied specimen, however the Kok Fm at Costone Lambertenghi is dated to the mid-Ludlow (SCHONLAUB, 1980).

Geographic occurrence: Beside the Carnic Alps, the taxon has been reported only from Bohemia.

Manuscript received on 21.VII.2014, accepted on 1.IX.2014.

Acknowledgements

Thanks are due to dr. Giuseppe Muscio, director of Museo Friulano di Storia Naturale in Udine for providing the speci-

men for study. The authors are indebted to prof. Annalisa Ferretti and dr. Kathleen Histon for constructive suggestion and critical reading. This paper is a contribution to IGCP Project 591 "The Early to Middle Palaeozoic revolution".

References

- BARRANDE, J. 1855. Note sur le remplissage organique du siphon dans certain Céphalopodes paléozoïques. *Bulletin de la Société Géologique de France* 2^{ème} Série, 12: 441-89.
- BARRANDE, J. 1859. Dépôt organique dans les loges aériennes des Orthoceres. *Bulletin de la Société Géologique de France* 2^{ème} Série, 14: 828-55.
- BARRANDE, J. 1877. *Système Silurien du centre de la Bohême: Recherches paléontologiques*. 2, Classe des Mollusques, Ordre des Céphalopodes: Pls 351-460 (1870), pts 4-5 (1877). Published by author: Prague.
- CORRADINI, C., M.G. CORRIGA, P. MÄNNIK & H.P. SCHÖNLAUB. 2014. Revised conodont stratigraphy of the Cellon section (Silurian, Carnic Alps). *Lethaia*, 16 pp. doi:10.1111/let.12087
- CORRADINI, C., M.G. CORRIGA, M. PONDRELLI, P. SERVENTI & L. SIMONETTO. 2010. Il Siluriano di Monte Cocco (Alpi Carniche). *Gortania Geologia, Paleontologia, Paleontologia* 31: 23-30.
- CRICK, R. E. 1988. Buoyancy regulation and macroevolution in nautiloid cephalopods. *Seckenbergiana lethaea* 69, n. 1-2: 13-42.
- DZIK, J. 1984. Phylogeny of the Nautiloidea. *Palaeontologia Polonica*, 45: 3-203.
- FISCHER, A.G., & C. Teichert. 1969. Cameral deposits in Cephalopod Shells. *The University of Kansas Paleontological Contributions* 37: 1-30.

- FLOWER, R.H. 1939. Study of the Pseudorthoceratidae. *Palaeontographica Americana* 2, n. 10: 1-214.
- FLOWER, R.H. 1941. Revision and internal structures of Leurocyloceras. *American Journal of Science* 239, n. 7: 469-88.
- FLOWER, R.H. 1955. Cameral deposits in orthoconic nautiloids. *Geological Magazine* 92, n. 2: 89-103.
- FLOWER, R.H. 1962. Notes on the Michelinoceratida. *New Mexico Institute of Mines and Technology, State Bureau of Mines and Mineral research, Memoir* 10: 21-42.
- FLOWER, R.H. 1964. Nautiloid shell morphology. *New Mexico Institute of Mines and Technology, State Bureau of Mines and Mineral research, Memoir* 13: 1-75.
- HISTON, K., & H.P. SCHÖNLAUB. 1999. The Palaeozoic of the Southern Alps. In *V International Symposium, Cephalopods - Present and Past, Carnic Alps Excursion Guidebook*, cur. K. HISTON, 6-30. Berichte der Geologisches Bundesanstalt, 47.
- HOLLAND, C.H. 1965. On the nautiloid Leurocyloceras from the Ludlovian of Wales and the Welsh Borderland. *Palaeontology* 7, n. 4: 525-40.
- KOLEBABA, I. 1974. A new Orthocerid with the cameral mantle. *Vestník Ustredniho ustavu geologickeho* 49: 293-7.
- KOLEBABA, I. 1999a. Siphon-cameral structures in some Silurian cephalopods from the Barrandian area (Bohemia). *Acta Musei Nationalis Pragae* 55, n. 1/2: 1-15.
- KOLEBABA, I. 1999b. Gradual opening of the siphonal tube in an orthoconic cephalopod from the Silurian of Central Bohemia (Czech Republic). *Journal of the Czech Geological Society* 44, n.1-2: 131-6.
- KOLEBABA, I. 2002. A contribution to the theory of the cameral mantle in some Silurian Nautiloidea (Mollusca, Cephalopoda). *Bulletin of the Czech Geological Survey* 77, n. 3: 183-6.
- KRÖGER, B. 2008. Nautiloids before and during the origin of ammonoids in a Siluro-Devonian section in the Tafilalt, Anti-Atlas, Morocco. *Special Papers in Paleontology* 79: 112 pp.
- KRÖGER, B., & M. ISAKAR. 2006. Revision of annulated orthocerid cephalopods of the Baltoscandic Ordovician. *Fossil Record* 9, n. 1: 137-63.
- MAREK, J. 1998. Pallioceratida ordo n. - A new order of the Palaeozoic cephalopods (Mollusca, Cephalopoda). *Bulletin of the Czech Geological Survey* 73, n. 2: 181-2.
- MUTVEI, H. 1956. A preliminary report on the structure of the siphonal tube and on the precipitation of lime in the shells of fossil nautiloids. *Arkiv för Mineralogi och Geologi* 2: 179-90.
- MUTVEI, H. 2002a. Connecting ring structure and its significance for classification of the orthoceratid cephalopods. *Acta Palaeontologica Polonica* 47, n. 1: 157-68.
- MUTVEI, H. 2002b. Nautiloid systematics based on siphuncular structure and position of muscle scars. *Abhandlungen der Geologischen Bundesanstalt* 57: 379-92.
- SCHÖNLAUB, H.P. 1980. Field Trip A, Carnic Alps. In *Second European Conodont Symposium-ECOS II*, cur. H.P. SCHÖNLAUB, 5-57. Abhandlungen der Geologischen Bundesanstalt 35.
- SCHÖNLAUB, H.P. 1997. The Silurian of Austria. In *IGCP-421 Inaugural Meeting Wien*, cur. H.P. SCHÖNLAUB, 20-41. Berichte der Geologischen Bundesanstalt 33.
- SCHÖNLAUB, H.P. 1998. Review of the Paleozoic Paleogeography of the Southern Alps. The perspective from the Austrian side. In *Southern Alps Field Trip Guidebook, Ecos VII*, cur. M.C. PERRI & C. SPALLETTA, 59-68. *Giornale di Geologia* s. 3, 60, Spec. Issue.
- SCHÖNLAUB H.P., & HISTON K. 2000. The Palaeozoic Evolution of the Southern Alps. *Mitteilungen der Österreichischen Geologischen Gesellschaft* 92: 15-34
- SERVENTI, P. 2002. Nuova segnalazione di Cefalopode ortocono dal Siluriano delle Alpi Carniche. *Giornate di Paleontologia 2002, Abstracts*: 50.
- SWEET, W.C. 1964. Subfamily Leurocyloceratinae. In *Treatise on Invertebrate Paleontology, Part K, Mollusca* 3, cur. R. MOORE, K230. Lawrence: The Geological Society of America and The University of Kansas Press.
- TEICHERT, C. 1933. Der Bau der actinoceroiden Cephalopoden. *Palaeontographica* Abt. A 78: 111-230.
- TEICHERT, C. 1961. Les nautiloïdes des genres Arthrophyllum Beyrich et Lamellorthoceras Term. and Term. *Annales de Paléontologie* 47: 91-113.
- TEICHERT, C., B. KUMMEL, W.C. SWEET, W.M. FURNISH, F. GLENISTER, H.K. ERBEN, R.C. MOORE & D.E. NODINE ZELLER. 1964. Descriptions of Subclasses and Orders. In *Treatise on Invertebrate Paleontology, Part K, Mollusca* 3, cur. R. MOORE. Lawrence: The Geological Society of America and The University of Kansas Press.
- WENZEL, B. 1997. Isotopenstratigraphische Untersuchungen an silurischen Abfolgen und deren paläozoanographische Interpretation. *Erlanger geologischen Abheilung* 129: 1-117.

Authors' addresses - Indirizzi degli Autori:

- Paolo SERVENTI
Dipartimento di Scienze Chimiche e Geologiche
Università degli Studi di Modena e Reggio Emilia
Largo Sant'Eufemia 19, I-41100 MODENA
e-mail: paolo.serventi@unimore.it
- Carlo CORRADINI
Dipartimento di Scienze Chimiche e Geologiche
Università degli Studi di Cagliari
Via Trentino 51, I-09127 CAGLIARI
e-mail: corradin@unica.it
- Luca SIMONETTO
Museo Friulano di Storia Naturale
Via Marangoni 39-41, I-33100 UDINE
e-mail: luca.simonetto@comune.udine.it