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Wenlock Chitinozoans of SE Sardinia (Italy)

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ABSTRACT – The Silurian sequence of south-eastern Sardinia is exposed throughout the Gerrei and Sarrabus region, included in the homonymous tectonic units of the Outer Nappe Zone of the Hercynian Sardinian Chain. From the Llandovery, vesiculosus graptolite biozone, up to the Pridoli, Scyphocrinites layers, and crossing the Silurian - Devonian boundary, the sequence consists of the “Lower Graptolitic Shales” unit with graptolitic lydites and alum-shales (Llandovery to lower Ludlow); the “Ockerkalk” (up to near the top of the Pridoli), and the “Upper Graptolitic Shales” unit crossing the Pridoli-Lochkovian boundary (M. uniformis, M. praehercynicus and M. hercynicus Biozones). In the Goni section, an investigation on chitinozoans has been conducted from the flexilis/belophorus to colonus/nilssoni graptolite biozones (upper Sheinwoodian to basal Ludlow). Of the nine graptolite biozones investigated, three yielded chitinozoans in full relief, three were barren, three only contained graphitized tests. A low specific diversity characterizes the Goni associations, among which three informal assemblages have been recognized on the basis of the appearance of new species and of the relative frequency of certain taxa. Among the taxa found the presence of Conochitina subcyatha, biozonal marker of Baltoscandia and Avalonia for the same stratigraphical interval is worthy of note. Five new species, Conochitina goniensis, Sphaerochitina ichnussae, Sphaerochitina jaegeri, Sphaerochitina serpaglii, ?Eisenackitina ampulla, characterizing the Goni assemblages, have been described.

RIASSUNTO – [Chitinozoi del Siluriano medio della Sardegna sudorientale] – Nel presente lavoro vengono descritte le associazioni a Chitinozoi ritrovati nell'unità litostratigrafica delle «Argilliti Inferiori a Graptoliti» che affiora estesamente nel Gerrei e in particolare nei dintorni di Goni. La sequenza studiata è compresa tra le Biozone a Monograptus belophorus e Monograptus vulgaris-gerhardi, comprensiva della parte alta dello Sheinwoodiano e dell' Homeriano. Lo stato di conservazione è molto differente, da graptoliti per i Chitinozoi estratti dalle meta-argilliti a ben conservati, esemplari perfettamente tridimensionali, per quelli estratti dai noduli e dai livelli millimetrici fosfatici frequenti nei sedimenti wenlockiani affioranti nell'area; l'abbondanza, per grammo di roccia, varia invece da pochi esemplari a diverse decine. Le associazioni, a bassa diversità specifica, registrano ingressi di nuove specie nella parte inferiore e superiore della Biozona a lundgreni e scompaiono nella successiva Biozona a dubius-parvus. Sono state distinte tre associazioni sulla base delle comparse dei taxa e delle frequenze relative. Tra le specie presenti è rilevante il ritrovamento, nell'intervallo rigidus e «lower lundgreni» di Conochitina subcyatha specie indice della Baltoscandia e Avalonia per lo stesso intervallo biocronologico. Vengono descritte cinque nuove specie: Conochitina goniensis, Sphaerochitina ichnussae, Sphaerochitina jaegeri, Sphaerochitina serpaglii e ?Eisenackitina ampulla, che caratterizzano le associazioni di Goni.

INTRODUCTION

The paper concerns some chitinozoan faunulas found in the “Lower Graptolitic Shales” unit exposed in a section near the Goni village (Text-fig. 1) in SE Sardinia. The Silurian sequence of this part of the island is highly tectonized and deformed by the Hercynian polyphasic tectonics and included in the Gerrei and Genn'Argiolas Tectonics Units of the Outer Nappe Zone of the Sardinian basement. Following Jaeger (1976, 1977) and Barca & Jaeger (1990) the Silurian sequence is composed of the following lithofacies (Text-fig. 2):

The Lower Graptolitic Shales, about 30-40 m thick, consists of:

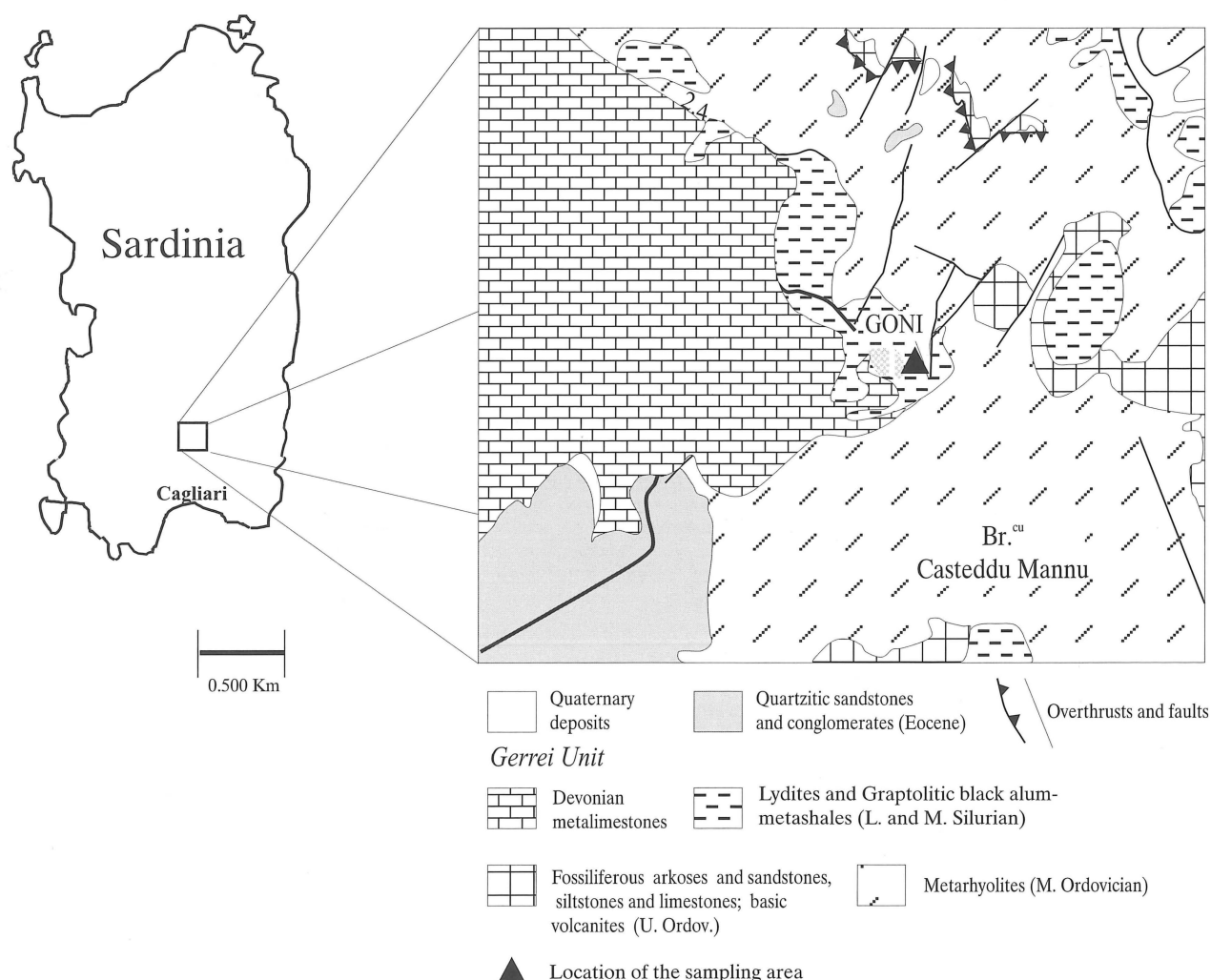
- alternating decimetric layers of lydites, enriched in quartz lenses bearing radiolarians, (Greiling, 1977) with black alum metashales, rich in graptolites from the vesiculosus up to the spiralis Biozones, spanning the stratigraphic interval from upper Rhuddanian to upper Telychian with exclusion of upper Aeronian which has not been documented so far.
- carbon-rich, pyritized and tectonically deformed

graptolite bearing, black alum slates containing isolated phosphorite nodules which, in the upper portion of the unit, become more frequent and form thin centimetric layers of phosphorite. According to its graptolite content the sequence covers the belophorus to colonus/nilssoni stratigraphic interval, equivalent to the late Sheinwoodian to early Ludlow.

The Ockerkalk, a flaser limestone, more or less 30 m thick, with Scyphocrinites loboliths of early Ludlow to latest Pridoli (Barca & Jaeger, 1990; Corradini *et al.*, 1998). This dating has been confirmed by the presence of conodonts indicating several biozones from the hamata up to the detortus Biozones (Serpagli, Corradini & Ferretti, 1998; Corradini & Serpagli, 1999; Corradini, Ferretti & Serpagli, 2000).

The Lochkovian age of the about 30 m thick Upper Graptolitic Shales is documented by the three graptolite biozones: M. uniformis, M. praehercynicus, M. hercynicus (Jaeger, 1976).

The sedimentation environment has been interpreted (Barca & Jaeger, 1990) as a pelagic deposits similarly to comparable graptolite fauna bearing



Text-fig. 1 - Location and schematic geological map of the Goni area (from Carmignani *et al.*, 1992, slightly modified and simplified).

deposits found in several basins of the Hercynian chain of Peri-Gondwanian areas of southern and central Europe.

This succession of three units from the Gerrei area differs significantly from the one in SW Sardinia in lithology and palaeontological content. In SW Sardinia the Llandovery is less lyditic, the Wenlock shaly and calcareous, and the Ludlow, Pridoli and lower Devonian mainly calcareous. In the latter area the fossil assemblages are rather different and benthic and shallow pelagic assemblages are reported (Gnoli *et al.*, 1990; Ferretti & Serpagli, 1996). The bivalve and pelagic ostracod communities and the nautiloid and graptolitic limestones suggest an evolution from shallow to deeper marine environment for the deposits in SW Sardinia.

THE GONI SECTION

Goni is a village of the Gerrei region situated in

SE Sardinia. Middle and upper Silurian black metashale outcrops are present all around the village, and from one of which Meneghini (1857) and Gortani (1922 a; 1922 b; 1922 c) collected Wenlock and Ludlow graptolitic faunas.

The investigated section is exposed north of the village, near a pig-farm, where Jaeger (Barca & Jaeger, 1990) recovered the Wenlock and Ludlow (*sensu* Jaeger) graptolite faunas. In the north-south oriented section there are about 35 m of alum slates exposed, more or less vertically dipping, with an imbricate structure, in between two Ockerkalk cliffs. A biozonal succession was established in this sequence (Barca & Jaeger, 1990; Jaeger, 1991) where the Wenlock-Ludlow transition was proposed to be at the boundary between the *lundgreni* and *dubius parvus* graptolite biozones corresponding with a worldwide biological crisis including the extinction of giant graptolites and the subsequent appearance of small graptolites recorded throughout the Mediterranean Province fauna

Series	Lithostratigraphy		Graptolite Biozones
L. Devonian		Tentaculitic nodular limestone	
		U. Graptolitic Shales	<i>M. hercynicus</i> <i>M. praehercynicus</i> <i>M. uniformis</i>
Prìdoli			
Ludlow		Ockerkalk	<i>M. dubius</i> <i>cf. thuringicus</i>
Wenlock			<i>M. colonus (nilssoni)</i> <i>M. vulgaris/M. gerhardi</i> <i>M. praedeubeli</i> <i>M. deubeli</i> <i>M. dubius/G. nassa</i> <i>M. dubius parvus</i> <i>[M. testis]</i> <i>C. lundgreni</i> <i>C. rigidus</i> <i>M. belophorus (=flexilis)</i>
		Lower Graptolitic Shales	
Llandovery			<i>M. spiralis (curvus)</i> <i>M. griestoniensis</i> <i>M. crispus</i> <i>M. turriculatus</i> <i>M. convolutus/C. cometa</i> <i>M. gregarius/triangulatus</i> <i>C. vesiculosus</i>
Upper Ordovician		Quartz-arenites	tectonic contact

Text-fig. 2 - Synthetic stratigraphic section of the Silurian – Lower Devonian of southeastern Sardinia.

(Berry & Wilde, 1990). It is worthwhile mentioning that the stratigraphic commission on the Silurian decided to put the Wenlock – Ludlow boundary higher in the sequence: between the *ludensis* and *nilssoni* graptolite biozones (Holland & Bassett, 1989).

The *C. rigidus*, *C. lundgreni*, *M. parvus*, *M. dubius/G. nassa*, *M. praedeubeli*, *M. deubeli*, *M. vulgaris/gerhardi* and *M. colonus (nilssoni)* graptolite biozones were recognized in the same transect; the layers bearing *M. belophorus* were recorded just nearby.

According to the faunal composition Jaeger (Barca & Jaeger, 1990) distinguished a lower and upper portion in the *lundgreni* Biozone, the upper one ideally corresponding to *M. testis* (Subzone). Actually he had never found *M. testis* in that locality but it was documented by himself more to the south at Riu Ollastu (Sarrabus). Moreover the presence of *M. ellesae* graptolite biozone was hypothetical because the index fossil of that biozone has never been recorded in Sardinia.

SAMPLING

Samples were collected in a transect of about 7,5 m thick. The oak tree rooted on the section was taken as datum level (0 m). Sampling progressed in stratigraphical order as reported in the scheme (Text-fig. 3). The *belophorus* metashales lie less than one meter to the east of the oak-tree.

RESULTS

In total nineteen samples were collected in the *belophorus*, *rigidus*, *?ellesae*, *lundgreni* (lower and upper portion), *dubius parvus*, *dubius nassa*, *praedeubeli*, *deubeli* and *vulgaris-gerhardi* Biozones. Between 60 and 100 gram of rocks were dissolved and nine samples were fertile.

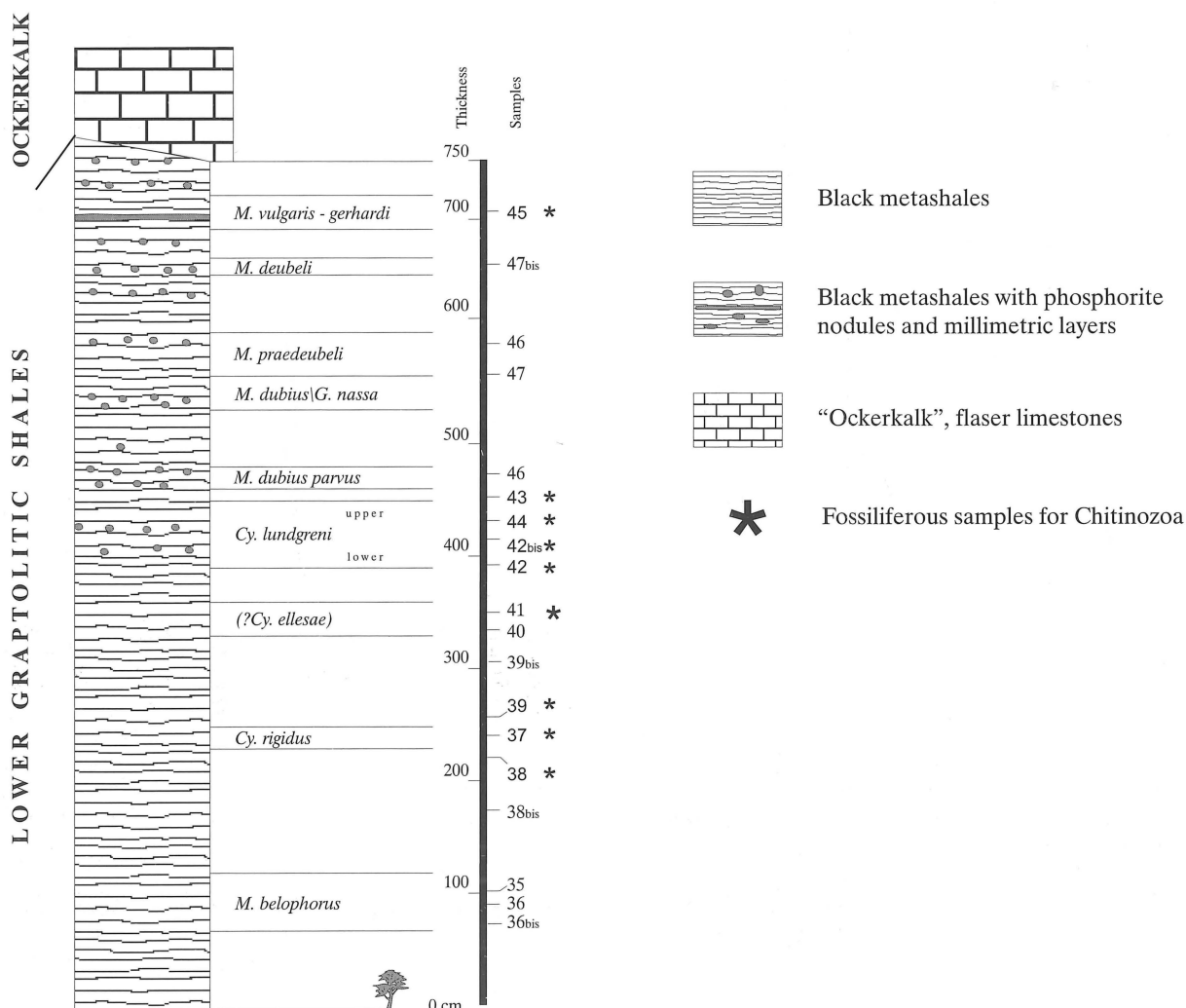
Chitinozoans preserved in the phosphorite nodules are in full relief and abound variably in the rock: from 0,2 chitinozoans/gram of rock up to several

tens/gram. Those preserved in the metashales are completely graphitized and undeterminable. They are mostly filled with framboidal pyrite, probably produced by the intense bacterial activity in the environment and visible at high magnification on the chitinous tests.

Monograptus belophorus Biozone (three samples)

A large amount of chitinous tubules, cylindrical and straight, usually open at both ends, sometimes closed on one side has been recovered from this biozone. Their wall is thin and no branching or dichotomia have been observed. The tubules are around 16 µm in diameter and 130-200 µm or more long. We tentatively refer these fossils to skeleton parts of *Hydroida*.

Chitinozoans found in the samples are totally graphitized and undeterminable; tubules have been preserved in full relief.



Text-fig. 3 - The Goni section, showing the location of samples studied for Chitinozoa.

Series	Stages	Standard Graptolite Biozones											ASSEMBLAGES																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
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Tab. 1 - Range chart of the Chitinozoan species recorded in the Goni section from the *rigidus* to the *vulgaris-gerhardi* Biozones.*Cyrtograptus rigidus* Biozone (three samples)

A chitinozoan faunula, with very low specific diversity and abundance has been found in this graptolite biozone. Their state of preservation is fairly good even if tests are rather flattened. About 95% of the specimens has been taxonomically determined as belonging to only three species: *Conochitina subcyatha*, *Conochitina cf. tuba* and *Conochitina goniensis* n. sp. Also undetermined long sized (560-1150 µm) Conochitinae are shown to occur very rarely.

Interval between the *rigidus* and *lundgreni* Biozones (*?ellesae* Biozone; three samples)

In two samples some three-dimensional *Conochitina goniensis* n. sp., flattened *Conochitina subcyatha* and *Conochitina cf. tuba* have been found. Several long and poorly preserved tests of Conochitinae have also been observed, for which no further taxonomic identification has been possible. In addition, organic spherules (foraminifers?) are present.

Cyrtograptus lundgreni Biozone (lower portion; two samples)

In these rich levels, almost all the specimens have

been taxonomically identified. The chitinozoans are in full relief and the bulk of the association is composed of new, so far unreported species, in addition to those present in the *rigidus* Biozone.

The new species appearing in this biozone are: *Sphaerochitina ichnussae* n. sp., *Sphaerochitina jaegeri* n. sp., *Sphaerochitina serpaglii* n. sp.; other species present are: *Conochitina subcyatha*, *Conochitina tuba* and *Conochitina goniensis* n. sp.. The most abundant species is *Conochitina goniensis* n. sp., and all other are present only in small amounts. The marked difference in composition between the *rigidus* and the *?ellesae* Biozones and the lower *lundgreni* Biozone levels, is further highlighted by the enormous amount of organic spherules of unknown biological origin (foraminifers?) found at this level. Their abundance in individuals per gram of rock exceeds that of the chitinozoans. This poorly known and normally rare marine organic fossil, is likely indicative of peculiar paleoceanographic conditions, the meaning of which needs to be elucidated.

Cyrtograptus lundgreni Biozone (upper portion; two samples)

As in the lower portion of the biozone, very rich chitinozoan faunulas have been recovered, in a good state of preservation and with tests in full relief.

One species dominates the assemblage: *Sphaerochitina serpaglii* n. sp., a quite distinct chitinozoan, varying only slightly in morphology. The other species present in the association are much less abundant, some are new: *Conochitina* sp. a and *?Eisenackitina ampulla* n. sp.; some are inherited from the underlying layers, like *Conochitina goniensis* n. sp., *Sphaerochitina jaegeri* n. sp. (few specimens), *Sphaerochitina ichnussae* n. sp. (some tens of specimens) and some, under open nomenclature, are also present in small amounts: *Conochitina* cf. *pachycephala*, *Tanuchitina* sp. a, *Rhabdochitina* sp. a, not being distinctive for specific recognition.

The abundance of organic spherules decreases markedly at this stratigraphic level. Within this upper portion of the *lundgreni* Biozone, likely corresponding to the *Monograptus testis* Subzone (Barca & Jaeger, 1991) there is a remarkable change in the chitinozoan assemblage composition which is reflected by the turn-over of the dominating species with respect to the assemblage composition of the «lower *lundgreni*» portion.

Moreover, at the top of the biozone (sample 44) the chitinozoan community becomes impoverished in abundance and in diversity revealing deterioration in the environmental conditions. With the exception of *Conochitina goniensis* n. sp. and organic spherules all other species disappear.

From the *Monograptus dubius parvus* up to the *Monograptus deubeli* Biozones, no chitinozoans are present in any of the processed samples.

In the *M. vulgaris-gerhardi* Biozone, only *Conochitina pachycephala* whose specimens are in full relief, is observed. Organic spherules appear again, being in all aspects similar to those found in the older stratigraphic layers.

The stratigraphic interval under investigation is well dated by means of graptolites, and covers part of the Sheinwoodian and the entire Homerician. Unfortunately, the chitinozoans record is incomplete, not necessarily because of tectonics.

Three informal Chitinozoa assemblages may be recognized, globally spanning the *rigidus*/*?ellesae* and *lundgreni* Biozones, in ascending order:

I-G ASSEMBLAGE

An assemblage poor in species only recognizable by the presence of *Conochitina subcyatha*, *Conochitina* cf. *tuba* and *Conochitina goniensis* n. sp., besides undetermined long *Conochitina* sp. Its lower limit is placed at the appearance of *goniensis* n. sp. but cannot be constrained versus the graptolite biozonation due to lack of fossiliferous data below the *rigidus* Biozone. The upper limit is placed at the base of the covering biozone (see below).

The I-G assemblage is chronostratigraphically referable to the upper part of the Sheinwoodian, and correlated biostratigraphically with the «*rigidus* and *?ellesae*» graptolite biozones.

II-G ASSEMBLAGE

It is characterized by the consistent presence of *Conochitina goniensis* n. sp. and the concurrent presence of *Conochitina subcyatha*, *Sphaerochitina jaegeri* n. sp., *Sphaerochitina ichnussae* n. sp. and *Sphaerochitina serpaglii* n. sp. The lower limit is placed at the appearance of *Sphaerochitina ichnussae* n. sp., *Sphaerochitina jaegeri* n. sp. and *Sphaerochitina serpaglii* n. sp.; its upper limit at the last occurrence of *Conochitina subcyatha* and the appearance of *?Eisenackitina ampulla* n. sp. and *Conochitina* sp. a.

The II-G assemblage is chronostratigraphically referable to the early Homerician, and correlated biostratigraphically with the lower portion of the *lundgreni* graptolite biozone (*radicans* Subzone?).

III-G ASSEMBLAGE

The abundance of *Sphaerochitina serpaglii* n. sp. and the presence of *S. ichnussae* n. sp. and *?Eisenackitina ampulla* n. sp. distinguishes this assemblage from the preceding one. Other chitinozoans, sporadically present, are *Conochitina* aff. *proboscifera*, *Rhabdochitina* sp. a, *Tanuchitina* sp. a, *Conochitina* sp. a. Its lower limit is placed at the appearance of *?Eisenackitina ampulla* n. sp. and *Conochitina* sp. a, and its upper limit at the disappearance of all species except *Conochitina goniensis* n. sp.

Chronostratigraphically the biozone is referable to the early Homerian, and biostratigraphically it corresponds to the upper portion of the *lundgreni* graptolite biozone (*M. testis* Subzone ?).

The first two assemblages, I-G and II-G, may be partly correlated with the *Conochitina subcyatha* biozone of Estonia (Nestor, 1994), while the third, III-G, is not comparable with any of the known biostratigraphic units. The presence of *Sphaerochitina ichnussae* (= ? *Sphaerochitina sphaerocephala* in Dufka, 1992) in biostratigraphically equivalent levels (*M. testis* Subzone) of Bohemia (Dufka, 1992) means that this biozone is not exclusive to Sardinia.

BIOSTRATIGRAPHY AND CORRELATION

Correlation between SE Sardinia and other parts of Northern Gondwana has unfortunately been hampered by the scarcity of data in Gondwana for this time interval with the exception of the assemblages reported from Bohemia (Dufka, 1992; 1995; Kriz *et al.*, 1993), Portugal (Paris, 1981) and Brazil (Grahn & Paris, 1992). We find similarities with the *testis* Subzone of the Prague Basin (Dufka, 1992) in the presence of *Conochitina tuba* and the morphotype reported as ?*Sphaerochitina sphaerocephala* (Pl. 3, fig. 12 Dufka, 1992) which, based on comparison with the plates, has a quite similar shape to the Goni's *Sphaerochitina ichnussae* n. sp. in the same stratigraphic level. We do not have any coeval assemblages with the chitinozoans of Portugal (Paris, 1981) likely referred to the (?)*dubius* Biozone. In the Belgian Wenlock, at the top of the D2 Assemblage (Verniers, 1981), we notice the common presence of *Conochitina subcyatha* (Verniers, 1999). Similarities are also observed between the Chitinozoa from graptolite-dated sections of the Builth Wells district (Verniers, 1999) and the Goni section. In the *lundgreni* Biozone the common species to both areas are *Conochitina subcyatha* and *Sphaerochitina jaegeri* n. sp. (*Ancyrochitina* sp. A and *Ancyrochitina* sp. B, Verniers, 1999), the last one spanning a long biozonal range, from *centrifugus* to *ludensis-nassa* in the Builth Wells.

With respect to the global Chitinozoa biozonation proposed by Verniers *et al.* (1995), our stratigraphic level falls within the *Conochitina pachycephala* Biozone but the index fossil was only found in a few parts of Northern Gondwana (see above). Distinctive *Conochitina pachycephala* in full relief have now been found in the *vulgaris-gerhardi* Biozone in our study area (Homerian, Wenlock), but we have no data regarding its extension below this biozone in the studied section. We notice that the presence of *Conochitina tuba* is consistent in the range of this species indicated in the global biozonation chart.

Finally, the presence of *Conochitina subcyatha* allows a direct correlation with the Baltic and Avalonia biozonations (Nestor, 1994; Verniers *et al.*,

1995; Verniers, 1999) in which this taxon spans the same stratigraphic interval in relation to the graptolite biozonation.

TAXONOMY (by Paola PITTAU)

The suprageneric classification of Chitinozoa, as reported by Paris (1981), Miller (1996) and Paris *et al.*, 1999 is used below. The symbols used for biometric data are as follows:

L = total vesicle length
lc = chamber length
ln = neck length
Dmax = maximum diameter of the chamber
db = base diameter
dn = neck diameter
A = oral aperture.

Order PROSOMATIFERA Eisenack, 1972

Family CONOCHITINIDAE Eisenack, 1931 emend.

Paris, 1981

Subfamily CONOCHITININAE Paris, 1981

Genus CONOCHITINA Eisenack, 1931 emend. Paris, 1981

Type species – *Conochitina claviformis* Eisenack, 1931.

CONOCHITINA GONIENSIS n. sp.

Pl. 1, fig. 2; Pl. 2, figs. 1-2, 6-7; Pl. 3, figs. 7, 9-11

Derivation of the name – From the village of Goni.

Holotype – Pl. 2, fig. 6; DST-CP: 05 - 2742.

Type locality – Section outcropping in the Peinconi locality, near "via dei Graptoliti"; Goni village, SE Sardinia, Italy.

Type stratum – Lower Graptolitic Shales lithostratigraphic unit; black alum metashale with millimetric layers of phosphorite; *Cyrtograptus lundgreni* Biozone (lower portion).

Material – Hundreds of specimens recorded in the lower portion of the *lundgreni* Biozone; few tens of specimens recorded in the *rigidus*, *ellessae* and in the upper portion of the *lundgreni* Biozones.

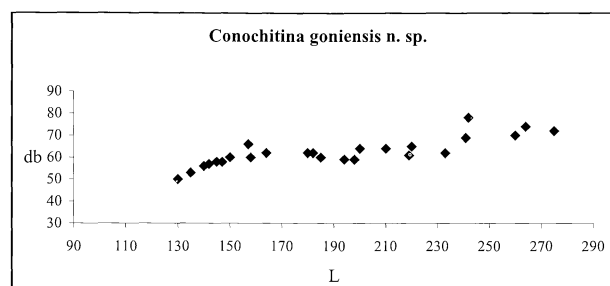
Diagnosis – Medium sized *Conochitina* species with perfectly straight flanks gradually tapering towards the aperture. Chamber and neck indistinct; collarette thin and straight; basal edge moderately rounded to sharp; base flat to slightly convex; outer vesicle wall smooth. The vesicle's maximum diameter lies just above the basal edge. L/Dmax = 2.4 to 3.7.

Description – This new species of *Conochitina* exhibits only slight morphologic variation: its outline is quite distinct and in a large population monotonous; small differences are present in the base shape, sometimes being flat, sometimes very slightly convex. When the base is well exposed a small basal scar is present. The collarette is simple, not flaring and just straight but not always preserved. The outer vesicle wall is smooth and in many specimens molds of clay minerals are visible at high magnification. A lot of specimens are filled with pyrite crystals and the intense bacterial activity of the embedding sediment is witnessed by the fossilized bacteria all over the test surface and even inside the ectoderm layer. Under transmitted optical light they are black and the presence of a prosome cannot be checked.

Dimensions (in μm) – The size was measured from 30 complete three-dimensional specimens. Data on the total length and the diameter of the base of the measured specimens, represented in the scatter diagram, clearly shows that the increase in length is not proportional to the increase of the diameter of the base. Indeed in the smaller forms the total length base diameter ratio is between 2.4 and 2.6 while in the larger forms between 3 and 3.8.

	L	db	A
Range	130 - 278	50 - 76	36 - 52
Mean	204	63	44
Holotype	265	70	40

Comparisons – By the absence of flexure it is distinguished from *Conochitina subcyatha* Nestor, 1982; by its almost flat base and sharp basal edge it is distinguished from *Conochitina praeproboscifera* Nestor, 1994; by its smooth outer vesicle surface it is distinguished from *Conochitina visbyensis* Laufeld, 1974 and *Conochitina* sp. 7 Nestor, 1994. *Conochitina argillosa* Laufeld, 1974 is similar to *Conochitina goniensis* in the upper portion of the test but differs



Text-fig. 4 - Scatter diagram for *Conochitina goniensis* n. sp., total vesicle length (L, in μm) in relation to chamber diameter of base (db, in μm).

for having a basal constriction and a bluntly basal edge. Goni's species is also similar to *Conochitina fortis* Nestor, 1982 in the silhouette of the test but differs for not having the conical mucron.

Occurrence – *Conochitina goniensis* n. sp. appears in the *Cyrtograptus rigidus* Biozone where it is rare; it is abundantly present in the lower portion of the *Cyrtograptus lundgreni* Biozone, where it has its acme, and it is present in the upper and uppermost portions of the *lundgreni* Biozone.

CONOCHITINA sp. a
Pl. 2, fig. 5

Material – Only one complete specimen.

Description – Medium sized chitinozoan with conical chamber and cylindrical neck ending in a simple and straight oral aperture. Chamber flanks perfectly straight, faint flexure at about $2/3$ from the base of the total vesicle length. Base flat and sharp to gently rounded basal edge. Vesicle surface smooth.

Dimensions (in μm) – L = 286; db = 61; ln = 85; dn = 41; A = 41.

Occurrence – Rare; upper portion of the *lundgreni* Biozone.

EXPLANATION OF PLATE 1

- Fig. 1 - *Tanuchitina* sp. a; (x 430); *lundgreni* Biozone (lower portion).
- Fig. 2 - *Conochitina goniensis* n.sp.; (x 285); *rigidus* Biozone.
- Fig. 3 - *Rhabdochitina* sp.a; (x 380); *lundgreni* Biozone (lower portion).
- Fig. 4 - *Conochitina* cf. *tuba*; (x 230); *rigidus* Biozone.
- Fig. 5 - *Conochitina subcyatha*; (x 200); *lundgreni* Biozone (lower portion).
- Fig. 6 - *Conochitina subcyatha*; (x 280); *lundgreni* Biozone (lower portion).
- Fig. 7 - *Conochitina* aff. *proboscifera*; (x 600); detail of fig. 12; *lundgreni* Biozone (lower portion).
- Fig. 8 - Organic spherules (foraminifers?); (x 230); *lundgreni* Biozone.
- Fig. 9 - ? Hydroida tubules; (x 480); *belophorus* Biozone.
- Fig. 10 - ? Hydroida tubules; (x 580); *belophorus* Biozone.
- Fig. 11 - ? Hydroida tubules; (x 600); *belophorus* Biozone.
- Fig. 12 - *Conochitina* aff. *proboscifera*; (x 210); *lundgreni* Biozone (lower portion).



Remarks – The elegant and graceful silhouette serves to distinguish *Conochitina* sp. a from any other known species. This is most probably a new species but as there is only one specimen, it has been left in open nomenclature.

CONOCHITINA aff. PROBOSCIFERA Eisenack, 1937
in Nestor, 1994
Pl. 1, figs. 7, 12

Description – Large sized chitinozoan with sub-cylindrical test and slightly convex flanks tapering towards the oral aperture; the base convex bears in its centre a short mucron; the basal edge is rounded and the outer vesicle wall is smooth. The largest diameter lays a little above the basal edge.

Dimensions – Only uncomplete specimens, the longest one reaching 280 µm in length; D_{max} = 70 µm.

Occurrence – Rare; upper portion of the *lundgreni* Biozone.

Previous recording – In Estonia *C. aff. proboscifera* occurs in the Jamaja and in the lower portion of the Sörve Formations, referred to the Jaagarahu Stage, largely equivalent to the top of the *rigidus* to the lower portion of the *colonus*, covering the stratigraphic interval of this finding.

Remarks – Nestor (1994) distinguishes *C. aff. proboscifera* from *C. proboscifera* on the basis of the test thickness. In the absence of any complete specimens the species is left in open nomenclature.

CONOCHITINA SUBCYATHA Nestor, 1982
Pl. 1, figs. 5-6; Pl. 3, fig. 12

1981 *Linochitina* aff. *L. erratica* (Eisenack 1931) - VERNIERS, pl. 2, fig. 29.

1982 *Conochitina* sp. E VERNIERS, pl. 3, figs. 63 A, B.

1982a *Conochitina subcyatha* NESTOR, p. 109, pl. 4, figs. 1-5.

1990 *Conochitina subcyatha* - NESTOR, p. 81, pl. 15, fig. 2.

1994 *Conochitina subcyatha* - NESTOR, p. 38, pl. 16, figs. 8-11.

1999 *Conochitina subcyatha* - VERNIERS, pl. 2, figs. 4, 5.

Description (based on almost complete specimens) – The subconical chamber passes to the cylindrical neck through a flexure situated halfway up the vesicle; shoulders are very faintly developed. The basal edge is sharp or gently rounded; the base is flat and a circular scar is present in its center. The oral aperture is simple and straight. The vesicle surface is smooth.

Dimensions (in µm) –

	L	D _{max}	dn	db	lc
Range	200 - 325	62 - 85	40 - 60	55 - 75	110 - 160
Mean	270	66	55	69	130

Occurrence – This species is present from the *rigidus* and *?ellesae* to lower portion of the *lundgreni* Biozone.

Previous recording – In Estonia *C. subcyatha* occurs in the Upper Wenlock in a stratigraphical interval equated to part of the *lundgreni* Biozone (*radians* and part of the *testis* Subzones) (Nestor, 1994). In Belgium it is reported at the top of the D2 assemblages zone from an imprecise middle or late Wenlock age (Verniers, 1981, 1982) correlated with the *cingulata* and partly of the *pachycephala* biozones of the Builth Wells (Verniers, 1999). From Builth Wells district (Wales U.K.) it has been reported from the *lundgreni* to *ludensis-nassa* (= *vulgaris-gerhardi*; see Zalasiewicz & Williams, 1999) Biozones (Verniers, 1999).

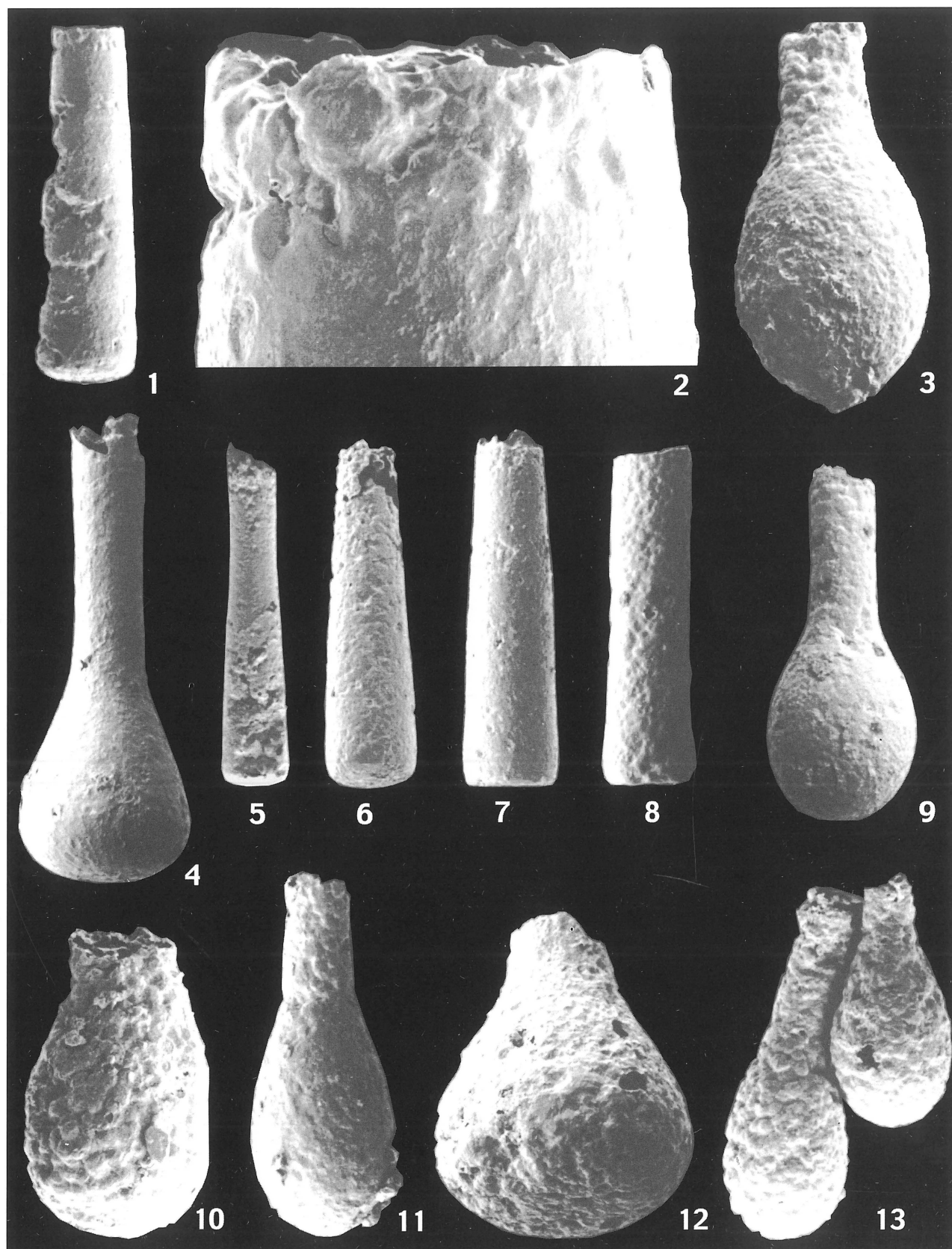
Remarks – The presence of this species in North Gondwana is noteworthy, particularly for the coinciding stratigraphic range with Estonia and for a partial stratigraphic range (the lower part) with Avalonia.

CONOCHITINA cf. TUBA Eisenack, 1932
Pl. 1, fig. 4

Description (based on fragments of partially flattened tests) – Subcylindrical with more or less parallel flanks, slightly convex after volume restoration.

EXPLANATION OF PLATE 2

- Fig. 1 – *Conochitina goniensis* n. sp.; (x 200); *lundgreni* Biozone (lower portion).
Fig. 2 – *Conochitina goniensis* n. sp.; (x 1.500); detail of fig. 1.
Fig. 3 – *Sphaerochitina serpaglii* n. sp. x 550; *lundgreni* Biozone. (lower portion). Paratype.
Fig. 4 – *Sphaerochitina jaegeri* n. sp.; (x 450); *lundgreni* Biozone (lower portion). Holotype.
Fig. 5 – *Conochitina* sp. a; (x 175); *lundgreni* Biozone (upper portion).
Fig. 6 – *Conochitina goniensis* n. sp.; (x 230); *lundgreni* Biozone. (upper portion). Holotype.
Fig. 7 – *Conochitina goniensis* n. sp.; (x 210); *lundgreni* Biozone (upper portion).
Fig. 8 – cf. *Rabdochitina* sp. a; (x 230); *lundgreni* Biozone (upper portion).
Fig. 9 – *Sphaerochitina ichnussae* n. sp.; (x 350); *lundgreni* Biozone (upper portion). Paratype.
Fig. 10 – *?Eisenackitina ampulla* n. sp. (x 530); *lundgreni* Biozone (upper portion). Holotype.
Fig. 11 – *Sphaerochitina serpaglii* n. sp.; (x 400); *lundgreni* Biozone (upper portion). Paratype.
Fig. 12 – *Sphaerochitina jaegeri* n. sp. (x 760); *lundgreni* Biozone (upper portion).
Fig. 13 – *Sphaerochitina serpaglii* n. sp.; (x 350); *lundgreni* Biozone (upper portion). Holotype (specimen on left).



Base flat bearing a basal scar in the concave centre. Basal edge rounded; vesicle surface smooth.

Dimensions (in μm) – The vesicle maximum diameter is between 75 and 80.

Remarks – The fragments observed are not expressive enough for a species assignment. Nevertheless in all specimens the base is distinctly flat and bears in its centre a depressed basal scar, never protruding outward. For this feature and the cylindrical lower chamber this species seems the most appropriate to this test.

Occurrence – Common in the *rigidus* and *?ellesae* Biozones; rare in the lower portion of the *lundgreni* Biozone.

Genus RHABDOCHITINA Eisenack, 1931

Type species – *Rhabdochitina magna* Eisenack, 1931.

RHABDOCHITINA sp. a
Pl. 1, fig. 3

Material – Less than 10 specimens of which only one complete and three-dimensional.

Description – Cylindrical, sometimes curved vesicle with flat base and blunt basal edge. Oral aperture slightly evased and collarette simple in the only one specimen where it is observed. Outer vesicle wall smooth, with internal and external imprints of pyrite framboids.

Dimensions (in μm) – L = 307; the vesicle maximum diameter is from 56 to 68; A = 70.

Occurrence – Rare; upper portion of the *lundgreni* Biozone.

Subfamily TANUCHITININAE Paris, 1981

Genus TANUCHITINA Jansonius, 1964 emend.
Paris *et al.*, 1999

Type species – *Tanuchitina ontariensis* Jansonius, 1964.

TANUCHITINA sp. a
Pl. 1, fig. 1

Description (based on two complete specimens and some fragments) – Subcylindrical test with straight flanks, weakly orally tapering. Basal edge rounded; base moderately concave. Oral tube indistinct from chamber; collarette straight. The vesicle surface is unornamented and shows a peculiar undulated surface texture. Below the basal edge a very narrow rim, not a true carina is present, which makes the

generic designation of this species in the *Tanuchitina* genus questionable.

Dimensions (in μm) – L = 205 - 270; Dmax = 65 - 70; A = 56.

Occurrence – Rare; upper portion of the *lundgreni* Biozone.

Family LAGENOCHITINIDAE Eisenack, 1931
Subfamily LAGENOCHITININAE Paris, 1981

Genus SPHAEROCHITINA Eisenack, 1955 emend.
Paris *et al.*, 1999

Type species – *Lagenochitina sphaerocephala* Eisenack, 1932.

SPHAEROCHITINA SERPAGLI n. sp.
Pl. 2, figs. 3, 11, 13; Pl. 3, figs. 1-3

Derivation of the name – Dedicated to Prof. Enrico Serpagli, Italian paleontologist, who much studied the Sardinian Palaeozoic.

Holotype – Pl. 2, fig. 13; DIST – CP: 05 - 2743.

Paratypes – Pl. 2, figs. 3, 11; Pl. 3, fig. 1.

Type locality – Section outcropping in the Peinconi locality, near “via dei Graptoliti”; Goni village; SE Sardinia, Italy.

Type stratum – Lower Graptolitic Shale lithostratigraphic unit; black alum metashale with millimetric layers of phosphorite; *Cyrtograptus lundgreni* Biozone (upper portion).

Material – Hundreds of three-dimensional specimens recorded in the upper portion of the *lundgreni* Biozone; few specimens recorded in the lower portion of the same biozone.

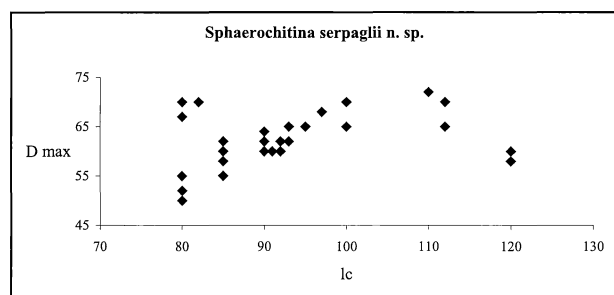
Diagnosis – Medium sized *Sphaerochitina* species with ovoid chamber and cylindrical neck; ogival base and shoulder rarely developed. Flexure sharp, oral aperture simple and straight. The greatest diameter is a little below the lower half of the chamber. Surface vesicle rugose with diffuse *punctae*.

Description – The distinctiveness of the species is in the ovoid chamber with ogival base and the largest diameter lying in the lower half of the chamber. Generally the flanks taper straight, without shoulders, towards the chamber – neck flexure, but in a few specimens the development of shoulders is noted (Pl. 2, fig. 3). The neck, cylindrical, is less than 1/2 the total vesicle length, but may also be less. The vesicle

surface is irregular, showing sparse *punctae*. This species is very distinct by its pointed base.

Dimensions (in μm) –

	L	D _{max}	dn	db	lc
Range	139 - 208	50 - 72	32 - 46	59 - 88	80 - 120
Mean	173	61	39	73	100
Holotype	182	70	40	69	112



Text-fig. 5 - Scatter diagram for *Sphaerochitina serpaglii* n. sp.; chamber length (lc, in μm) in relation to the maximum diameter of the chamber (Dmax, in μm).

Occurrence – Abundant in the upper portion of the *lundgreni* Biozone; rare in the lower portion of the same biozone.

Remarks – The population of *S. serpaglii* n. sp. shows a high morphological uniformity, and, as far as size is concerned, the total length – vesicle maximum diameter ratio is between 2.2 and 2.7.

SPHAEROCHITINA ICHNUSSAE n. sp.
Pl. 2, fig. 9; Pl. 3, figs. 4, 8

1992 ?*Sphaerochitina sphaerocephala* DUFKA, pl. 3, fig. 12.

Derivation of the name – From «Ichnussa», ancient name of Sardinia.

Holotype – Pl. 3, fig. 4; DST – CP: 05 – 2742.

Paratypes – Pl. 3, fig. 8; Pl. 2, fig. 9.

Type locality – Section outcropping in the Peinconi locality, near «via dei Graptoliti»; Goni village, SE Sardinia, Italy.

Type stratum – Lower Graptolitic Shales lithostratigraphic unit; black alum metashale with millimetric layers of phosphorite; *Cyrtograptus lundgreni* Biozone (upper portion).

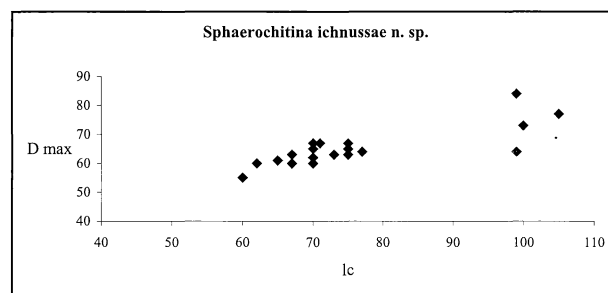
Material – Several tens of three-dimensional specimens.

Diagnosis – Medium sized *Sphaerochitina* species with ovoid to subspherical chamber and cylindrical neck; base convex or hemispherical; shoulders developed; flexure, gradual; oral aperture simple and straight. The greatest diameter lays roughly in the middle or in the lower half of the chamber. Surface vesicle rugose with diffuse *punctae*.

Description – Often the chamber is more or less spherical with shoulders present; sometimes it is ovoid, pear-shaped with flanks gradually taper into the neck without developing shoulder; the base is always widely convex.

Dimensions (in μm) –

	L	D _{max}	dn	lc
Range	120 - 184	55 - 84	24 - 34	60 - 105
Mean	162	61	25	75
Holotype	184	64	30	99



Text-fig. 6 - Scatter diagram for *Sphaerochitina ichnussae* n. sp.; chamber length (lc, in μm) in relation to the maximum diameter of the chamber (Dmax, in μm).

Occurrence – Present in the lower portion of the *lundgreni* Biozone; common in the upper portion of the same biozone. Previously recorded in the *testis* Subzone of the Prague Basin (Dufka, 1992).

Comparison – The species differs from *Sphaerochitina serpaglii* n. sp. in the chamber shape which in the former is subspherical rather than ovoid, and in the shape of the base which is distinctly convex rather than ogival. It is similar to, if not the same as, *Sphaerochitina sphaerocephala* reported by Dufka (1992) from coeval stratigraphical layers of Bohemia.

SPHAEROCHITINA JAEGERI n. sp.
Pl. 2, figs. 4, 12; Pl. 3, figs. 5-6

1999 *Ancyrochitina* sp. A VERNIERS, p. 370, pl. 2, fig. 13.

1999 *Ancyrochitina* sp. B VERNIERS, p. 370, pl. 2, fig. 14.

Derivation of the name – Dedicated to Prof. Hermann Jaeger.

Holotype – Pl. 2, fig. 4; DIST – CP 05 - 2743.

Type locality – Section outcropping in the Peinconi locality, near “via dei Graptoliti”; Goni village, SE Sardinia, Italy.

Type stratum – Lower Graptolitic Shales lithostratigraphic unit; black alum metashale with millimetric layers of phosphorite; *Cyrtograptus lundgreni* Biozone, lower and upper portions.

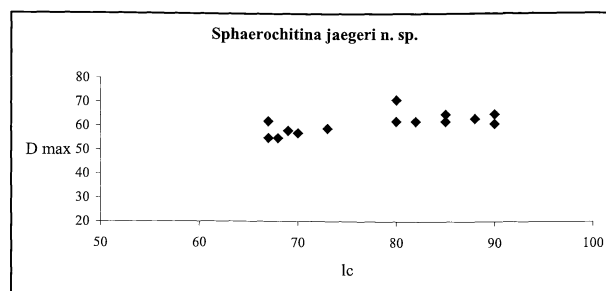
Material – Six of three-dimensional specimens, complete; several with broken neck.

Diagnosis – Medium sized chitinozoan with truncated-cone chamber and cylindrical neck; base flat to moderately convex, basal edge rounded, flexure present, oral aperture simple. Maximum diameter of the chamber at 1/4 from the base. Vesicle wall with sparse *punctae*.

Description – This chitinozoan is characterized by its elegant silhouette; the chamber usually shows straight flanks except when it is filled by pyrite having, in that case, convex flanks. The basal edge is well rounded so that the base is narrow; the basal scar seems to be absent. The cylindrical and narrow neck is generally longer than chamber length; the collarete is simple and thinner than the chamber wall. The outer surface shows sparse small ornamentations in the shape of *punctae*.

Dimensions (in μm) –

	L	D _{max}	dn	db	lc
Range	160 - 180	55 - 65	25	75 - 98	71 - 90
Mean	170	60	25	86	78
Holotype	180	64	25	90	90



Text-fig. 7 - Scatter diagram for *Sphaerochitina jaegeri* n. sp.; chamber length (lc, in μm) in relation to the maximum diameter (D max, in μm) of the chamber.

Occurrence – Present in the *lundgreni* Biozone, lower and upper portions.

Remarks – By its truncated-cone chamber it is easily distinguishable from *S. serpaglii* n. sp. and *S. ichnussae* n. sp.. A similar form to *S. jaegeri*, although possessing smooth test and smaller size, occurs in the *lundgreni* Biozone of Built Wells district (Verniers, 1999); it is illustrated in pl. 2, figs. 13 and 14 under the name *Ancyrochitina* sp. A and *Ancyrochitina* sp. B and it is possibly the synonymous to *S. jaegeri* n. sp.. In that area the species is reported from the *centrifugus* up to the *ludensis-nassa* biochronological interval (Verniers, 1999).

Order OPERCULATIFERA Eisenack, 1972
Subfamily EISENACKITININAE Paris, 1981

Genus EISENACKITINA Jansonius, 1964

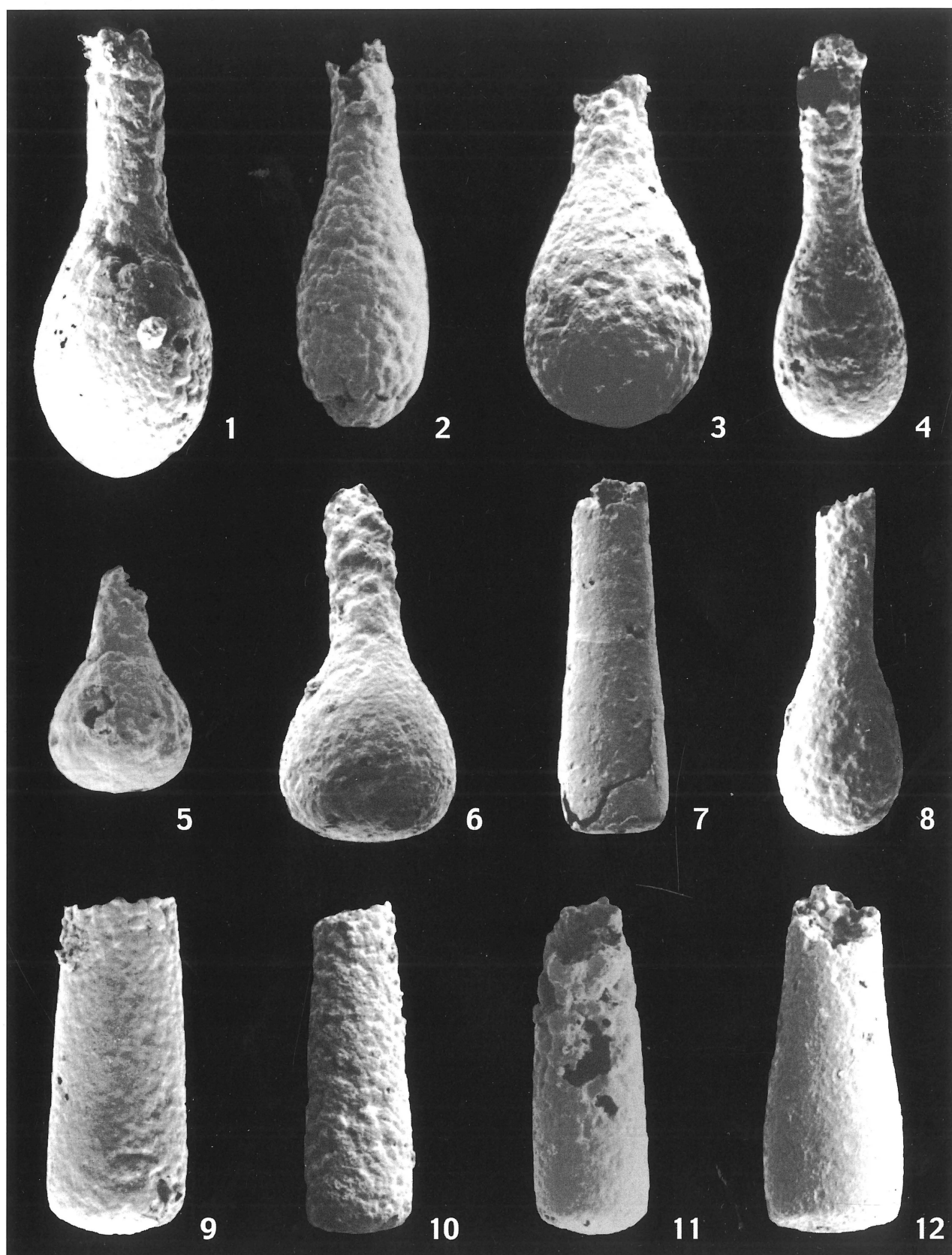
Type species – *Eisenackitina castor* Jansonius, 1964.

?EISENACKITINA AMPULLA n. sp.
Pl. 2, fig. 10

Derivation of the name – From chamber's shape, in the form of ampulla; latin for a glass vase.

EXPLANATION OF PLATE 3

- Fig. 1 - *Sphaerochitina serpaglii* n. sp.; (x 125); *lundgreni* Biozone (upper portion). Paratype.
Fig. 2 - *Sphaerochitina serpaglii* n. sp.; (x 350); *lundgreni* Biozone (lower portion).
Fig. 3 - *Sphaerochitina serpaglii* n. sp.; (x 420); *lundgreni* Biozone (upper portion).
Fig. 4 - *Sphaerochitina ichnussae* n. sp.; (x 350); *lundgreni* Biozone (lower portion). Holotype.
Fig. 5 - *Sphaerochitina jaegeri* n. sp.; (x 410); *lundgreni* Biozone (upper portion).
Fig. 6 - *Sphaerochitina jaegeri* n. sp.; (x 425); *lundgreni* Biozone (upper portion). Paratype.
Fig. 7 - *Conochitina goniensis* n. sp.; (x320); *lundgreni* Biozone (lower portion).
Fig. 8 - *Sphaerochitina ichnussae* n. sp.; (x 335); *lundgreni* Biozone (upper portion). Paratype.
Fig. 9 - *Conochitina goniensis* n. sp.; (x 300); *lundgreni* Biozone (lower portion).
Fig. 10 - *Conochitina goniensis* n. sp.; (x 310); *lundgreni* Biozone (lower portion).
Fig. 11 - *Conochitina goniensis* n. sp.; (x 320); *lundgreni* Biozone (lower portion).
Fig. 12 - *Conochitina subcyatha*; (x 390); *lundgreni* Biozone (lower portion).



Holotype – Pl. 2, fig. 10; DST – CP: 05 - 2743.

Type locality – Section outcropping in the Peinconi locality, near “via dei Graptoliti”; Goni village, SE Sardinia, Italy.

Type stratum – Lower Graptolitic Shales lithostratigraphic unit; black alum metashale with millimetric layers of phosphorite; *Cyrtograptus lundgreni* Biozone, upper portion.

Material – Twelve complete specimens; fifteen broken or pitted internal moulds.

Description – Small sized chitinozoan with ovoid chamber and neck reduced to a cylindrical short and simple collar; aperture small. Test surface smooth, unornamented. Chain not observed.

Dimensions (in μm) –

	L	db	A
Range	95 - 102	62 - 68	32 - 38
Mean	98	65	35
Holotype	102	68	38

Occurrence – Common in the upper portion of the *lundgreni* Biozone.

Remarks – The ovoid chamber instead of a truncated-cone one and the absence of any ornamentation makes the attribution of this species to *Eisenackitina* genus questionable. *?Eisenackitina ampulla* differs from any other known species of this genus because of its shape; the most similar species is *Eisenackitina* sp. A, illustrated by Verniers (1981), which differs from ours in that it has a cylindrical-conical chamber.

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