

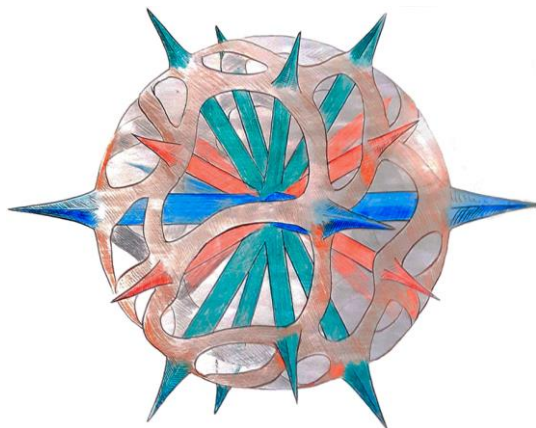
VALANGINIAN RADIOLARIANS OF NE SARDINIA (ITALY) IN THE FRAME OF THE WEISSERT EVENT

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Abstract This article presents the very rich radiolarian fauna from the S'Ozzastru section of the Siniscola Marl cropping out in the northern part of Mt Albo massif (NE Sardinia, Italy). The formation was ascribed to the lower part of the upper Valanginian on the basis of the ammonite fauna indicating the Verrucosum Zone and the nannofossil content suggesting the Zone NK3. Due to the scarcity of pantanelliids and especially of the absence of *Cecrops septemporatus*, radiolarian marker of the upper Valanginian, radiolarians can only indicate a Valanginian age. Investigations for integrated litho-, bio-, and chemostratigraphy allowed the identification of the Valanginian Weissert Oceanic Anoxic Event (OAE), testified by a positive carbon isotope excursion (CIE) with values up to 2.98 ‰. Radiolarian study includes not only a determination of the species for biostratigraphic interpretations, but also a revision of the systematics of the radiolarians occurring in the section. One new family (Crococapsidae), 3 new genera (*Apiaromitra*, *Microsandwichia* and *Ocellicapsa*) and 43 new species are erected. The fauna has some elements in common with the Valanginian faunas from the Mediterranean area and many more with those from Japan, proving a wide circulation between the western and eastern Tethys.

Keywords: Radiolarians, new taxa, late Valanginian, Sardinia, litho- and biostratigraphy, Weissert Oceanic Anoxic Event.



Schematic radiolarian reproduced after an autograph drawing by Squinabol.

DEDICATION

This work is dedicated to the Italian palaeontologist Senofonte Squinabol (1861-1941), known for his important and forerunning studies on Mesozoic Radiolaria. The schematic radiolarian figured to the left is a reproduction of an autograph drawing by him.

INTRODUCTION

This study is a continuation of the palaeontologic and biostratigraphic characterization of the upper Valanginian of the S'Ozzastru section from the north-eastern part of Sardinia that highlighted the presence of a positive carbon isotope shift. This shift matches with the late Valanginian Weissert OAE (Bottini et al., 2018). Since many geological aspects of the Valanginian occurring in this area (macrofauna, calcareous nannofossil biostratigraphy, stable isotope data, environmental aspects, etc., discussed in chapters 2-6) are already known, and the sponge spicules, abundant or frequent in the whole succession of the Valanginian of this area are already studied and have been very recently published (Lukowiak et al., 2022), this study is focused on the radiolarian assemblages occurring in this section. As their assemblages are practically

unknown, except a few photos published by Dieni & Massari (1991), and their preservation is very good, the present study has as main goal a detailed taxonomic study of these microfossils.

GEOLOGIC AND STRATIGRAPHIC SETTING

In the study area the sedimentary cover of the Palaeozoic crystalline basement is represented by a thick Middle Jurassic-Lower Cretaceous succession, mostly consisting of shallow-marine dolostones and limestones. The investigation is specifically concerned with the Lower Cretaceous deposits cropping out in the northern part of the Mt Albo, a fault-bounded massif elongated in a NE-SW direction. In this area (Fig. 1) quartz-arenitic brown

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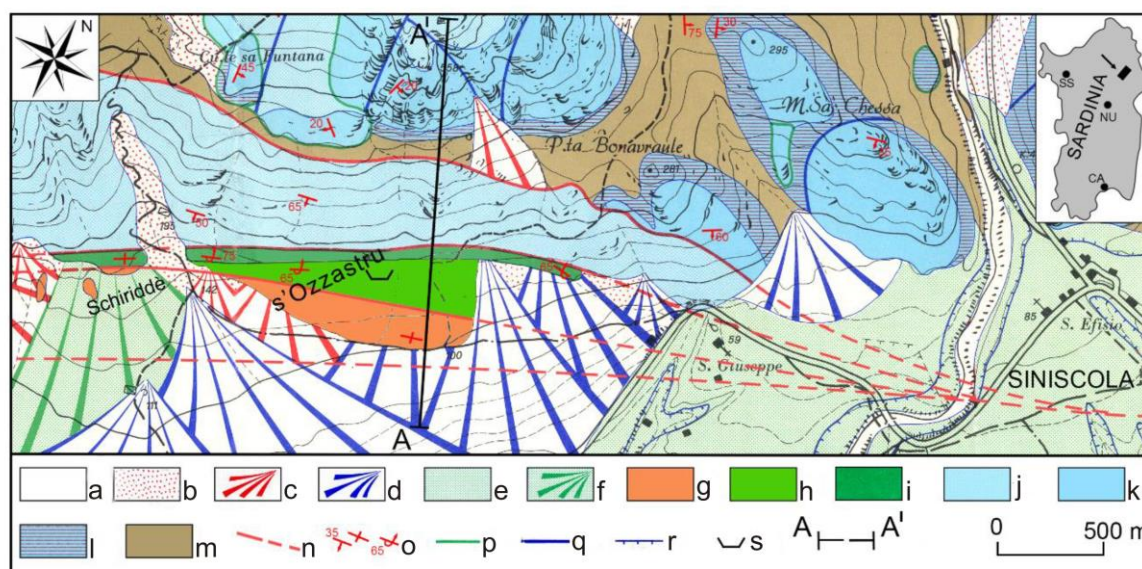


Fig. 1 Geologic map of the Siniscola area, NE Sardinia (from Dieni & Massari, 1971, updated in 1986). Legend: **a** - Recent and present alluvial deposits (*Holocene*). **b** - Scree deposits (*Würm-Holocene*). **c** - Detrital cones mostly composed of gelifraction limestone clasts (“éboulis ordonnés”) (*Würm-Holocene*). **d** - Uncemented alluvial cones mostly consisting of limestone clasts (*Würm-Holocene*). **e** - Terraced alluvial deposits composed of clasts of basement rocks (*Riss?*). **f** - Tightly cemented and dismembered alluvial cones mostly made up of gelifraction limestone clasts (*Riss?*). **g** - Cuccuru ’e Flores Conglomerate: polymict, chaotic and thick-bedded breccia and stratified sandstone (*middle Eocene*). **h** - Siniscola Marl: grey and grey-yellow marl and, in the upper part, alternating marl/marly limestone with ammonites and very abundant radiolarians and sponge spicules (*late Valanginian*). **i** - Schiriddè Limestone: light-brown cherty limestone and limestone with marly interbeds, containing ammonites, radiolarians, sponge spicules and calpionellids (*early Valanginian*). **j** - Monte Bardia Limestone: thick-bedded to massive white limestone in places bioconstructed, with corals, nerineids, etc. (*early Tithonian - late Berriasian*). **k** - S’Adde Limestone: light-brown to grey fine-grained, well-bedded limestone, condensed with hardgrounds near the base, cherty in the upper part, with ammonites and belemnites in the uppermost part (*latest Bathonian - earliest Tithonian*). **l** - Dorgali Formation: well bedded quartz-arenitic and locally ooidal brown dolostone (*middle-late Bathonian*). **m** - Crystalline basement (phyllite, micaschist, paragneiss, quartzite, etc.) (*Palaeozoic*). **n** - Fault. **o** - Attitude of beds and schistosity planes. **p** - Limits of slumped masses of Jurassic formations (*Quaternary*). **q** - Concave-upward slip surfaces delimiting rotational slumps (*Quaternary*). **r** - Edge of fluvial terrace. **s** - Quarry. **A-A’** Trace of the geological section of Fig. 2. (extracted from Bottini et al., 2018).

dolostones evolving to ooidal dolostones of the Dorgali Formation of middle-late Bathonian age are followed by fine-grained, well-bedded middle- to outer-ramp limestones and cherty limestones of latest Bathonian - earliest Tithonian age (S’Adde Limestone), with hardgrounds in the lowermost part and cherty limestones in the upper part, containing belemnites and ammonites of the upper Kimmeridgian Beckeri Zone (Dieni et al., 1966). This interval is followed by a thick carbonate-platform complex of early Tithonian to late Berriasian age (Monte Bardia Limestone), consisting of thick-bedded to massive white limestones, mostly made up of biosparites and algal boundstones, and in places with patch reefs in the lower part (Dieni & Massari, 1985, 1991).

In the southern Mt Albo, as well as in several areas of central-eastern Sardinia, the upper Monte Bardia Limestone includes in the lower Berriasian a characteristic interval consisting of predominant mud-cracked micritic laminites with intercalated layers of storm-related washover deposits and black pebble breccias, corresponding to the well-known “Purbeckian facies” of the literature. This interval contains oligotypic assemblages suggesting a restricted environment of very shallow-water and temporarily emergent wide inter- to supratidal flats disseminated with lagoonal to lacustrine ponds. The facies association of these deposits points to a marked regressive trend which is consistent with a scenario of lowstand

conditions, as generally observed in the uppermost Jurassic to lower Berriasian successions of the central and northern European area (Hallam et al., 1991; Dera et al., 2011, with references). This interval is absent on the northern termination of the Mt Albo, where Valanginian deposits directly overlie the upper Berriasian limestones of the uppermost part of the Monte Bardia Limestone and appear tectonically squeezed between the latter and middle Eocene rudites and arenites of the Cuccuru’e Flores Conglomerate (Fig. 2).

The faults bounding the deposits are part of a positive flower structure belonging to a Tertiary transpressional system of regional importance. This structure crosses whole Sardinia and was activated in the middle Eocene in an inferred foreland setting with respect to the Alpine orogen, and re-activated in the late Oligocene – early Miocene initial stages of the Apenninic history, when the Corsica-Sardinia microplate behaved as hinterland of the Apenninic migrating front (Dieni & Massari, 1991; Carmignani et al., 1992; Dieni et al., 2008; Massari & Dieni, 2014).

THE BERRIASIAN-VALANGINIAN SUCCESSION OF THE S’OZZASTRU SECTION

The Valanginian deposits which are the subject of this work have been analyzed in the S’Ozzastru quarry

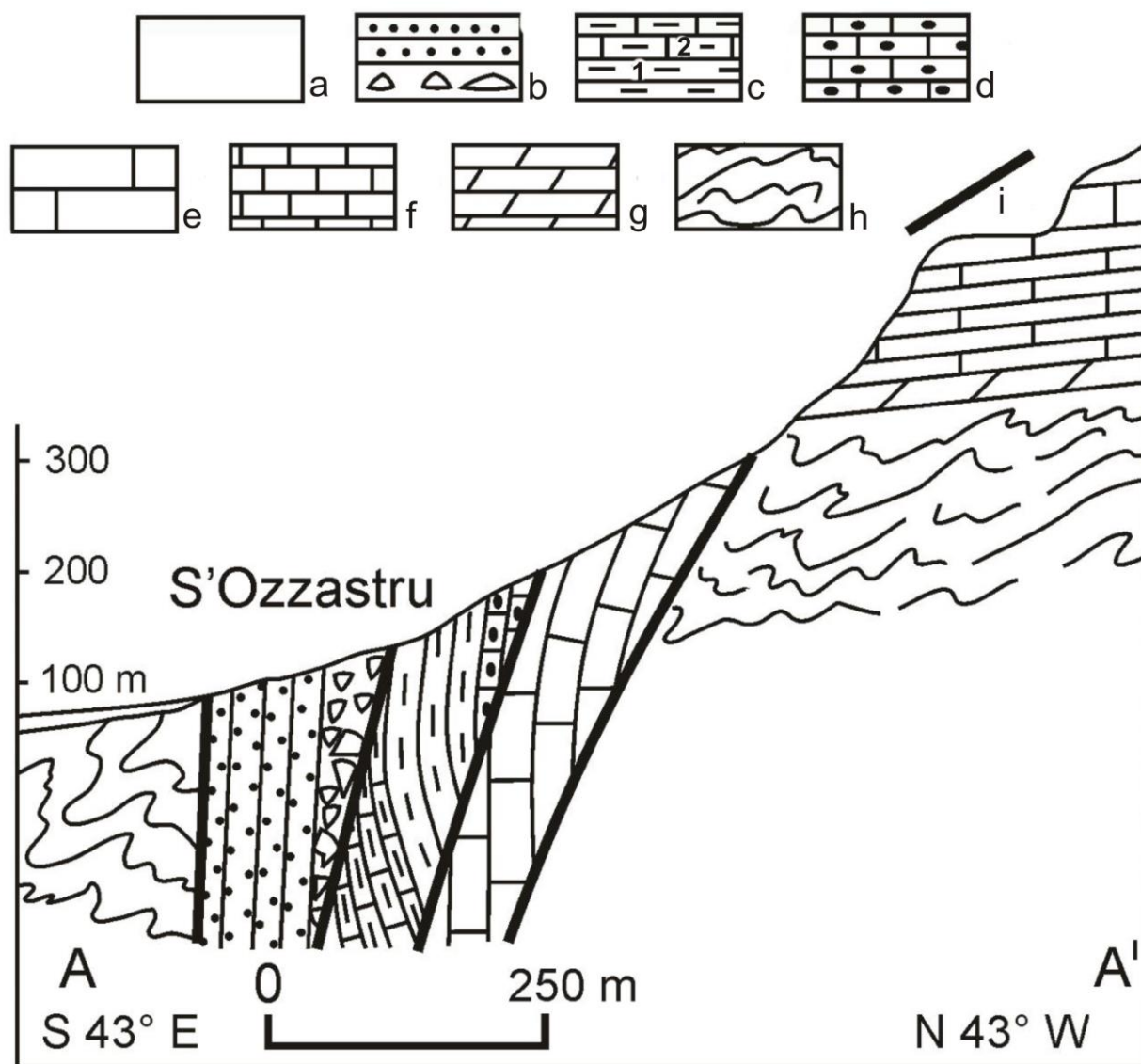


Fig. 2 Geological section across the S'Ozzastru area (trace A-A' in the geological map of Fig. 1). Legend: **a** - Recent and present alluvial deposits (*Holocene*). **b** - Cuccuru 'e Flores Conglomerate: sandstone and breccia (*middle Eocene*). **c** - Siniscola Marl: marl (1) and marly limestone (2) (*late Valanginian*). **d** - Schiriddè Limestone: cherty limestone (*early Valanginian*). **e** - Monte Bardia Limestone: limestone (*early Tithonian - late Berriasian*). **f** - S'Adde Limestone: limestone and cherty limestone (*latest Bathonian - earliest Tithonian*). **g** - Dorgali Formation: dolostone (*middle-late Bathonian*). **h** - Metamorphic basement (*Palaeozoic*). **i** - Fault (modified from Bottini et al., 2018).

section (already briefly described by Dieni et al., 1987a), located near the village of Siniscola, close to the northern corner of Mt Albo. The last 30 m of the carbonate platform complex of the Monte Bardia Limestone cropping out in the small Riu Siccu valley, located about 2.2 Km SW of S'Ozzastru (Fig. 1), are represented by platform-margin white biosparites. In the S'Ozzastru section the above deposits grade upwards into light-brown biomicrites and intramicrites of about 10 m thickness (uppermost Monte Bardia Limestone). The microfaunal content is represented by *Coscinoconus* ex gr. *alpinus-elongatus* Leupold, 1935, and *Protopenneroplis ultragranulata* (Gorbatchick, 1971), accompanied by common calpionellids including *Calpionellopsis simplex* (Colom, 1939), *Cps. oblonga* (Cadisch, 1932), *Praecalpionellites murgeanui* (Pop, 1974), in order of occurrence, and *Calpionella alpina* Lorenz, 1902, *Remaniella cadischiana*

(Colom, 1948), *Tintinnopsella carpathica* (Murgeanu & Filipescu, 1933), and *T. longa* (Colom, 1939). This assemblage indicates a late Berriasian age.

At the top of the succession a sharp lithologic change, probably corresponding to a short stratigraphic gap of the uppermost Berriasian indicated by the absence of *Praecalpionellites dadayi* (Knauer, 1963) (see Grün & Blau, 1997), marks the transition to grey-light brown micritic and slightly marly, commonly bioturbated limestones about 2 m thick, with *Calpionellites dardereri* (Colom, 1934), *P. murgeanui* (Pop, 1974), *T. carpathica*, and *T. longa*, indicating an early Valanginian age.

The following yellowish cherty limestones about 15 m thick (reported in the lower part of the first segment of the log in Fig. 3) contain ammonites, including *Busnardoites campylotoxus* (Uhlig, 1910), *B. cf. campylotoxus*, *Neocomites neocomiensis* (d'Orbigny, 1841),

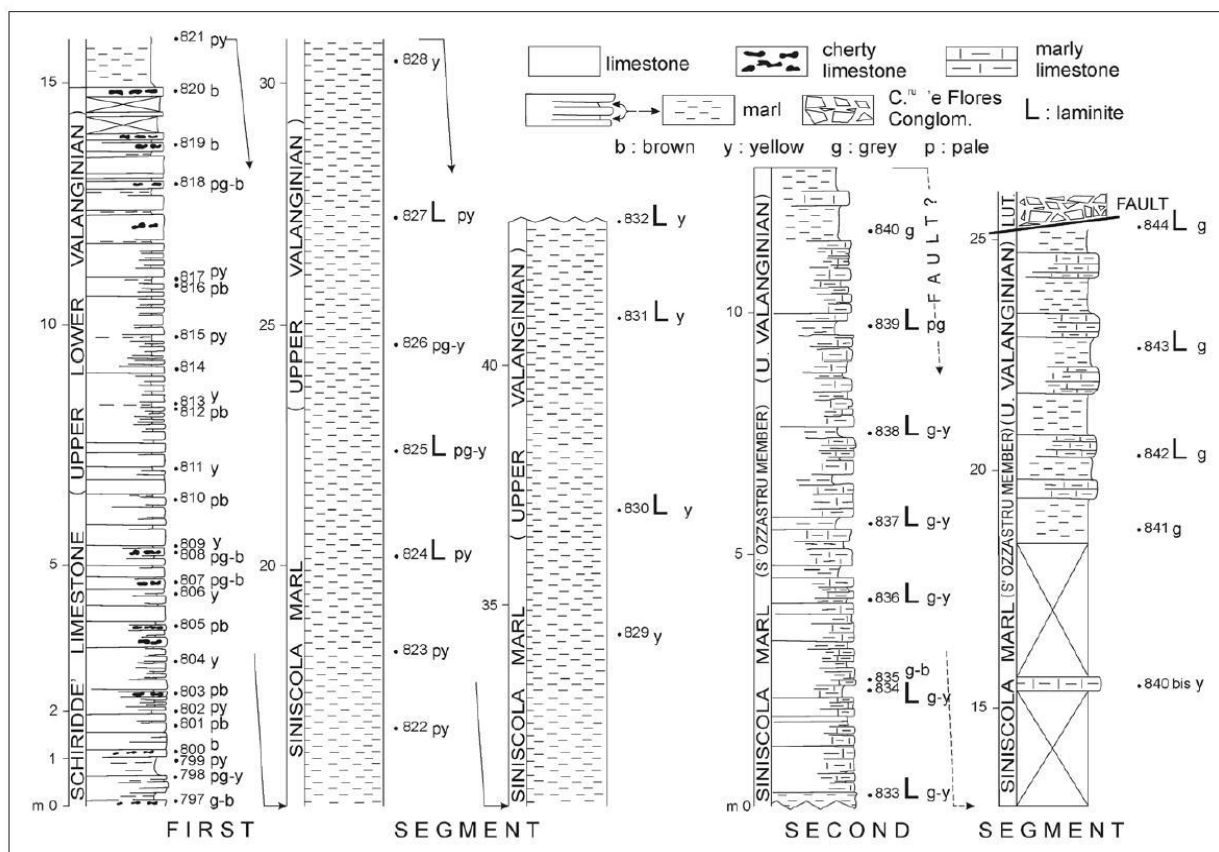


Fig. 3 Stratigraphic log of the Valanginian succession in the S'Ozzastru section. Numbers refer to the sampled horizons.

Neohaploceras sp. juv.?, *Olcostephanus* sp., and *Teschenites* cf. *teschenensis* (Uhlig, 1902). This assemblage indicates the Inostranzewi Zone of Reboulet et al. (2014) (= *Campylotoxus* Zone *auctt.*) of late early Valanginian age (see Bottini et al., 2018, and Reboulet et al., 2014, with references). The microfossil assemblages are very rich in sponge spicules, associated with radiolarians and sparse benthic foraminifers. For the overall lower Valanginian interval Dieni and Massari (in Bottini et al., 2018) proposed the formational name of "Schiriddè Limestone", with type-section in the S'Ozzastru area (Fig. 3). This interval grades into about 30 m thick grey marls with laminated, sapropel-like layers (upper part of the first segment of the log in Fig. 3, passing to alternating dark-grey marls and marly limestones (yellowish when weathered) rich in organic matter and again with laminated sapropel-like intervals (second segment of the log, 25 m thick; Fig. 3). For this complex Dieni and Massari (in Bottini et al., 2018) proposed the formational name of "Siniscola Marl", with type-section again in the S'Ozzastru area.

The second segment of the succession is separated in the log as a member, which has been named "S'Ozzastru Member". The estimated thickness of the Siniscola Marl is somewhat imprecise, due to the increasingly tectonized upper part of the succession, where the formation is in contact by fault with the middle Eocene Cuccuru'e Flores Conglomerate (Figs. 1, 2).

The first segment of the Siniscola Marl yielded some ammonites, among which *Neocomites neocomiensis* (d'Orbigny, 1841) and *Neocomites platycostatus* (Sayn,

1907) (fig. 7 of Bottini et al., 2018). Concerning the age assignment, *N. neocomiensis* is currently recorded from the uppermost part of the lower Valanginian (FOD in the Inostranzewi Zone) to the middle part of the upper Valanginian (LOD in the Peregrinus Zone, Nicklesi Subzone), and *N. platycostatus* from the upper part of the Inostranzewi Zone (FOD in the Platycostatus Subzone) to the Verrucosum Zone (LOD in the lower part of the Pronocostatum Subzone) (Reboulet & Atrops, 1999; Reboulet et al., 2014). Consequently, the more restricted biostratigraphic interval is given by the occurrence of *N. platycostatus*. In conclusion, the ammonite fauna, integrated with the nannofossil content (see below), suggests that the Siniscola Marl may be attributed to the lower part of the upper Valanginian (Verrucosum Zone).

The marls are intensely bioturbated, except in the finely laminated layers, and are particularly rich in very well preserved radiolarians and sponge spicules, locally iso-oriented (see Bottini et al., 2018, fig. 6b).

The specific characteristics of the Siniscola Marl, such as the abundance of siliceous organisms and presence of sapropel-like laminites, indicate a relatively deep, probably upper slope environment with episodes of high organic productivity and probably dys- to anaerobic conditions favouring silica preservation.

CALCAREOUS NANNOFOSSIL BIOSTRATIGRAPHY

According to the biostratigraphic scheme proposed by Roth (1978) and modified by Bralower et al. (1995), the only zonal marker species found in the S'Ozzastru

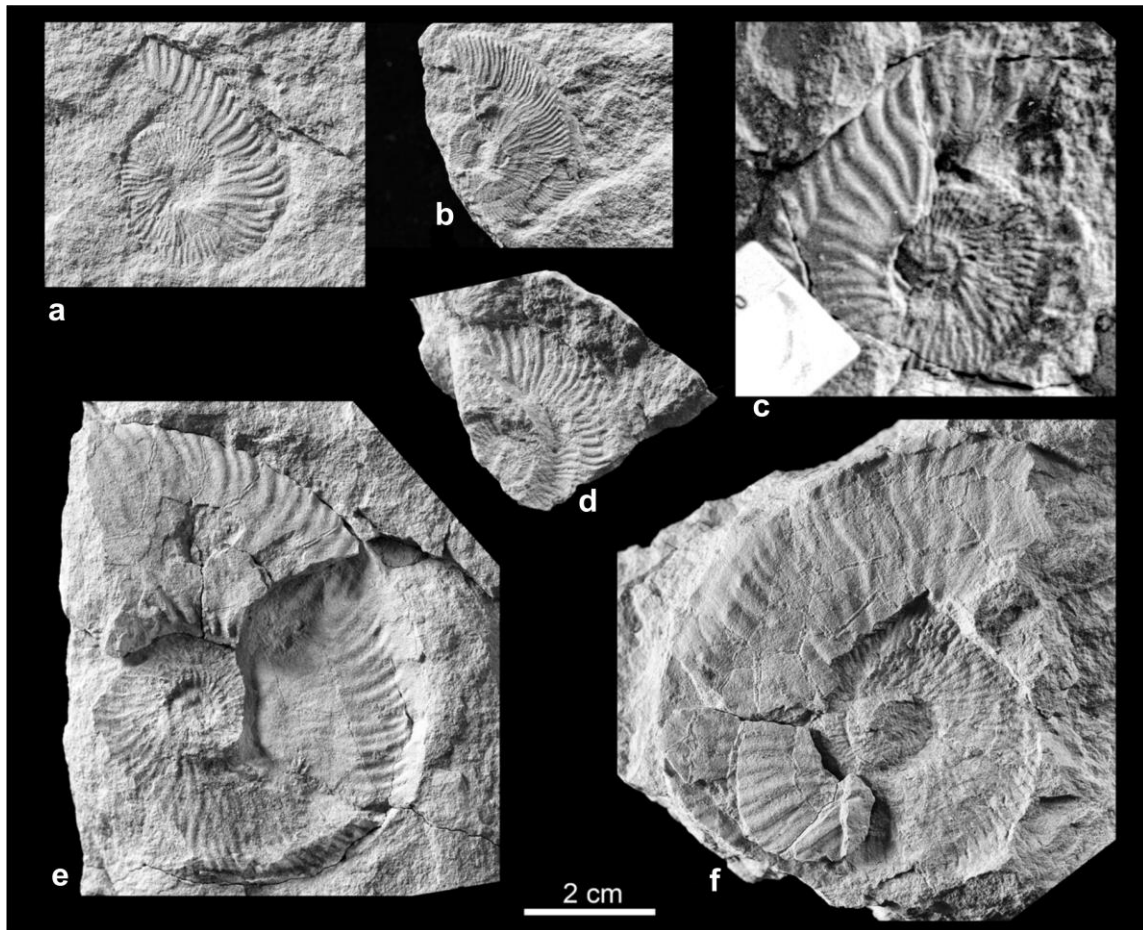


Fig. 4 Ammonites from the lower Upper Valanginian (Verrucosum Zone) (Siniscola Marl, S'Ozzastru area). **a, c, d** - *Neocomites platycostatus* Sayn, 1907 (MGP-PD 31531, 31534). **b, e, f** - *Neocomites neocomiensis* (d'Orbigny, 1841) (MGP-PD 31532, 31535, 31533). The specimens are housed and catalogued in the Geological and Palaeontological Museum of the Padova University (MGP-PD). (From Bottini et al., 2018).

section is *Calcicalathina oblongata* Thierstein, 1971 (identified from sample 821 up to the top of the section). The First Occurrence (FO) of this species defines the base of Zone NK3 in the early Valanginian and its extinction occurs at the end of the Hauterivian. *Tubodiscus verena* Thierstein, 1973, which has the FO in the middle Valanginian (basal part of Zone NK3) and the Last Occurrence (LO) in the latest Valanginian (marking the base of Zone NC4), was found very rare in sample 833. The stratigraphic position of *C. oblongata* and *T. verena* within the S'Ozzastru section indicates that the studied interval is comprised within the nannofossil Zone NK3. This interpretation is supported by the absence of *Nannoconus bucheri* Brönnimann, 1955, which is a relatively common low-latitude taxon and has its FO in the latest Valanginian-earliest Hauterivian (Zone NC4) above the LO of *T. verena* (Fig. 5). The nannofossil assemblages detected within the Siniscola Marl are thought to record the "nannoconid decline interval" (e.g., Erba et al., 2019). The taxonomic list of calcareous nannofossils present in the S'Ozzastru section and related figures are presented in Bottini et al. (2018).

STABLE ISOTOPE DATA

The S'Ozzastru section has been subjected to a chemostratigraphic analysis by measurement of the carbon

isotope values. According to the results presented in Bottini et al. (2018), the values range between -8.2% and $+2.98\%$ (Fig. 5). The C-isotope signal in the Schiriddè Limestone, altered by diagenesis, prevents the certain identification of the onset of the positive carbon isotope excursion (CIE) in the succession.

The positive CIE (from ca. 1 to 2.9 ‰) detected within the Siniscola Marl is interpreted to be indicative of the Weissert OAE CIE (Fig. 5). In the section the CIE corresponds to the nannofossil Zone NK3 and to the uppermost part of the ammonite Inostranzewi Zone and the Verrucosum Zone (Upper Valanginian). The end of the Weissert OAE CIE is not recorded because of the suppression of the upper part of the succession for tectonic causes (Figs. 1, 2).

ENVIRONMENTAL SETTING

In the S'Ozzastru section, the positive CIE (from ca. 1 to 2.9 ‰) detected within the Siniscola Marl is interpreted to be indicative of the Weissert OAE CIE (Fig. 5). Sedimentological information suggests that the change from the Berriasian "Purbeckian facies" to the lithology of the Valanginian Siniscola Marl reflects a significant environmental change. A first modification in depositional conditions with probable evidence of increased humidity combined with enhanced freshwater input occurred in the

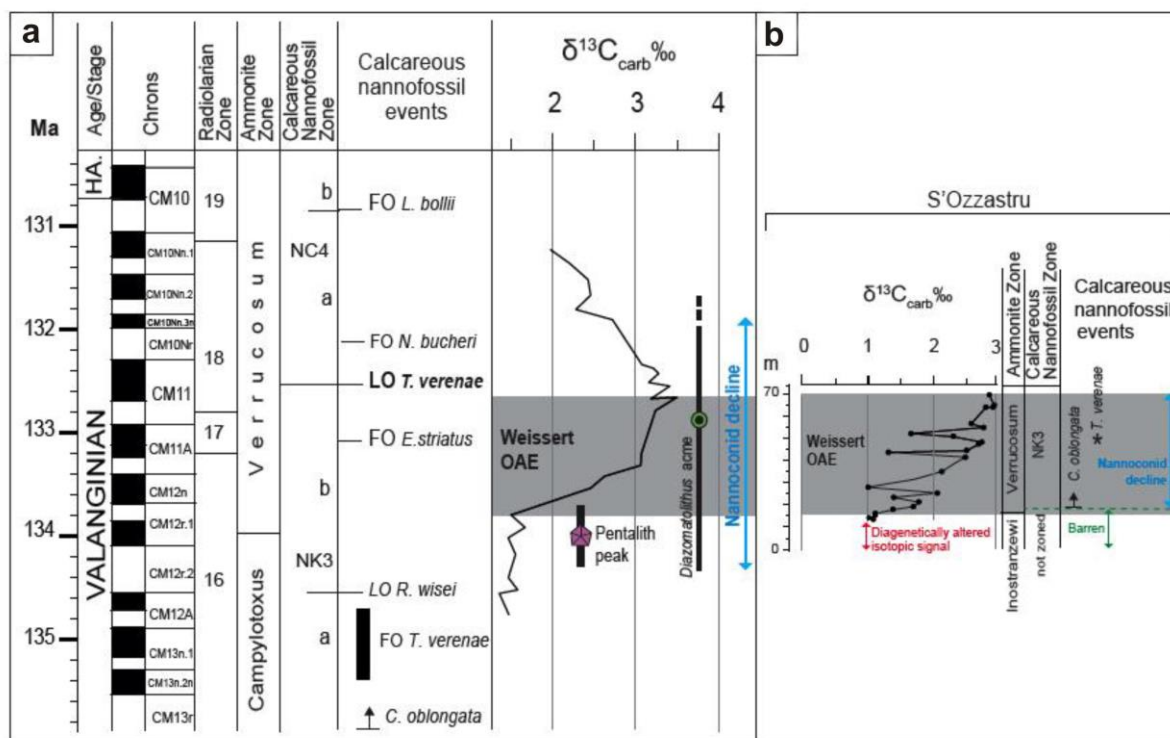


Fig. 5 a - Bio-chrono-magnetostratigraphic scheme of the Valanginian-early Hauterivian interval modified from Channell et al. (1995) and Weissert & Erba (2004). Numerical ages are based on time scales of Malinverno et al. (2012). Simplified C isotopic curve is after Weissert et al. (2008). Calcareous nannofossil zones after Bralower et al. (1995); **b** - Synthesis of S'Ozzastru section stratigraphic dataset (from Bottini et al., 2018). Note that the Campylotoxus Zone *auctt.* corresponds to the Inostranzewi Zone of Reboulet et al. (2014) and the "Nannoconid decline" is *sensu* Erba & Tremolada (2004).

"Purbeckian facies" interval. This fact, together with the first appearance of biosiliceous components (radiolarians and sponge spicules) in the lower Valanginian chert-bearing Schiriddè Limestone, and predominance of these components in the following Siniscola Marl, suggests that the Weissert Event was preceded by a phase of progressive change starting in the Berriasian and culminating in the late Valanginian. This indicates that the environmental change occurred in steps and that it began well before the positive CIE. As commonly observed elsewhere (e.g., Kuhn et al., 2005; Chatalov et al., 2015), palaeoenvironmental stress and biotic crisis led to the progressive decline and subsequent demise of the Tithonian-Berriasian carbonate factory, accompanied by a shift from protozoan to heterozoan communities.

The change of sedimentary regime at the transition from cherty limestones (Schiriddè Limestone) to marls (Siniscola Marl) in the S'Ozzastru section marks a significant increase in fine-grained terrigenous input, inferred to be driven by increased runoff and terrestrial weathering resulting in a change in the carbon cycle (e.g., Weissert, 1990). The particular abundance of biosiliceous component in the marls is thought to represent the consequence of enhanced fertility of marine waters by chemical weathering and continental runoff under humid climate conditions (Baumgartner, 2013; Celestino et al., 2017). The presence of layers characterized by sapropel-like fine lamination in the upper Valanginian marls (Fig. 3) probably indicates periodic anoxic conditions. However, it is surprising that, in spite of sapropel-like levels, no radiolarians were found preserved in pyrite.

RADIOLARIAN ASSEMBLAGES AND BIOSTRATIGRAPHY

This work is focused on the radiolarians occurring in the S'Ozzastru section cropping out in a quarry of the cement factory located near the village of Siniscola (province of Nuoro), in proximity of the northern termination of the Mt Albo massif (Fig. 1).

Field work included identification and characterization of the lithostratigraphical units, and sedimentological observations on a measured and sampled section (Figs. 1, 3). All the numbered horizons indicated in Fig. 3 have been studied according to their lithology either through thin-sections or washing and sieving. Furthermore, the S'Ozzastru section has been analyzed for its palaeontological content and for integrated litho-, bio-, and chemostratigraphy. All the studied materials (including thin sections and macro- and microfaunas) are housed and catalogued in the Geological and Palaeontological Museum of the University of Padova with the acronym MGP-PD. Siliceous microfossils (radiolarians and sponge spicules) have been extracted by using diluted hydrochloric acid (HCl), followed by boiling in water with very few H₂O₂ and Calgon to clean the specimens, washed under a sieve with 62 μm meshes and dried. From the dried residue the specimens have been picked under binocular microscope using a hair of a cat moustache. A variable number of specimens of each species recognized under this microscope have been mounted on a single stub (PD120) where the specimens have been arranged in

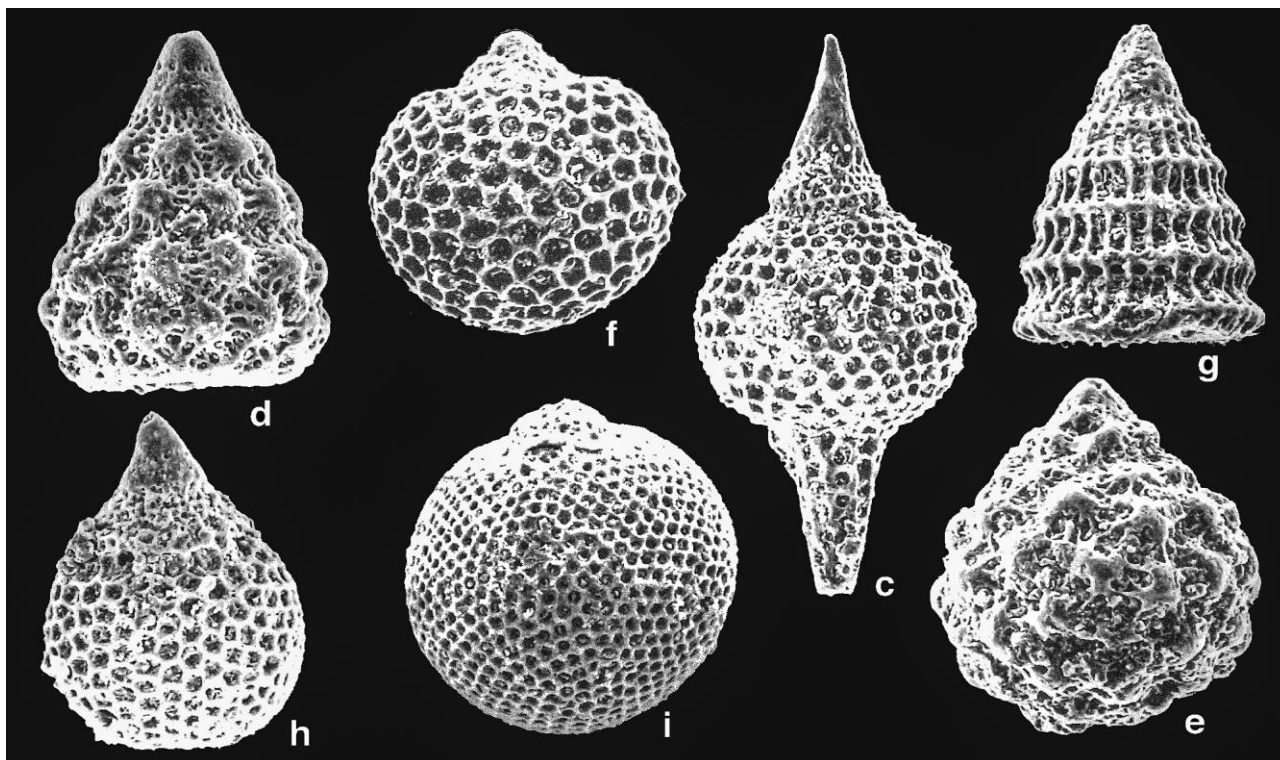


Fig. 6 Radiolarians illustrated by Dieni & Massari, 1991 in their Fig. 23c-i which correspond to the letters from that article: **c** - *Favosyringium affine* (Rüst), **d** - *Pseudoxitus seriola* - Dumitrică, **e** - *Williriedellum peterschmittae* Schaaf, **f** - *Cryptamphorella Dumitricăi* Schaaf, **g** - *Ristola nakatonbetsensis* Tumanda, **h** - *Crococapsa zweili* (Jud), **i** - *Cryptamphorella circumthoracica* Dumitrică n. sp., Fig. **c** x200, figs. **d-i** x250.

practically parallel rows, each row corresponding to a sample, and photographed under scanning electronic microscope. Each photo includes the sample number (OZ836, for instance), the row number (R01 to Rn), the specimen number along the rows (01 to n) and the magnification. When the same specimen was photographed in two or more positions its number is followed by a letter, for instance 10a, 10b etc. The best-preserved specimens from each species, holotypes and paratypes in the case of the new taxa, have been mounted on 10 plates (Figs. 7-16).

The investigated material will be housed and catalogued in the Geological and Palaeontological Museum of the University of Padova with the acronym MGP-PD, stub PD120. In the same collection and under the same acronym will be stored the cardboards with the radiolarians picked from the residues of radiolarian samples.

The first mention of some radiolarian species in the Valanginian of the S'Ozzastru section is due to Aita (in Dieni et al., 1987b, p. 148) who prepared a preliminary list of species published in the guide of an excursion in the Cretaceous of eastern Sardinia, including taxa not identified in the present work. Later, Dieni & Massari (1991, fig. 23 c-i), illustrated seven species which were preliminarily ascribed by Dumitrică (in Bottini et al., 2018) to *Podobursa* sp. (c), *Pseudoxitus omanensis* Dumitrică (d), *Williriedellum peterschmittae* Schaaf (e), *Cryptamphorella* cf. *conara* (Foreman) (f), *Pseudocrolanium puga* (Schaaf) (g), *Hiscocapsa zweili* (Jud) (h), and *Hemicryptocapsa* sp. (i). Their correct names are indicated in the chapter on the palaeontological part (Fig. 6) of the present study. As concerns the sponge spicules, very abun-

dant at some levels (see Bottini et al., 2018, fig. 6b), their study has been published in a separate paper in *Cretaceous Research* under the authorship of Magdalena Lukowiak et al., as mentioned in first chapter.

As the stratigraphic log of the deposits occurring in the S'Ozzastru quarry shows (Fig. 3), the succession comprises the Schiriddè Limestone (samples OZ797- OZ820) (upper lower Valanginian), Siniscola Marl (821-832) (upper Valanginian), including in the upper part the S'Ozzastru Member (833-844). For the present radiolarian study a number of 19 samples have been selected from the whole section (see Table 1). The table with the distribution of the species and their abundance shows that in the Schiriddè Limestone radiolarians are scarce, become common or very abundant in the Siniscola Marl (824-829), very rare in 831, common again in the S'Ozzastru Member (834-840) and again sparse in the last samples (841, 844). The list of species identified under the binocular microscope is incomplete, as some very small species are difficult to recognize; these species have been determined or described only after detailed morphological analysis in SEM microscopy, allowing for example to identify the type of pores, presence or absence of apertures and their types (distal or sutural pore), details of superficial structures, etc. The same problems of complete registration can happen in the case of rare species, when the assemblage is very poor: a species can be present in an assemblage but absent in a small sample, as is the case of the samples from the S'Ozzastru section. For these reasons, the occurrence of species in the examined section is primarily based on the specimens illustrated with SEM micrographs and completed with specimens

Table 1

Species	Samples																		
	806	811	813	817	824	825	826	827	829	831	833	834	836	837	838	839	840	841	844
<i>Alievium eurasicum</i> Dumitrica n.sp.						X													
<i>Alievium incomptum</i> Dumitrica n.sp.						X													
<i>Alievium regulare</i> Wu & Li													X						
<i>Alievium rotundum</i> Dumitrica n.sp.												X	X						
<i>Alievium</i> sp. 1						X				X	X								
<i>Amphipyndax zybrevi</i> Dumitrica n.sp.						X													
<i>Apiaromira apiarium</i> (Rüst)				X		X	X	X	X	X	X	X			X				X
<i>Apiaromitra tyaughtonensis</i> (Cordey)	X									X			X						
<i>Arcanicapsa (?) alieviana</i> Dumitrica n.sp.						X								X					
<i>Arcanicapsa simplicissima</i> Dumitrica n.sp.													X						
<i>Archaeodictyomitra conica</i> (Aliev)																	X		
<i>Archaeodictyomitra conicoscalaris</i> Dumitrica																	X		
<i>Archaeodictyomitra dienii</i> Dumitrica n.sp.												X	X						
<i>Archaeodictyomitra ellipsoidalis</i> Dumitrica n.sp.			X						X							X			
<i>Archaeodictyomitra excellens</i> (Tan)											X					X			
<i>Archaeodictyomitra humerosa</i> Dumitrica n.sp.				X	X		X	X	X	X			X	X					X
<i>Archaeodictyomitra inflata</i> Dumitrica n.sp.												X							
<i>Archaeodictyomitra judae</i> Dumitrica n.sp.															X	X			
<i>Archaeodictyomitra longipora</i> Dumitrica n.sp.													X						
<i>Archaeodictyomitra massarii</i> Dumitrica n.sp.				X	X					X	X				X				
<i>Archaeodictyomitra pumila</i> Dumitrica n.sp.											X								
<i>Archaeodictyomitra robustovum</i> Dumitrica n.sp.														X					
<i>Becus coronatus</i> Dumitrica n.sp.																X			
<i>Becus triangulocentrum</i> Dumitrica			X	X	X				X										
<i>Campanomitra pulchella</i> (Rüst)																X			
<i>Crococapsa cf. horocanaiensis</i> (Kawabata)												X							
<i>Crococapsa uterculus</i> (Parona)				X	X	X	X			X	X	X							X
<i>Crococapsa zweilii</i> (Jud)						X	X					X							
<i>Cryptamphorella circumthoracica</i> Dumitrica n.sp.																X			
<i>Cryptamphorella cordiforma</i> Dumitrica n.sp.															X				
<i>Cryptamphorella dumitricai</i> Schaaf	X			X					X	X	X	X	X	X	X	X	X		
<i>Cryptamphorella crassilabrosa</i> Dumitrica n.sp.															X				
<i>Doliocapsa erbae</i> Dumitrica n.sp.												X							
<i>Doliocapsa favopora</i> Dumitrica n.sp.												X							
<i>Doliocapsa mediterranea</i> Dumitrica n.sp.												X							
<i>Doliocapsa utoi</i> Dumitrica n.sp.					X														
<i>Doliocapsa weisserti</i> Dumitrica n.sp.												X							
<i>Emiluvia chica</i> Foreman						X						X	X						
<i>Eucyrtidiellum sardoum</i> Dumitrica n.sp.						X					X	X	X		X	X			
<i>Favosyringium affine</i> (Rüst)												X							
<i>Favosyringium cf. affine</i> (Rüst)																X			
<i>Favosyringium quadriculeatum</i> Steiger															X				
<i>Godia (?) lens</i> Dumitrica n.sp.						X													
<i>Godia (?) lenticulata</i> Dumitrica n.sp.												X							
<i>Gongylothorax</i> sp.												X							
<i>Gongylothorax oculoporus</i> Dumitrica n.sp.					X	X													
<i>Gongylothorax werbeeki</i> (Tan)					X														

<i>Hemicryptocapsa (?) bellireticulum</i> (Wu &)					X	X							X	X			
<i>Hemicryptocapsa capita</i> Tan	X			X	X		X	X	X	X	X	X	X	X	X	X	
<i>Hiscocapsa aitai</i> Dumitrica n.sp.				X													
<i>Hiscocapsa grutterinki</i> (Tan)									X					X			
<i>Hiscocapsa lagunculoides</i> Dumitrica n.sp.									X				X				
<i>Hiscocapsa rugosacutis</i> Dumitrica n.sp.							X										
<i>Hiiscocapsa tuberculata</i> Dumitrica n.sp.							X										
<i>Hiscocapsa ventriosa</i> Dumitrica n. sp.										X				X			
<i>Kozurium hindei</i> (Tan)				X	X				X	X	X	X	X	X	X	X	X
<i>Loopus nudus</i> (Schaaf)				X					X				X				
<i>Loopus cf. primitivus</i> (Matsuoka & Yao)									X								
<i>Microsandwichia plana</i> (Hori)									X								
<i>Mictyoditra thiensis</i> (Tan)										X							
<i>Novixitus quadripartitus</i> Dumitrica n.sp.									X	X							
<i>Novixitus robustus</i> Wu				X	X		X	X		X							
<i>Ocellicapsa ruthae</i> Dumitrica n.sp.				X	X				X	X	X	X					
<i>Pantanellium squinaboli</i> (Tan)										X						X	
<i>Pantanellium cf. squinaboli</i> (Tan)										X							
<i>Pantanellium</i> sp. 1					X												
<i>Pantanellium</i> sp. 2										X							
<i>Praeconocaryomma copiosa</i> Wu					X				X	X		X					
<i>Praeconocaryomma thurowi</i> Dumitrica n.sp.							X										
<i>Praeconosphaera antiqua</i> (Parona)				X	X				X	X			X				
<i>Praeconosphaera sphaeroconus</i> (Rüst)				X	X		X			X							
<i>Pseudodictyomitra cf. carpatica</i> (Lozynyak)				X						X							
<i>Pseudodictyomitra (?) irregularis</i> Dumitrica n.sp.										X	X						
<i>Pseudodictyomitra nodocostata</i> Dumitrica				X											X		
<i>Pseudoxitus laguncula</i> Dumitrica n.sp.										X			X	X			
<i>Pseudoxitus seriola</i> Dumitrica	X			X		X	X	X	X	X			X	X	X		
<i>Pseudoxitus wui</i> Dumitrica n.sp.													X				
<i>Squinabolum elegans</i> Dumitrica n.sp.				X	X	X			X	X							
<i>Squinabolum cf. elegans</i> Dumitrica n.sp.						X											
<i>Svinitium depressum</i> (Baumgartner)	X			X	X		X	X	X	X	X	X	X	X	X	X	X
<i>Tethysetta cingulifera</i> Dumitrica												X	X	X			
<i>Tethysetta reducta</i> Dumitrica n.sp.												X	X				
<i>Tethysetta ovoidalis</i> Dumitrica n.sp.										X							
<i>Tethysetta usotanensis</i> (Tumanda)										X	X						
<i>Thanarla minuta</i> Dumitrica n.sp.										X							
<i>Thanarla pulchra</i> (Squinabol)				X	X		X		X	X	X				X		X
<i>Thanarla cf. pulchra</i> (Squinabol)						X				X	X						
<i>Triactoma tithonianum</i> Rüst					X					X							
<i>Trirabs ewingi</i> (Pessagno)											X						
<i>Williriedellum buekkense</i> (Kozur)				X										X			
<i>Williriedellum occultithorax</i> Dumitrica n.sp.						X											
<i>Williriedellum cordiforme</i> Dumitrica n.sp.												X					
<i>Williriedellum gilkei</i> Dumitrica													X				
<i>Williriedellum labeosum</i> Dumitrica n.sp.										X		X	X				
<i>Williriedellum peterschmittae</i> Schaaf												X					
<i>Xitus vermiculatus</i> (Renz)									X				X				
<i>Zhamoidellum ovum</i> Dumitrica														X			

recognized under binocular at a magnification of maximum x200.

Generally, the radiolarian assemblages from S'Ozzastru section are very little diversified by comparison with the assemblages recorded in the Western Tethys at the levels of the Valanginian and Lower Hauterivian (Jud, 1994; Baumgartner et al., 1995; Dumitrică, 1995). The studied assemblages are, for example, very poor in species of many genera and families, especially of flat Spumellaria with 3 or 4 arms, and also of Nassellaria, most taxa being cryptothoracic nassellarians that, by their spherical or subspherical shape, give the impression of a fauna consisting of spherical spumellarians when the magnification is not too high.

In this situation, a biostratigraphical study and zonation based on radiolarian assemblages of the S'Ozzastru section are difficult because most species used for the definition of the Unitary Association Zones (UAZ) of the Lower Cretaceous have been defined in the Western Tethys (Jud, 1994; Dumitrică-Jud, 1995; Baumgartner et al., 1995; Dumitrică, 1995) are missing in the assemblages of the section. For example, worth mentioning is the lack of the pantanelliid species *Cecrops septemporatus* (Parona, 1890), a cosmopolitan species and marker of the upper Valanginian according to Pessagno (1977b), which is rather common in the Western Tethysian fauna studied by Jud (1994) and in the pyritized fauna from the Valanginian and lower Hauterivian from Svinița, Romania (Dumitrică, 1995) and in the Pacific region with shallow water masses within a mesopelagic depth (Cui et al., 2022). Its absence should be done to special paleoecological conditions for the radiolarian fauna in the Sozastru area.

Because of these reasons, the S'Ozzastru section cannot, unfortunately, be ascribed to the UA radiolarian zones proposed by Baumgartner et al., (1995), because of the absence of the marker species. However, the presence of *Hemicryptocapsa capita* Tan Sin Hok, 1927, an easily recognizable taxon, whose occurrence is currently reported in the UAZ 17-18 indicates the upper Valanginian – lowermost Hauterivian. This radiolarian species is recorded in almost all samples from the section, except for the two uppermost ones, probably because of the scarcity of their radiolarian assemblages.

Although the Valanginian radiolarians of the S'Ozzastru section are very well preserved, many specimens show dissolution or break of some parts of shell as, for instance, apical parts of cephalis of many conical nassellarians (Figs. 11d, f, I, k, l, n, o; 12r; 13g, j, h, m-p, t; 14b, f, l, k, n; 15a-e, i, j, l, n; 16e), spines of pantanelliids (Fig. 7j-o) and *Emiluvia* (Fig. 7f-h), arms of larger three-armed spumellaria (Fig. 7e) etc. The cryptothoracic or cryptocephalic nassellarians, whose shape is practically spherical or subspherical, do not seem to be touched by these phenomena. These facts are in agreement with the presence of bottom current activity suggested by the local lamination and iso-orientation of elongate sponge spicules (Bottini et al., 2018, fig. 6).

Given the very good preservation of the studied radiolarians and the scarce literature data on Lower Cretaceous assemblages, this article is primary focused on their detailed taxonomic study, which resulted particularly in the proposal of one new family, two new genera and 42 new species.

COMPARISON OF THE VALANGINIAN RADIO-LARIAN FAUNA FROM SARDINIA WITH OTHER FAUNAS

As remarked above, the Valanginian radiolarian fauna from the S'Ozzastru section, although rich at some levels, is less diversified by comparison with other faunas from Western Tethys, as for example those studied by Jud (1994) from the Maiolica of Umbria-Marche (Italy) and other areas and Dumitrică (1995) from the Murguceva Formation from Svinița, Romania. It contains, especially, cryptothoracic Nassellaria and related taxa, few archaeodictyomitrids, parvicingulids, xitids and others, and very rare Spumellaria, all very well preserved. The fauna from Umbria-Marche is rather diversified (see Jud, 1994) and preserved in crystallized silica. The fauna from the Murguceva Formation is also very diversified and very well preserved in pyrite.

It is interesting that the fauna from S'Ozzastru section contains many species in common with the Valanginian sample YK546 from the Yokonami Mélange of Shimanto Belt, Shikoku, Japan, illustrated by Okamura & Uto (1982). This resemblance would suggest wide connections with the Eastern Tethys and a rather similar ecosystem.

TAXONOMY

Class Radiolaria Müller, 1858

Subclass Polycystinea Ehrenberg, 1839, emend. Riedel, 1967

Order Spumellaria Ehrenberg, 1875

Family **Parvivaccidae** Pessagno & Yang, 1989, emend. Dumitrică & Caulet, in De Wever et al. (2001)

Subfamily Acaeniotylinae Yang, 1993

Type genus: *Acaeniotyle* Foreman, 1973, emend. Yang, 1993

Genus ***Praeconosphaera*** Yang, 1993

Type species: *Conosphaera sphaeroconus* Rüst, 1898.

Praeconosphaera sphaeroconus (Rüst, 1898)

Fig. 7a

1898 *Conosphaera sphaeroconus* Rüst, p. 13-14, pl. 4, fig. 8.

1973 Actinomids, gen. and sp. indet. – Foreman, p. 272, pl. 1, figs. 4, 6.

1986 *Praeconocaryomma globosa* Wu, p. 357, pl. 1, figs. 15, 19.

1993 *Praeconosphaera sphaeroconus* (Rüst) – Yang, p. 105, pl. 17, figs. 2, 6, 12, 16, 23.

1997 *Praeconosphaera sphaeroconus* (Rüst) – Dumitrică et al., p. 21, pl. 3, fig. 3.

Remarks. The species is well recognizable by its bigger size and cupola-shaped or hemispherical tubercles, each tubercle rounded and with one or two pores on the top, and also with thicker intervening bars as compared with the intervening bars in the intertuberculate areas. Although no microsphere was remarked until present in this species, it should have existed because other members of the family Acaeniotylidae have it.

Range and occurrence: Lower Tithonian to Hauterivian, cosmopolitan.

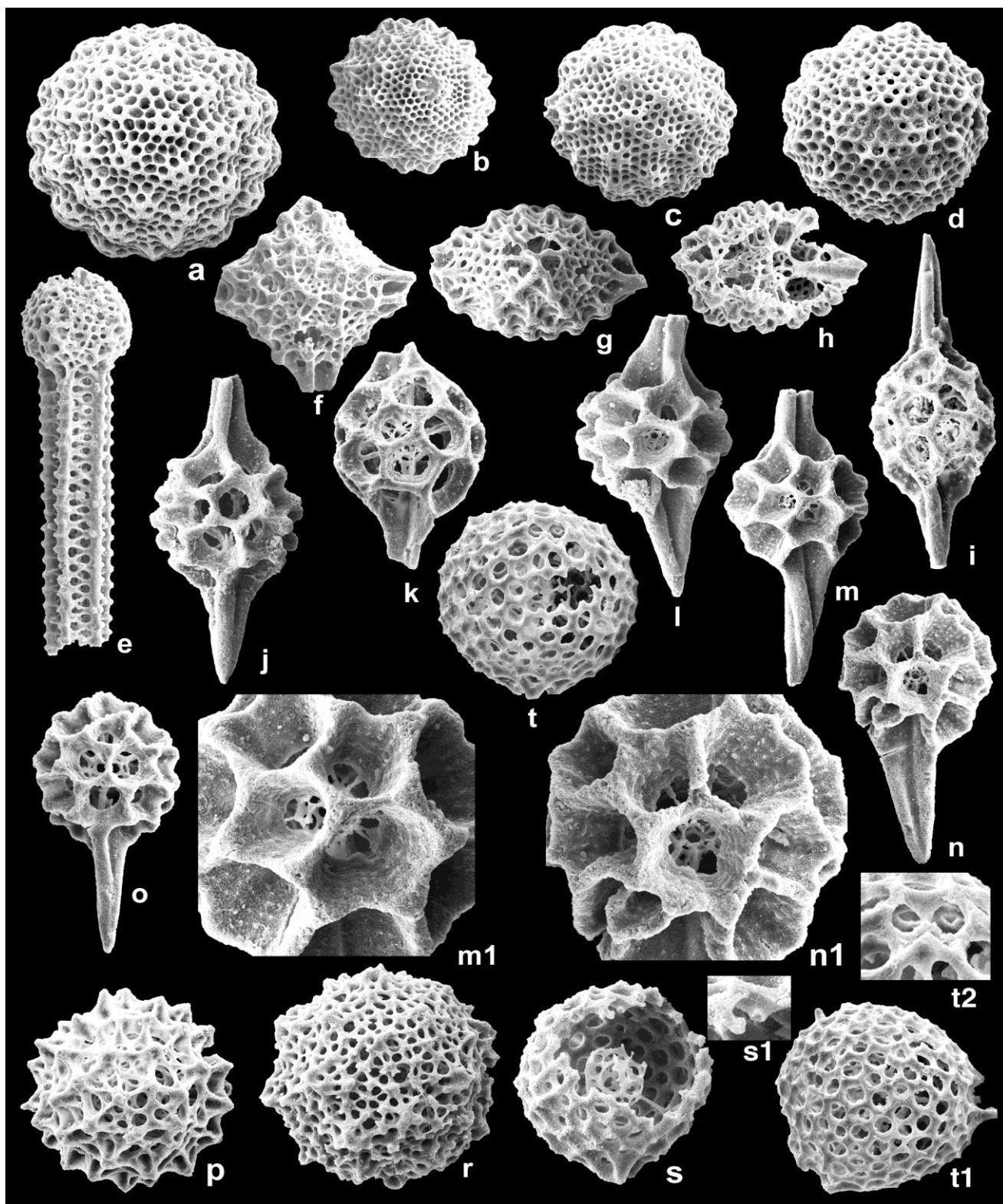


Fig. 7 a - *Praeconosphaera sphaeroconus* (Rüst OZ826. b-d - *Praeconosphaera antiqua* (Parona): b - OZ834, c - OZ838, d - OZ825. e - *Tritrabs ewingi* (Pessagno), arm in lateral view, OZ836. f-h - *Emiluvia chica* Foreman, OZ836; f - face view, g - lateral view from a spine, h - lateral view of a broken specimen showing the medullary test. i - *Pantanellium* sp. 1, OZ825. j, l-n1 - *Pantanellium squinaboli* (Tan): j - OZ834; l, m - OZ834, n - OZ836; m1, n1, details of inner wall of pores. k - *Pantanellium* sp. 2, OZ834. o - *Pantanellium* cf. *squinaboli* (Tan), OZ836; p - *Praeconocaryomma copiosa* Wu, OZ836. r - *Praeconocaryomma thurovi* Dumitrică n. sp., OZ836. s, t - *Triactoma tithonianum* Rüst, side views; s - OZ834, broken off specimen showing medullary shell; t - OZ825, equatorial view, t1 - face view; s1, t2 - detail of the base of spines of figs. s and t, respectively, x800. Figs. a-h, l-n x200; i-k, o-r x300; s, t x400, m1, n1 x500.

Praeconosphaera antiqua (Parona, 1890)

Figs. 7b-d

1890 *Conosphaera antiqua* Parona, p. 149, pl. 1, fig. 10.

1973 Actinommids, gen. and sp. indet. – Foreman, p. 272, pl. 1, figs. 3, 4, 6.

1982 *Praeconocaryomma* sp. – Okamura & Uto, pl. 4, fig. 1, not 2.?1993 *Praeconosphaera multiconus* Yang, p. 104, pl. 17, figs. 8, 20.*Description.* Cortical shell spherical, tuberculate, tubercles rounded pyramidal.*Studied material.* Three specimens in samples PD120-OZ825-R12-19, PD120-OZ834-R09-26 and PD120-OZ838-R05-13.*Dimensions.* Diameter of shell 165-185 µm.*Remarks.* Although generally it is not easy to assign specimens illustrated under scanning electron microscope to species illustrated in thin sections by Rüst (1898), Parona (1890) and others, it seems that the specimens shown in the three figures represent the species illustrated by Parona from Cittiglio, Lombardy, Italy. This species differs from *Praeconosphaera sphaeroconus* (Rüst, 1898) by being smaller and, especially, by having less rounded tubercles, and their top with intervening bars, which are also of the same thickness as those of the intertuberculate areas.*Range and occurrence.* Tithonian to Valanginian or younger, Tethys.Family **Tritrabiidae** Baumgartner, 1980

Subfamily Tritrabinae Baumgartner, 1980

Genus **Titrabs** Baumgartner, 1980Type species. *Paronaella* (?) *casmaliaensis* Pessagno, 1977.*Remarks.* The Tritrabide, as most spumellarian radiolarians, are extremely rare in the Sardinian fauna, the only specimen found is the illustrated fragment of an arm.***Titrabs ewingi*** (Pessagno, 1971)

Fig. 7e

1971 ?*Paronaella ewingi* Pessagno, p. 47, pl. 19, figs. 2-5.1980 *Paronella* (?) *ewingi* Pessagno – Holzer, p. 159, pl. 1, fig. 15, non 16 and 17 = *Archaeotitrabs gracilis* Steiger 1992).1980 *Titrabs ewingi* (Pessagno) – Baumgartner, p. 293, pl. 4, figs 5, 7, 17, 18.1986 *Titrabs worzeli* (Pessagno) – De Wever et al., pl. 8, fig. 9, not 8.1984 *Titrabs ewingi* (Pessagno) – Baumgartner, p. 791, pl. 10, fig. 10.1994 *Titrabs ewingi* (Pessagno – Jud, p. 116, pl. 23, figs. 12, 13.1995 *Titrabs ewingi worzeli* (Pessagno) – Baumgartner et al., p. 608, pl. 3115, figs. 1, 2, p. 609.2017 *Titrabs ewingi* (Pessagno) – Xu & Luo, figs. 3R, 3Z.*Studied material.* A single fragment of an arm in PD120-OZ836-R07-07.*Remarks.* The illustrated fragment and a few other smaller remains of arms are the only representative not only of this species but also of the whole family Tritrabiidae inthe upper Valanginian section from Sardinia. This species is extremely rare and difficult to separate from *Titrabs worzeli* (Pessagno) when the ray tips are not very well preserved, as is the case of this specimen.*Range and occurrence.* Late Bajocian to late Barremian or early Aptian.Family **Hagiastridae** Riedel, 1971

Subfamily Emiluviinae Dumitrică, 1995

Type genus: *Emiluvia* Foreman, 1973Genus **Emiluvia** Foreman, 1973Type species. *Emiluvia chica* Foreman, 1973***Emiluvia chica*** Foreman, 1973, emend. Pessagno, 1977a
Figs. 7f-h1973 *Emiluvia chica* Foreman, p. 262, pl. 8, fig. 7.1975 *Emiluvia chica* Foreman – Foreman, p. 612, pl. 5, figs. 12, 13.1977a *Emiluvia chica* Foreman – Pessagno, p. 76, pl. 4, figs. 11-13.1984 *Emiluvia chica* Foreman – Ozvoldova & Sykora, p. 264, pl. 4, figs. 1-3.1986 *Emiluvia chica* Foreman – De Wever et al., pl. 4, fig. 4.1987 *Emiluvia chica* Foreman – Kito, pl. 1, fig. 2.1987 *Emiluvia chica* Foreman – Ozvoldova & Petercakova, p. 119, pl. 32, figs. 3, 4.1992 *Emiluvia tecta* Steiger, p. 54, pl. 15, figs. 3-11.1994 *Emiluvia chica decussata* Steiger – Jud, p. 76, pl. 9, figs. 12-14.1995 *Emiluvia chica* s.l. Foreman – Baumgartner et al., p. 198, pl. 3213, fig. 3.1995 *Emiluvia chica decussata* Steiger – Baumgartner et al., p. 198, pl. 5132, figs. 1-81997 *Emiluvia chica* Foreman – Dumitrică et al., p. 27, pl. 3, fig. 10.2017 *Emiluvia chica* Foreman – Xu & Luo, fig. 3Y, ?3X.2017 *Emiluvia* sp. 2 – Xu & Luo, fig. 3O.*Studied material.* Three broken specimens in the stub PD120-OZ836-R07-19, PD120-OZ836-R08-14 and PD120-OZ838-R04-05.*Dimensions.* Length of square sides 130 µm, thickness of shell 120 µm.*Remarks:* Although the spines are not preserved, the morphology of the central shell and the age of the fauna prove undoubtedly that the illustrated specimens belong to this species.*Range and occurrence.* Late Tithonian to earliest Hauterivian, Tethys.Family **Pantanelliidae** Pessagno, 1977b, emend. Pessagno & Blome, 1980

Subfamily Pantanelliinae Pessagno, 1977b

Type genus. *Pantanellium* Pessagno, 1977a*Remarks.* The pantanelliids are rare and always incomplete in the S'Ozzastru samples, being only represented by a few specimens of the genus *Pantanellium*. Because of this scarcity a detailed taxonomic study of the species occurring in this fauna is difficult to do.Genus **Pantanellium** Pessagno, 1977aType species. *Pantanellium riedeli* Pessagno, 1977a

Pantanellium squinaboli (Tan, 1927)

Figs. 7j, l-n1

1927 *Stylosphaera squinaboli* Tan, p. 35, pl. 6, figs. 9a-d.1981 *Sphaerostylus lanceola* (Parona, 1890) group – Schaaf, p. 438, pl. 7, fig. 6; pl. 16, figs. 5-a-b.1981 *Sphaerostylus lanceola* (Parona) – Kanie et al., pl. 1, fig. 6.1994 *Pantanellium squinaboli* (Tan) – Jud, p. 90, pl. 15, figs. 10-12.1995 *Pantanellium squinaboli* (Tan) part. – Baumgartner et al., p. 372, pl. 5067, figs. 1, 2, 4, not 3, 5-7.1997b *Pantanellium corriganensis* Pessagno, p. 33, pl. 3, figs. 5, 6.2014 *Pantanellium squinaboli* Tan – Robertson et al., fig. 10(B), 2.2017 *Pantanellium squinaboli* Tan – Xu & Luo, figs. 3 P, Q.**Dimensions.** Diameter 122-135µm, length without spines 130-150 µm, length of spines 75-100 µm.**Remarks.** What is very characteristic of this species in the S'Ozzastru fauna, besides its general morphology with wide pores, nodes at vertices and a very thick cortical shell, is the ornamentation of the internal faces of pores, which have numerous tiny pustules disposed in radial and circular rows (Figs. 7m1, 7n1). These pustules are nothing else than remains of a dense spongy meshwork that infilled the pore cavities and the surface of the cortical shell. Such a spongy meshwork is common in an unpublished pantanellid species occurring in the very well-preserved lower Tithonian radiolarian fauna of the sample Mo 22 from the Solnhofen area partly published by Zügel (1997), Dumitrică & Zügel (1998, 2003, 2008) and Dumitrică (2013a, 2013b). In the Solnhofen species, this spongy meshwork, when very well preserved, is so thick that the species determination is almost impossible.**Range and occurrence.** Tithonian to late Barremian.***Pantanellium* cf. *squinaboli*** (Tan, 1927)

Fig. 7o

2014 *Pantanelium masirahense* Dumitrică gr. – Robertson et al., Fig. 10(B), 13, non 12, 14).**Remarks.** This species differs from *P. squinaboli* (Tan) by having a spherical, smaller and thinner shell, and also thinner spines.**Dimensions.** Diameter 83 µm, length of the preserved spine 65 µm.**Occurrence.** A single specimen in sample OZ836.***Pantanellium* sp. 1**

Fig. 7i

1885 *Xiphosphaera* cf. *tredecimporata* Rüst, p. 288, pl. 27, fig. 15.?1974 *Sphaerostylus lanceola* Parona (ancestral form) – Riedel & Sanfilippo, p. 780, pl.1, fig. 4; pl. 12, fig. 1.?1997 *Pantanellium tredecimporatum* (Rüst) – Dumitrică et al., p. 20, pl. 1, figs. 18, 24.**Dimensions.** Diameter of shell 70 µm, length of shell without spines 93 µm, length of spines 50-70 µm.**Remarks.** This species differs from the other two species occurring in the fauna herein studied by having a long ellipsoidal shape with wide pores and relatively thin cortical shell. Its spines are pointed, unequal in length and have relatively thick blades. The species resembles ratherwell the specimens determined as *Pantanellium tredecimporatum* (Rüst) illustrated by Dumitrică et al. (1997) from samples of the Masirah Island, Oman, considered as being Berriasian in age.**Occurrence.** A single specimen in the sample OZ825.***Pantanellium* sp. 2**

Fig. 7k

Remarks. This specimen differs from the other specimens herein illustrated in having a smooth surface, no nodes at frame vertices, a smaller wall thickness, a slightly ellipsoidal shell, and spines with rather thin blades. Also, pore frames are slightly thickened on the external border of shell and the centre of the vertices of the pore frames are depressed, forming small cavities. Inner surface of pores contains also remains of a spongy framework, but they are less common and irregularly disposed. Although the spines are broken off, one can see that their blades are thin and their length does not seem to be bigger than the length of the spines of the other species occurring in this assemblage.**Dimensions.** Diameter 86 µm, length 100 µm.**Occurrence:** A single specimen in the sample OZ834.Family **Xiphostylidae** Haeckel 1881, emend. Pessagno & Yang, 1989Genus **Triactoma** Rüst 1885, p. 289Type species. *Triactoma tithonianum* Rüst, 1885***Triactoma tithonianum*** Rüst, 1885

Fig. 7s, s1, t, t1, t2

Selective synonymy due to absence of spines:

1885 *Triactoma tithonianum* Rüst, p. 289, pl. 28, fig. 5.1973 *Triactoma tithonianum* Rüst - Foreman, p. 289, pl. 2, fig. 1.1986 *Triactoma* sp. C – Aita & Okada, p. 122, pl. 1, fig. 4.1994 *Triactoma tithonianum* Rüst – Jud, p. 115, pl. 23, figs. 11, non 10.1995 *Triactoma tithonianum* Rüst – Baumgartner et al., p. 592, pl. 3097, figs. 1-3.**Description.** Skeleton double shelled, spherical externally to slightly rounded triangular in face view bearing 3 three-bladed spines of unknown length and morphology. Pores circular and polygonally (hexagonally to pentagonally) framed on surface. Medullary shell double consisting of a small spherical microsphere with a few pores and a concentric and smooth outer medullary shell with circular or subcircular pores, both closely interconnected by simple or forked radial bars. Medullary shell interconnected to cortical shell by a few very thin radial bars, no one (it seems) aligned with the external spines.**Studied material.** Two partly broken specimens: one in PD120-OZ834-R10-13 (fig. 7s), the other one in PD120-OZ825-R12-09 (7t).**Dimensions.** Diameter of cortical shell of both specimens 85 µm, of medullary shell 29 µm.**Remarks.** The two illustrated specimens seem to belong indubitably to this species in spite of the absence of the three spines. Interesting is the presence of a double medullary skeleton, although the diagnosis of the genus *Triactoma* and the family to which it has been assigned (Pessagno et al., 1989, p. 202) mentions that the skeleton

consists only of a cortical shell. However, Dumitrică (in De Wever et al., 2001, fig. 63.2) mentioned and illustrated internal centripetally directed radial bars aligned with the spines, which he considered as remains of a medullary shell. This shell, as seen in *T. tithonianum* would differ from that of the Middle Jurassic species by not being connected with the cortical shell by rays aligned with spines. Outer medullary shell is connected with the cortical one by a very small number (5-6 probably) of thin radial bars, no one extended outside. Cortical shell is spherical or very slightly rounded triangular in face view. Pores are circular or subcircular and polygonally framed, but frames are not of equal thickness in radial direction. Tops of them are irregular, some of them may be higher and slightly protruding. Base of spines is reinforced by an inner triradial support structure rotated 30° around the axis of spines relative to the blade of spines (Figs. 7sa, ta). Such a structure is not rare in Spumellaria and Entactinaria radiolarians (Dumitrică, 2013b, p. 85) but its morphology is variable.

Range. UAZones 6-22 (mid Bathonian to late Barremian – early Aptian)

Family **Praeconocaryommidae** Pessagno, 1976

Type genus. *Praeconocaryomma* Pessagno, 1976

Genus ***Praeconocaryomma*** Pessagno, 1976

Type species. *Praeconocaryomma universa* Pessagno, 1976

Praeconocaryomma copiosa Wu, 1986

Fig. 7p

1986 *Praeconocaryomma copiosa* Wu, p. 357, pl. 2, figs. 18, 23.

Description. Shell small, spherical with characteristic praeconocaryommid structure and pointed pyramidal tubercles. From each tubercle radiate usually 5 rays. Network rather loose with relatively wide rounded triangular, quadrangular or pentagonal meshes.

Studied material. A single specimen in sample OZ836, coll. MGP-PD, stub PD120-OZ836-R07-23.

Dimensions. Diameter 120 µm.

Remarks. Species very rare. The specimen resembles perfectly the holotype from probably Aptian of Tibet.

Range and occurrence. Probably Aptian of Tibet and upper Valanginian of Sardinia.

Praeconocaryomma thurowi Dumitrică n. sp.

Fig. 7r

1982 *Praeconocaryomma* sp. – Okamura & Uto, pl. 4, fig. 1, non 2.

1988 *Conocaryomma* sp. A (cf. *Praeconocaryomma* sp. A in Pessagno 1977b – Thurow, p. 399, pl. 9, fig. 5.

Description. Shell spherical with characteristic triangular meshes. Meshes small and nodes of the network are usually small and only some are higher developing a beginning of three-bladed spines marked by three-bladed pyramidal elevation. Number of layers difficult to establish, visible being only two or three externalmost layers.

Studied material. One specimen in Sardinia section (the holotype), plus the specimen illustrated by Thurow.

Holotype. Figure 7r, coll. MGP-PD, stub PD120-OZ836-R08-27.

Dimensions. Diameter 107-133 µm.

Etymology. The species is dedicated to J. Thurow who illustrated a rather similar specimen from the Hauterivian-lower Aptian radiolarian assemblages of North Atlantic. Similar specimens were also illustrated from the Lower Cretaceous sequence of chert in the Yokonamy Mélange of the Shimanto Belt, Japan.

Remarks. This taxon differs from *Praeconocaryomma copiosa* Wu by smaller size of the triangular meshes of the cortical shell and by development of some very short three-bladed elevations as bases of eventual short spines.

Range and occurrence. Very rare in the upper Valanginian of Sardinia and in the probably upper Valanginian from Japan and upper Hauterivian-lower Aptian of North Atlantic area according to Thurow (1988).

Family **Pseudoaulophacidae** Riedel, 1967, emend. Dumitrică, 1997

Type genus. *Pseudoaulophacus* Pessagno 1963

Genus ***Alievium*** Pessagno, 1972

Type species. *Theodiscus superbus* Squinabol, 1914, p. 271, pl. 20 (1), fig. 4

Alievium eurasicum Dumitrică n. sp.

Fig. 8p

1982 *Alievium* sp. – Okamura & Uto, pl. 5, fig. 10.

Description. Shell lenticular in lateral view and triangular with unequal sides in face view with three long primary spines with circular cross section. Surface of shell with numerous small triangular meshes with small nodes at cross meeting points of the network. Scattered on the surface there are also some rare bigger nodes.

Studied material. A single specimen in sample OZ825.

Holotype. Fig. 8p, coll. MGP-PD, stub PD120-OZ825-R12-11.

Dimensions. Height 135-136 µm.

Remarks. This species, of which we have only the illustrated specimen with the three spines broken off, seems to be close to the early Cenomanian *Alievium antiquum* Pessagno by having the same morphology, with very small and irregularly arranged triangular meshes and many superficial nodes. However, it differs from Pessagno's species by having some bigger nodes prolonged into very short spines and the three main spines are conical instead of three-bladed. The remain of one spine of the holotype proves that its section is circular similar to the specimen from Japan. By having three conical spines and some bigger nodes irregularly scattered on the surface of shell, it resembles perfectly the specimen illustrated by Okamura & Uto (1982) from the Lower Cretaceous sequence of chert in the Yokonami Mélange of Shimanto Belt, Shikoku, Japan.

This species differs especially from the other species of the Lower Cretaceous genus *Alievium* by having non-bladed primars spines.

Etymology. From its occurrence in Europe and Asia.

Range and occurrence. Very rarely in the upper Valanginian of Sardinia and Japan.

Alievium incomptum Dumitrică n. sp.

Fig. 8m

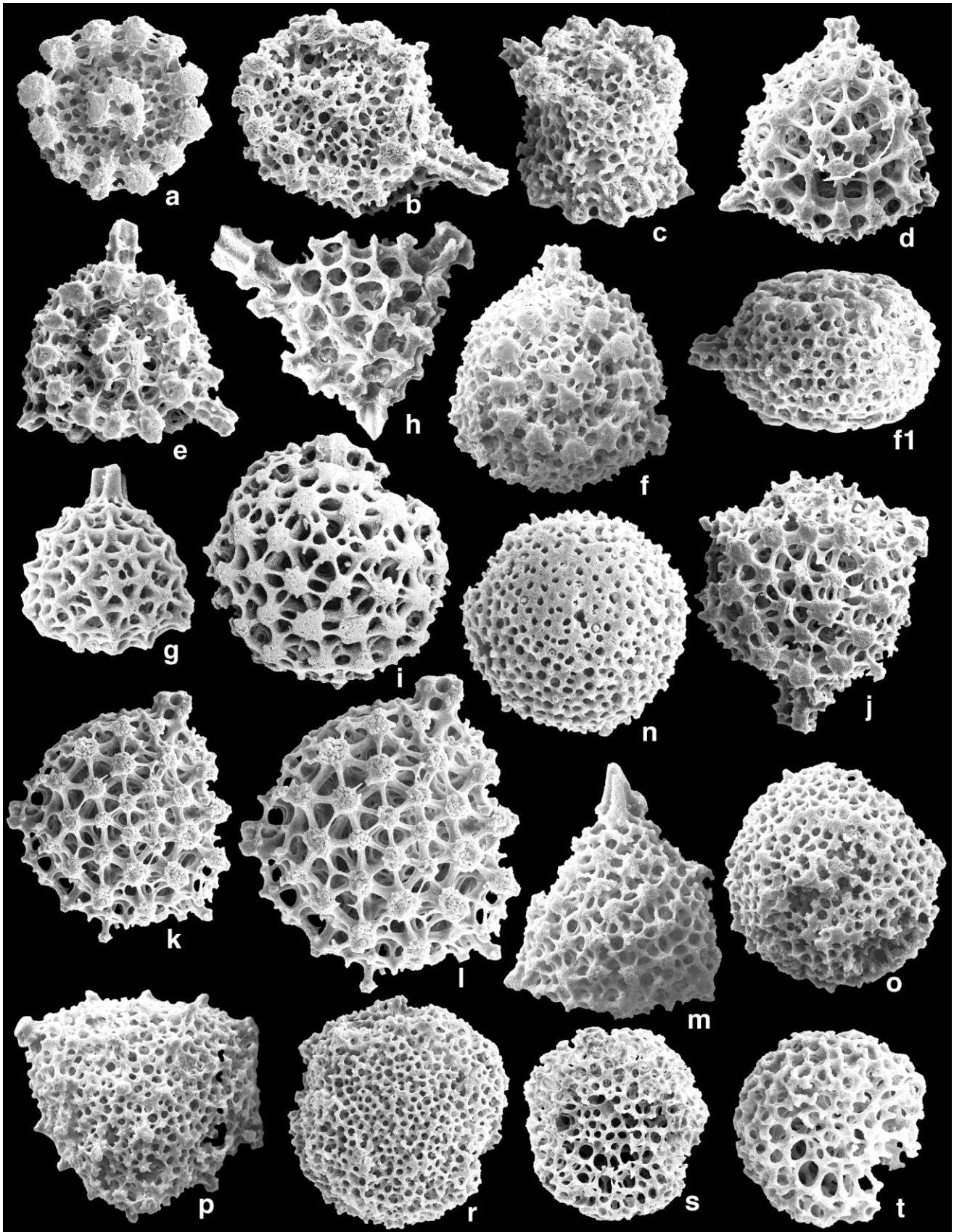


Fig. 8. **a** - *Becus coronatus* Dumitrică n. sp., OZ839. **b-f1, j** - *Becus triangulocentrum* Dumitrică, **b** - OZ836; **c** - same, lateral view, **d** - OZ836. **e, f** - OZ825, **f1** - lateral view of fig. **f**. **g** - *Alievium regulare* (Wu & Li), OZ836. **h, i, k, l** - *Alievium rotundum* Dumitrică n. sp.: **h**, specimen destroyed showing internal structure, OZ836; **i** - OZ836, **k, l** - holotype, OZ834. **m** - *Alievium incomptum* Dumitrică n. sp., OZ836. **n** - *Godia* (?) *lenticulata* Dumitrică n. sp., OZ834. **o** - *Godia* (?) *lens* Dumitrică n. sp., OZ825. **p** - *Alievium eurasicum* Dumitrică n. sp., OZ825. **r** - *Microsandwichia plana* (Hori), OZ834. **s, t** - Spumellarian gen. et sp. indet., OZ834. figs. **c, e-h, k, m, r, t** x250, figs. **a, b, d, i, j, l, p, s** x300; figs. **n, o, t** x400.

Description. Shell lenticular, triangular with short three-bladed spines at corners and slightly convex sides. Surface with well marked nodes interconnected by a network of thin bars forming triangular, quadrangular or irregular meshes, but not regular triangular ones, characteristic of other species.

Material. A single specimen, the holotype.

Holotype. Fig. 8m, sample OZ836, coll. MGP-PD, stub PD120-OZ836-R07-26.

Dimensions. Height of triangle 140-156 µm, maximum length of spines 40 µm.

Etymology. From the Latin *incomptus*, *-a*, *-um* – rough, due to its rough aspect.

Remarks. This species, represented only by the illustrated specimen, resembles *Alievium antiguum* Pessagno in shape and size, from which it differs by having the meshwork much larger, irregular and not consisting of only triangular meshes.

Occurrence. Found only in the cited sample.

Alievium regulare (Wu & Li, 1982)

Figs. 8g

1973 *Alievium* sp. – Foreman, p. 262, pl. 9, figs. 1, 2.

1977b *Alievium* sp. A – Pessagno, p. 29, pl. 3, figs. 10, 18.

1980 *Alievium helenae* Schaaf – Baumgartner et al., p. 49, pl. 1, fig. 8.

1981 *Alievium helenae* Schaaf, p. 431, pl. 7, fig. 9, non pl. 10, figs. 2a-b (holotype).

1981 *Alievium helenae* Schaaf – Kocher, p. 53, pl. 12, fig. 6.

1981 *Alievium* sp. A. – Kanie et al., pl. 1, fig. 4

1982 *Praeconocaryomma regularis* Wu & Li, p. 65, pl. 1, figs. 2, 3.

1982 *Alievium* sp. A – Okamura & Uto, pl. 4, fig. 7; pl. 5, fig. 20.

1982 *Alievium* sp. – Okamura & Uto, pl. 6, figs. 13, 16.

1982 *Alievium* sp. – Matsuyama et al., p. 377, pl. 1, fig. 8.

1983 *Alievium helenae* Schaaf – Origlia-Devos, p. 114, pl. 13, fig. 6, non 7, 10.

1984 *Alievium helenae* Schaaf – Schaaf, p. 112-113, figs. 1-3, non h (holotype).

1984 *Alievium helenae* Schaaf – Baumgartner, p. 755, pl. 1, figs. 8-10.

1988 *Alievium helenae* Schaaf – Thurow, p. 397, pl. 9, fig. 9.

1989 *Alievium helenae* Schaaf – Tumanda, p. 34, pl. 1, fig. 9.

1992 *Alievium helenae* Schaaf – Ozvoldova & Petercaková, pl. 2, figs. 2, 7.

1992 *Alievium helenae* Schaaf – Steiger, p. 36, pl. 4, figs. 5, 6.

1992 *Alievium helenae* Schaaf – Matsuoka, p. 209, pl. 1, fig. 2.

1993 *Alievium helenae* Schaaf – Wu, p. 118, pl. 1, fig. 14.

1994 *Alievium helenae* Schaaf – Jud, p. 61, pl. 3, fig. 1.

1994 *Alievium helenae* Schaaf – O'Dogherty, p. 316, pl. 58, fig. 2.

1995 *Alievium helenae* Schaaf – Baumgartner et al., p. 80, pl. 3228, figs. 1, 3, 4, non 2 and 5.

1997 *Alievium regulare* (Wu & Li) – Dumitrică in Dumitrică et al., p. 79, pl. 2, fig. 7.

2009 *Alievium regulare* (Wu & Li) – Ishii et al., p. 341, pl. 4, fig. 1.

2014 *Alievium regulare* (Wu & Li) – Robertson et al., fig. 10(B), 7.

2017 *Alievium regulare* (Wu & Li) – Xu & Luo, fig. 3J, ?3K.

2017 *Alievium regulare* (Wu & Li) – Wu et al., p. 347, figs. 1.8-10.

Dimensions. Height of triangle 96 µm.

Remarks. This species, as it is understood in the present paper (see synonymy), is polymorphous. Under its name, several morphotypes seem to be comprised. The simplest specimen is the one herein illustrated on Fig. 8g, with its small shell, small tubercles and no spines on tubercles. Being so simple, it is, probably, a young specimen. Other specimens mentioned in the synonymy list have bigger or very big tubercles prolonged or not into spines of very variable length. These specimens seem to represent different ontogenetic stages, although it is also possible to represent local variations. To solve this problem, we need rich assemblages with rather well-preserved specimens as those studied by Dumitrică (1997).

Range and occurrence. Tithonian to Hauterivian or later, cosmopolitan.

Alievium rotundum Dumitrică n. sp.

Fig. 8h, i, k, l

Description. Shell circular or subcircular in face view with 3 three-bladed equatorial spines of unknown length. Structurally, shell consists exclusively of an equal triangular meshwork of thin bars interconnecting relatively thick nodes. Usually this triangular meshwork is complicated by development of very thin bars interconnecting the primary bars. Nodes not prolonged into spines but arranged in commonly straight parallel rows, the maximum number of nodes on rows varying between 6-7.

Studied materials. Eight specimens.

Holotype. Figure 8 k, l, coll. MGP-PD, stub PD120-OZ834-R10-28.

Dimensions. Diameter of shell 160-200 µm.

Etymology. From the Latin *rotundus*, *-a*, *-um* – round, circular.

Remarks. This species is the most common pseudoaulophacid in the Valanginian radiolarian fauna from Sardinia. It differs from *Alievium regulare*, as it is understood in the present article, by having larger size, more shell layers and by not having spines originated on tubercles. Fig. 8h is a broken specimen of probably *A. rotundum* showing the internal skeleton.

Occurrence. Upper Valanginian in Sardinia so far as known.

Genus *Becus* Wu, 1986

Type species. *Becus gemmatus* Wu, 1986.

Remarks. The genus was amply discussed by Dumitrică (1997, p. 214). According to him, *Becus* differs from *Alievium* Pessagno 1972, by having two types of superficial structures: a central one with a certain number of nodes in a rather constant dispositions (a central group and a peripheral circle of nodes), as external expression of the central internal structure, and a spongy peripheral one without nodes or with small ones consisting of a spongy

meshwork that can be easily dissolved during fossilization, in which case only the central part is preserved. Moreover, the nodes are not connected to one another by a single bar forming a meshwork of coarse triangular meshes as in *Alievium*, but by several interconnecting bars forming a relatively dense and irregular meshwork. By its morphology, *Becus* looks like a primitive *Pseudoaulophacus* Pessagno, 1963, from which it differs by having in the central part a tholus of nodes instead of a massive triangular network. In the S'Ozzastru section most specimens of this genus are partly dissolved so that description and determination are usually difficult.

***Becus coronatus* Dumitrică n. sp.**

Fig. 8a

Description. Shell drum-shaped in lateral view, circular in face view, with three closely interconnected central nodes and 12 nodes disposed in a peripheral circle. Peripheral nodes interconnected by 2-4 thin bars. Space between central and peripheral nodes depressionary with irregularly disposed polygonal meshes representing the surface of the spongy skeleton of the species.

Studied material. A single specimen in OZ839.

Holotype. Fig. 8a, coll. MGP-PD, stub PD120-OZ839-R01-01.

Dimensions. Diameter 110-120 µm.

Etymology. From the Latin *coronatus*, -a, -um = crowned.

Remarks. By its shape, this species resembles *Becus rotula* Dumitrică, 1997, from which it differs by having a circle of 12 nodes instead of 9, three central nodes instead of one, and by lacking the three primary spines. Its superficial ornamentation with 12 peripheral nodes suggests that it originates in *Becus triangulocentrum* Dumitrică, 1997, in a similar mode as *Becus rotula*, that is by the dissolution of the peripheral spongy test and of the spines. It is surprising that the holotype does not conserve any trace of primary spines, which are robust in *B. triangulocentrum*. It differs also from *B. triangulocentrum* by having very robust nodes. It is possible that this species represents, in fact, skeletal remains of well silicified specimens of *B. triangulocentrum* with dissolved superficial lateral skeleton.

Range and occurrence. Late Valanginian, S'Ozzastru section, Sardinia so far as known.

***Becus triangulocentrum* Dumitrică, 1997**

Figs. 8b-f1, j

1995 *Alievium helenae* Schaaf – Baumgartner et al., p. 80, pl. 3228, fig. 2, non 1-4.

1997 *Becus triangulocentrum* Dumitrică, p. 216, pl. 1, figs. 8, 9; pl. 2, figs 1, 2-4, ?5, ?6.

1997 *Becus triangulocentrum* Dumitrică – Dumitrică et al., p. 216, pl. 1, figs. 8, 9; pl. 2, figs. 1, 2-4, ?5, ?6.

2017 *Praeconocaryomma mammillaria* (Rüst) – Wu et al., p. 347, pl. 1, figs. 11, 12.

Remarks. Unlike the original types of the species (Dumitrică, 1997), the specimens from the S'Ozzastru section assigned to this species seem to exhibit a wider variability. The variability is mostly a result of the dissolution of the thin skeletal elements of the shell and also of some or all primary spines that seem to have a fragile root, so that many specimens are preserved just as circular disks without any remains of spines or with some remains (Figs. 8b,

8c). *Praeconocaryomma mammillaria* of Wu et al. (2017) is wrongly determined; it is not spherical as *Praeconocaryomma*, but lens-shaped with spongy lateral sides. Its face view exhibits very clearly the central triangle of nodes surrounded by a circle of 12 nodes. Fig. 8d, that shows very well the triangular meshwork is probably a young specimen that could not yet cover the initial structure.

Range and occurrence. Common in the Berriasian and Valanginian and sparse in the lower Hauterivian.

Genus *Godia* Wu 1986

Type species. *Godia floreusa* Wu 1986

Remarks. The following two species are questionally assigned to the genus *Godia* Wu described as having a lenticular circular shell with short peripheral spines. Although this genus was considered of Cenomanian age, all species illustrated in Wu (1986) are of Lower Cretaceous age (Valanginian to Aptian).

***Godia* (?) *lens* Dumitrică n. sp.**

Figs. 8o

Description. Shell lens-shaped, circular in face view, without equatorial spines. Skeleton apparently consists of many concentric layers, each layer with small nodes interconnected by thin bars forming a star-like structure with triangular meshes. On the central part of the holotype there is an irregular circle of slightly bigger nodes and in its centre a few much bigger nodes.

Studied material. Only the illustrated specimen.

Holotype. Fig. 8o, OZ825, coll. MGP-PD, stub PD120-OZ825-R12-16.

Dimensions. Diameter 102 µm.

Etymology. From the Latin word *lens* = lens.

Remarks. *Godia* (?) *lens* Dumitrică n. sp. differs from the other species of this genus by having on all parts of shell a pseudoaulophacid structure, no equatorial spines and no peripheral irregular spongy skeleton, all its surface consisting of regular and small triangular meshes of relatively equal sizes.

Occurrence. Only in the upper Valanginian of the S'Ozzastru section.

***Godia* (?) *lenticulata* Dumitrică n. sp.**

Fig. 8n

Description. Shell lenticular, circular in face view, probably consisting of many layers. External layer with small pores of different sizes and shape, and thickness of intervening bars also very different giving here and there the impression of forming imperfect triangular meshes as in the pseudoaulophacidae. Equatorial border of shell serrate.

Studied material. A single specimen in OZ834.

Holotype. Fig. 8n, coll. MGP-PD, stub PD120-OZ834-R09-18.

Dimensions. Diameter of shell 103 µm.

Remarks. This specimen differs from *Godia* (?) *lens* Dumitrică n. sp. by being perfectly lenticular, and by having very sparse triangular meshes and no circle of nodes. It differs also by having the structure with triangular meshes covered by a layer with circular pores especially on the central part.

Occurrence. Only in the mentioned sample.

Spumellaria incertae family

Genus *Microsandwichia* Dumitrică n. gen.

Type species: *Orbiculiforma* (?) *plana* Hori 1999

Diagnosis. Spongy flat circular skeleton consisting of two parallel cortical plates that can easily shift to one another during fossilization due probably to the very fine spongy skeleton between them.

Etymology. From its resemblance to a micro sandwich.

Remarks. According to its spongy skeleton, this radiolarian genus can not be an orbiculiformid. The Orbiculiformidae, as they have been used until present, represent a polyphyletic Jurassic and Cretaceous morphological group with a *Crucella*-type type species. The *Microsandwichia* seems to be a genus with a thin and completely spongy skeleton between the two faces occurring in the Upper Jurassic (Oxfordian of Carpathians to Tithonian of Japan and Tibet) and lower Cretaceous (upper Valanginian) of Sardinia, as the present specimen proves.

Microsandwichia plana (Hori 1999)

Fig. 8r

1999 *Orbiculiforma* (?) *plana* Hori, p. 62, figs. 4. 17-20.

Description. Shell flat, thin and circular, each face with dense and small circular pores arranged in different short parallel rows. Border without spines. The two faces slightly displaced from one another.

Studied material. A single specimen in sample OZ834, coll. MGP-PD, stub PD120-OZ834-R09-31.

Dimensions. Diameter of shell 165 µm.

Remarks. The specimen found in the upper Valanginian of Sozastru section resembles perfectly the Tithonian specimens illustrated by Hori (1999) from the Yamizo Mountains of central Japan.

Occurrence. Tithonian of Japan, late Valanginian of Sardinia.

Spumellaria gen et sp. indet.

Fig. 8s, t

Remarks. Although the two lenticular specimens seem to be similar, their determination is impossible. No species of this type was illustrated until present.

Order *Nassellaria* Ehrenberg, 1875

Family *Eucyrtidiellidae* Takemura, 1986

Type genus: *Eucyrtidiellum* Baumgartner, 1984

Genus *Eucyrtidiellum* Baumgartner, 1984

Type species: *Eucyrtidium* (?) *unumaensis* Yao, 1979

Remarks. According to the most recent data (O'Dogherty et al., 2009) the genus and the family itself became extinct in the latest Tithonian, the last species being *Eucyrtidiellum pyramis* (Aita, 1986) (Baumgartner et al., 1995). The new species, *Eucyrtidiellum sardoum* Dumitrică n. sp., that occurs throughout the studied section, proves the widened range of the genus, which to date was not known in the Berriasian and Valanginian.

Range: Early Jurassic to late Valanginian.

Eucyrtidiellum sardoum Dumitrică n. sp.

Figs. 9a, a1, b

Description. Shell conical of three segments separated by rather well marked constrictions. Cephalis smooth subglobular or conical with a very short apical spine and a

visible ventral pore at the boundary with thorax. Thorax poreless, truncate conical and smooth or with up to 14 longitudinal costae on half the perimeter. Costae very slightly visible to well developed. Abdomen globular, poreless except for distal part, and smooth, or with 6-12 longitudinal costae, usually developed on its proximal half. Lumbar constriction marked by 6-12 pores on half the diameter. Distal end of abdomen with a circular band of pores arranged usually in two irregular circles one of which is external, on the lateral part of the abdomen, and the other one on the base of this segment. Distal part of abdomen planiform, with a large circular aperture. Post-abdominal segment not preserved.

Studied material. Several tens of specimens, 6 of them photographed.

Holotype. Fig. 9a, coll. MGP-PD, stub PD120-OZ836-R08-15.

Paratype. Fig. 9b, coll. MGP-PD, stub PD120-OZ839-R02-13.

Dimensions. Total length of shell 100-114 µm, of abdomen 58-77 µm, diameter of abdomen 77-87.5 µm.

Etymology. From the Latin *sardous*, -a, -um = Sardinian.

Remarks. This new species differs significantly from the other species so far described, but shares some characters from other Upper Jurassic species as for instance: its abdominal costae resemble partly those of *E. ptyctum* (Riedel and Sanfilippo, 1974) from which they differ in being usually present only on the proximal part, and its thorax has costae somewhat similar to those of the thorax of *E. pyramis* (Aita, 1986), from which they differ in being more delicate and denser. These characters would suggest that *E. sardoum* n. sp. originates from *E. pyramis*, the upper Tithonian and youngest species so far as known and the only one that has costate thorax and abdomen, and a conical cephalis. What we don't know yet is the time of transition between these two species.

Range and occurrence. Late Valanginian so far as known but, since the last species of the genus was recorded in the latest Tithonian, its FAD should be in Berriasian.

Family *Gongylothoracidae* Bak, 1999

Genus *Gongylothorax* Foreman, 1968

Type species: *Dicolocapsa verbeeki* Tan Sin Hok, 1927

Range. Middle Jurassic, or older, to Maastrichtian.

Gongylothorax oculoporus Dumitrică n. sp.

Figs. 9f-f2

1981 ?*Gongylothorax verbeeki* (Tan Sin Hok) – Schaaf, p. 434, pl. 1, figs. 1a, b; pl. 9, figs. 9a, b.

Description. Shell dicyrtid, small and globular with a small cephalis partly sunk in the thorax so that what one can see is its rounded apical part. Thorax globular with a small circular distal aperture (fig. f2). No sutural pore could be seen, so that we do not know whether it is missing or, most probably, situated on the opposite side. Pores very small with double layers (Fig. f1): an inner layer with very small circular pores and an outer layer with larger cylindrical diameter. Pores arranged in curved rows. Surface rather smooth as the polygonal interporal frames are not sharp.

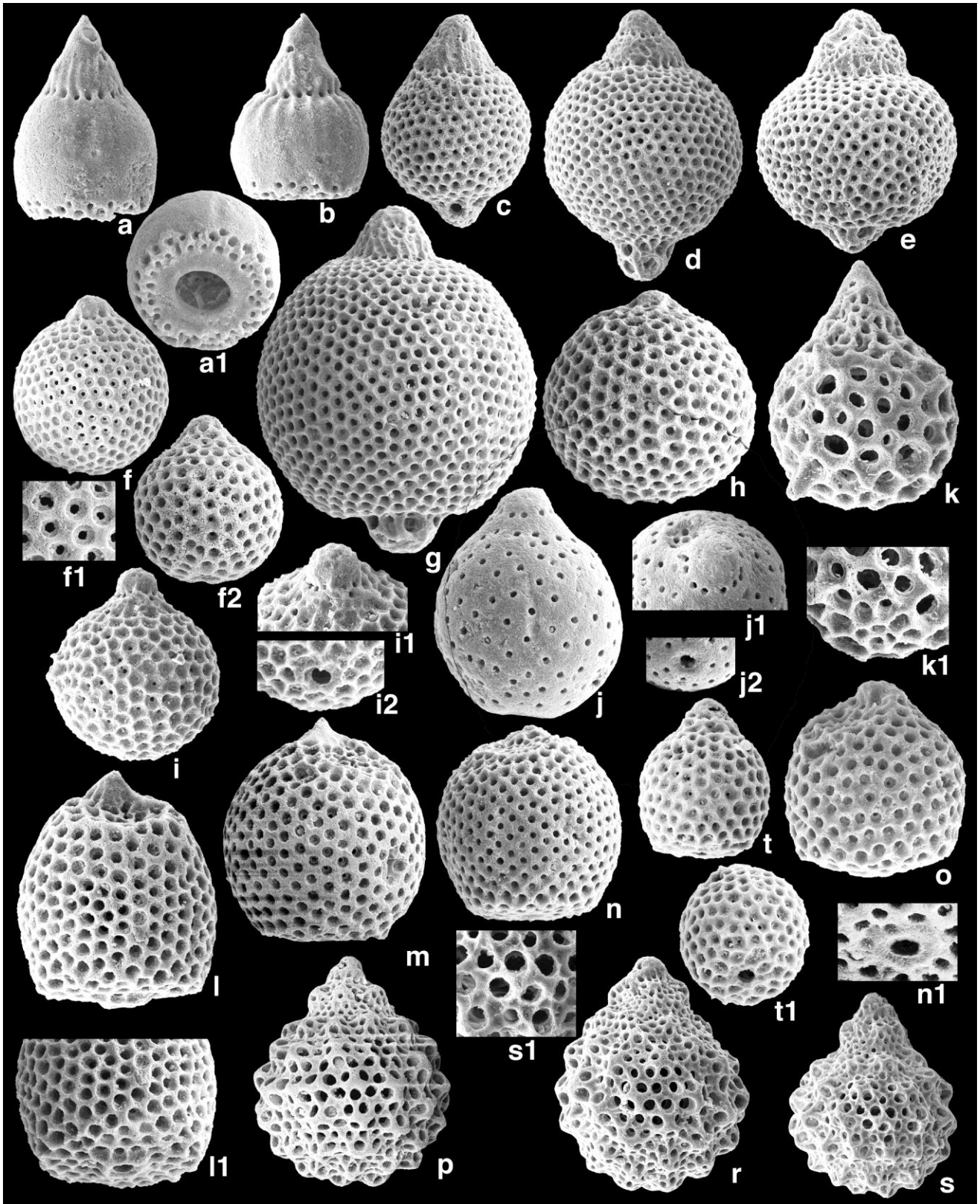


Fig. 9 **a, b** - *Eucyrtidiellum sardoum* Dumitrică n. sp.: **a, a1** - holotype, OZ836; **b** - paratype, OZ839. **c-e, g** - *Hemicryptocapsa capita* Tan: **c** - OZ838, **d** - OZ824, **e** - OZ837, **g** - OZ839. **f-f2** - *Gongylothorax oculoportus* Dumitrică n. sp.: OZ824 and OZ826. **h** - *Gongylothorax* (?) sp., OZ834. **i-i2** - *Gongylothorax verbeeki* (Tan), OZ824; **i1, i2** - details of apical and apertural parts. **j, j1, j2** - *Williriedellum buekkense* (Kozur), OZ824: **j** - lateral view, **j1** - apical view with sutural pore, **j2** - distal view. **k** - *Arcanicapsa simplicissima* Dumitrică n. sp., OZ836, **k1** - distal view showing the apical rosette. **l-o, t, t1, u** - *Kozurium hindei* (Tan): **l, l1** - OZ837, **m** - OZ839, **n** - OZ834, **o** - OZ836, **t-t1** x300, OZ825, **n1** - distal aperture of fig. **9n**. **p-s1** - *Cryptamphorella alieviana* Dumitrică n. sp.: **p, s** - OZ825, **r** - OZ837, **s1** detail of test of fig. **s**. Figs. **p-s** x200; figs. **c-e, g** x250; figs. **a, a1, b, f, f2, h, h1, i, k-o, t, t1**, x300; **i1, i2, m** x400.

Studied material. Two specimens, one in OZ824 and one in OZ826.

Holotype. Figs. 9f, f1, sample OZ824, coll. MGP-PD, stub PD120-OZ824-R13-35.

Paratype. Fig. 9f2, sample OZ826, coll. MGP-PD, stub PD120-OZ826-R11-13.

Dimensions. Length of shell 100-106 µm, of thorax 90 µm, diameter of thorax 88-90 µm.

Etymology. From the Latin *oculus* - eye and *porus* - pore, because, at high magnification (fig. 9f1), its pores resemble eyes with pupils in the centre.

Remarks. This species differs from *G. verbeeki* (Tan) by having pores with two diameters: very small diameter on the inner side of the wall and larger cylindrical opening on the outer side, and the passage between two diameters is abrupt, as if the wall consists of two layers.

Occurrence. Found only in the two cited samples.

Gongylothorax verbeeki (Tan, 1927)

Figs. 9i, i1, i2

1927 *Dicolocapsa verbeeki* Tan Sin Hok, p. 44, pl. 8, figs. 40, non 41.

non 1968 *Gongylothorax verbeeki* (Tan Sin Hok) – Foreman, p. 20, pl. 2, figs. 8a-c.

1994 *Hiscocapsa verbeeki* (Tan Sin Hok) – O’Dogherty, p. 199, pl. 31, figs. 1-6.

2009 *Zhamoidellum ovum* Dumitrică – Ishii et al., p. 348, pl. 21, fig. 12.

Studied material. One specimen in sample OZ824, stub PD120-OZ824-R13-28.

Dimensions. Length 123 µm, diameter of thorax 125 µm.

Remarks. The specimen from the S’Ozzastru section resembles very well the type specimen (lectotype, according to O’Dogherty, 1994). The Maastrichtian specimen illustrated by Foreman (1968) differs from the lectotype not only in age but also in shape. The lectotype is smaller, the apical part of thorax slightly conical and the pores are, on short portions, aligned in short rows, whereas the Californian specimen is “flat, centrally depressed”, and the frames of the pores are equal and show no lineation. However, Foreman, who had examined the topotypic material from Tan Sin Hok’s loc. 150, and remarked the presence of a tube on the thorax of this species (the sutural pore of Dumitrică 1970) wrote that it differs only slightly from the one present in the California form, fact that she did not consider it as representing sufficient evidence for separating these two forms into different species.

Occurrence. Lower Cretaceous of Tethys.

Gongylothorax sp.

Figs. 9h

Description. Dicyrtid shell with a very small cephalis partly included in a spherical thorax. Thorax globular with diameter slightly larger than the height. No sutural pore is present, but a small aperture seems to exist. Wall perforated by circular pores which are polygonally framed and partly quincuncially disposed.

Studied material. Only the illustrated specimen in OZ824 stub PD120-OZ834-R10-06 and 06a.

Dimensions. Length of test with cephalis 123 µm, diameter of thorax 126 µm.

Remarks. In the absence of the sutural pore, characteristic of the genus, and in the impossibility to see a distal aperture, the generic assignation of this species remains questionable.

Occurrence. Very rare in the upper Valanginian sample OZ824.

Family *Arcanicapsidae* Takemura, 1986

Genus *Arcanicapsa* Takemura, 1986

Type species. *Arcanicapsa sphaerica* Takemura, 1986

Remarks. The two new species described below are questionably assigned to this genus. This proves that the taxonomy of this type of nassellarians is rather imperfect.

Arcanicapsa (?) *alieviana* Dumitrică n. sp.

Figs. 9p, r, s, s1

1988 *Williriedellum* sp. A. – Thurow, p. 408, pl. 8, fig. 2.

2009 *Hiscocapsa grutterinki* (Tan) – Ishii et al., p. 347, pl. 20, fig. 9.

Description. Shell ovoid to conical, three-segmented, increasing very fast in diameter and length distally. Cephalis hemispherical, smooth and without apical horn, wall perforated by very small and sparse circular pores. Thorax twice as large as cephalis, with tubercles disposed in a single irregular circumferential row. Pores are very small, circular, distributed irregularly or in more or less regular circumferential rows. Collar boundary is rather well marked by the sudden enlargement of thorax. Sutural pore is not visible. Abdomen is very large, spherical or ovoidal and tuberculate, tubercles not interconnected by crests but by thicker intervening bars. Pores are circular and arranged in circumferential rows and quincuncially distributed. Pores are larger diameter at the middle part of the abdomen and smaller at the proximal and distal parts. At a greater magnification (Fig. 9s1) one can also see that the borders of pores are protruding and the middle parts of interporal areas are concave. Conversely, the bars at the top of the tubercles have the surface flat or convex. Lumbar boundary is rather well marked by the sudden increase in diameter of the abdomen. Distal part of abdomen has no aperture.

Studied material. Three illustrated specimens, two in sample OZ825, one in OZ837.

Holotype. Figure 9p, coll. MGP-PD, stub PD120-OZ825-R12-4.

Paratype 1. Figure 9s, coll. MGP-PD, stub PD120-OZ825-R12-7.

Paratype 2. Figure 9r, coll. MGP-PD, stub PD120-OZ837-R06-16.

Dimensions. Length of test 180-230 µm, of cephalis 20-25 µm, of thorax 25-35 µm, and of abdomen 130-155 µm; diameter of cephalis 6 µm, of thorax 60-70 µm, of abdomen 150-175 µm, total length of shell 180-230 µm.

Etymology. The species is dedicated to K. S. Aliev for his research on the Lower Cretaceous radiolarians of Azerbaijan at a time when the electron microscope was not a common research instrument as today.

Remarks. *Arcanicapsa* (?) *alieviana* n. sp. differs from all congeneric species with tuberculate shell by having the pores of the middle part of abdomen larger than those of the proximal and distal parts and arranged in circumferential rows moreover, the pores of each circular row alternate with those of neighbouring circular rows. A very

similar species was illustrated by Thurow (1988) as *Williriedellum* sp. A from the upper Hauterivian to lower Aptian assemblage of North Atlantic. In this species an arrangement of pores in circular rows and also a difference in the size of pores can be observed. Another specimen, quite similar to the Sardinian species, was illustrated by Ishii et al. (2009, pl. 20, fig.9) as *Hiscocapsa grutterinki* (Tan), from the Berriasian of ODP Hole 1213B-14R-1, 17-19 cm, North Pacific. On this specimen the difference in size between the abdominal pores of the middle part and those of the proximal and distal parts is also well visible.

Other species with which this new taxon can be compared and confounded are *Tricolocapsa clivosa* Aliev, 1967, *Cryptamphorella clivosa* (Aliev) in O'Dogherty (1994, p. 211, pl. 35, figs. 1-8) or *Williriedellum peterschmittae* Schaaf, 1981, and others, to cite only a few species with similar morphology occurring in the Lower Cretaceous. O'Dogherty's specimens assigned to *Tricolocapsa clivosa* Aliev do not seem to be conspecific with the species described from the Valanginian of the eastern Caucasus (NE of Azerbaijan) by Aliev (1967). The first argument is the difference in age (early Aptian, O'Dogherty's specimens, versus Valanginian, Aliev's species, age based on foraminifera and ammonites). The second argument refers to morphology: *T. clivosa* is ovoid, whereas the specimens illustrated by O'Dogherty are rather spherical. In this situation, the best candidate for our species could be Aliev's species that has the same age and also an ovoid shape with tuberculate wall. The problem is that we do not know exactly the typology of the abdominal pores of the specimen illustrated by Aliev, especially on the middle part of the abdomen. In his original description, he wrote that the pores are easily visible at a higher magnification and that they are circular in shape and disposed in a chess manner. This would mean "in square manner", which is very strange for tuberculate shells. Probably he would have liked to say "in a regular manner" like a quincuncial disposition, as in the specimens illustrated later by O'Dogherty. Aliev did not mention a circular disposition and a difference in size between the pores from the equatorial and periequatorial circles and those disposed toward the distal and proximal parts of the abdomen. So, Aliev's 1967 species *Tricolocapsa clivosa* is difficult to recognize not only in the SEM images of the specimens published by O'Dogherty, but also in our specimens. In this situation, despite the similar age (Valanginian), we prefer to consider our three specimens as belonging to a new species, that differs from *Tricolocapsa clivosa* by having the equatorial and "tropical" abdominal pores much larger than those disposed towards the proximal and distal parts of this chamber. As concerns *Williriedellum peterschmittae* Schaaf, it generally resembles *Cryptamphorella clivosa* (Aliev) of O'Dogherty 1994, from which it differs by having a distal aperture, which means that it belongs to another genus, as originally determined.

Other comparisons from general point of view could be made with the middle-late Jurassic species *Sethocapsa funatoensis* Aita 1987, the taxonomic place of which varied in time among *Sethocapsa*, *Zhamoidellum*, *Hiscocapsa* and *Arcanicapsa*, according to authors (see O'Dogherty et al. 2017, p. 45). With this species it has in

common only the three-segmented shell, tuberculate abdomen, the absence of distal aperture and sutural pore and little encased cephalis and thorax, but differs by having also tuberculate thorax and abdomen. In this situation we assigned it questionably to the genus *Arcanicapsa*.

Occurrence. Upper Valanginian of Sardinia, samples OZ825 and OZ837.

Arcanicapsa (?) *simplicissima* Dumitrică n. sp.

Figs. 9k, k1

2017 *Crococapsa tansinhoki* (Hull) – O'Dogherty et al., p. 39, fig. 8.46, ?8.47.

Description. Shell probably tetracyrtid with a pointed apical part and a globular distal part. Conical apical part consists probably of cephalis, thorax and abdomen. Cephalis conical imperforate except a circular pore with slightly protruding rim, well visible in the Fig. 9k1. Thorax and, probably, abdomen, in case of a tetracyrtid shell, truncated conical with irregularly distributed small pores which increase in size distally. Collar boundary not marked by a change in outline. Last segment globular, thick-walled, with circular or subcircular pores of irregular size and arrangement, and polygonally framed on the surface. It is armed with very few short three-bladed spines of irregular positions. Lumbar or postlumbar boundary, in case of a tetracyrtid shell, could be supposed in the place where there is a rapid increase in the size of pores and the shell has a concave outline due to the rapid increase in diameter. Distal end without an evident aperture but with a small central pore surrounded by a rosette of 6 small pores of variable shapes and sizes (fig. 9k1).

Studied material. A single specimen in sample OZ836.

Holotype. Fig. 9k, coll. MGP-PD, stub PD120-OZ836-R07-18.

Dimensions. Length 147 µm, diameter of last segment 113 µm.

Etymology. From Latin, superlative form of *simplex* = the simplest.

Remarks. This species, of which we have only the illustrated specimen, seems to be related to *Sethocapsa leiostraca* Foreman, 1973, *S. trachyostraca* Foreman, 1973, and other Tithonian and Lower Cretaceous taxa assigned before to the genus *Sethocapsa*, from which the new species differs by its smaller size, simple test with wide pores and absence of tuberculate or spiny last chamber. One of the specimens illustrated as *Crococapsa tansinhoki* (Hull) by O'Dogherty et al. (2017, fig. 8.46) resembles very well the specimen from Sardinia by having a very similar shape, pores of variable size and irregularly arranged, pointed apical part and intersegmental boundaries not marked outside by constrictions. The other specimen illustrated under the same species by these authors (fig. 8.47) differs by having a rather rounded apical part, more regularly sized pores and intersegmentary boundaries marked by constriction. The only resemblance with our specimen concerns the presence of a rosette of distal pores.

Range and occurrence. Upper Valanginian of Sardinia, sample OZ836.

Family **Williriedellidae** Dumitrică, 1970

Type genus. *Williriedellus* Dumitrică, 1970

Genus *Hemicryptocapsa* Tan, 1927 emend. Dumitrică 1970

Type species. *Hemicryptocapsa capita* Tan, 1927.

Emended diagnosis. Four, exceptionally three segmented, Nassellaria consisting of a conical or cupola-shaped cephalothorax, large inflated abdomen, and an inverted conical postabdominal segment of variable length. Cephalis without apical horn or with a very short one, and abdomen normally without sutural pore. Fourth segment inverted conical, very short, with or without a conical distal spine and bearing a few large pores. Cephalothorax partly hidden in the thoracic wall and cavity.

Remarks. When Dumitrică (1970) emended the genus *Hemicryptocapsa* Tan, the knowledge of Mesozoic radiolarians was very poor, and their taxonomy was at the beginning. For this reason and because Dumitrică had no specimen of the type species to section in order to see the internal skeletal structures, the emended diagnosis of this genus was a combination between what could be seen in the original drawing and what he saw himself by the study of the specimens occurring in the Upper Jurassic and Cretaceous radiolarian-bearing samples from Romania. One should also keep in mind that his paper was published before that of Foreman (1973), where she erected the subfamily Syringocapsinae. Due to this imperfect knowledge, Dumitrică (1970, p. 70) expressed the doubt whether the five Cretaceous species assigned by him to *Hemicryptocapsa* belong or not to this genus. At present, we know that *Hemicryptocapsa capita* differs from the other species initially assigned to this genus by Dumitrică by having a very small cap-like postabdominal segment that covers the abdominal aperture and by missing the sutural pore. This fact suggests other taxonomic relationships. Several inner casts of the skeleton of this species found in a Valanginian chert sample from the Batain Plain of Oman (Text-fig. 1) show very clearly the inner morphology of the type species (see discussion below).

A rather similar morphology has the uppermost Tithonian-upper Hauterivian *Syringocapsa agolarium* Foreman, 1973 (Baumgartner et al., 1995, p. 543) that externally differs from *Hemicryptocapsa capita* (upper Valanginian-lowermost Hauterivian) by only having a cylindrical apical horn of variable length and a similarly conical antapical one. Given this resemblance, the two species are regarded as congeneric, and *S. agolarium* should be transferred to *Hemicryptocapsa*. In this perspective, the Cretaceous species assigned by Dumitrică (1970) to *Hemicryptocapsa* should be, probably, transferred to *Holocryptocapsa* Tan Sin Hok, 1927, or to another cryptocephalic genus. Taking into account the FAD of the two species one can suppose that *H. capita* originated in *Syringocapsa agolarium* Foreman during the Valanginian by the loss of the cephalic horn and of the distal spine. If this hypothesis is true, *Hemicryptocapsa* should belong to the family Syringocapsidae Foreman, 1973 or Eusyringidae Steiger, 1992, rather than to the family Williriedellidae Dumitrică, 1970.

O'Dogherty et al. (2017) emended also the diagnosis of this genus, reducing it to the tricyrtid species lacking nodose outer surface, the ornamentation of the shell surface being only represented by the regular pore frames. This is an idea with which we do not completely agree.

Hemicryptocapsa capita Tan, 1927

Figs. 9c-e, g; Text-fig. 1

1927 *Hemicryptocapsa capita* Tan Sin Hok, p. 50, pl. 9, fig. 67.

1974 *Hemicryptocapsa* spp. cf. *H. capita* – Riedel & Sanfilippo, pl. 6, figs. 2, 3, 1?, 4?

1975 *Hemicryptocapsa* spp. cf. *H. capita* Tan – Foreman, p. 618, pl. 21, fig. 20, non 18.

1981 *Hemicryptocapsa* sp. cf. *H. capita* Tan – Kanie et al., pl. 1, fig. 10.

1982 *Hemicryptocapsa capita* Tan Sin Hok. – Okamura & Uto, pl. 2, fig. 20.

1986 *Hemicryptocapsa* cf. *capita* Tan Sin Hok – Suyari, p. 250, pl. 4, fig. 3.

1987 *Hemicryptocapsa capita* Tan Sin Hok – Kito, pl. 2, fig. 7.

1989 *Hemicryptocapsa capita* Tan Sin Hok – Tumanda, p. 37, pl. 6, fig. 8.

1989 *Hemicryptocapsa capita* Tan Sin Hok – Matsuoka, fig. 2. 9.

1991 *Hemicryptocapsa capita* Tan Sin Hok – Ishida & Hashimoto, p. 47, pl. 1, fig. 17.

1992 *Hemicryptocapsa capita* Tan – Matsuoka, 1992, p. 210, pl. 1, fig. 3.

1994 *Hemicryptocapsa capita* Tan – Goričan, p. 71, pl. 12, figs. 3, 4, non 5.

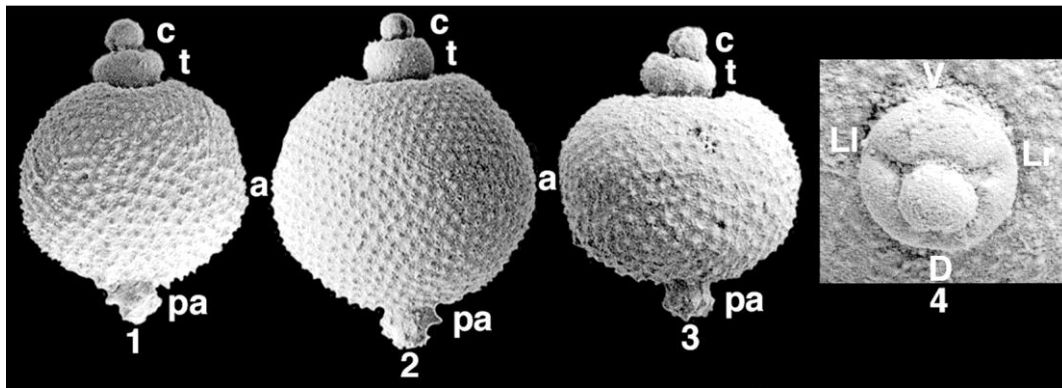
1995 *Hemicryptocapsa capita* Tan Sin Hok – Baumgartner et al., p. 248, pl. 4026, figs. 1-4, 6, ?5

non 1998 *Hemicryptocapsa capita* Tan – Matsuoka, p. 170, fig. 16 = *Syringocapsa agolarium* Foreman 1973.

2017 *Hemicryptocapsa capita* Tan – Xu & Luo, fig. 7M.

2017 *Hemicryptocapsa* sp. cf. *capita* Tan – Xu & Luo, fig. 7N.

Description. Test very thick with a large spherical abdomen, a short conical cephalothorax and an inverted conical or inverted hemispherical postabdominal segment. Cephalis simple, with rounded apex, imperforate or slightly perforate wall, and sometimes difficult to separate from the thorax outside. Dorsal and primary lateral bars of the initial spicule prolonged inside the thorax and attached to the inner side of its wall (Text-Fig. 1) but not prolonged in the abdominal cavity. They are marked on the inner cast of the thorax by two deep grooves (Text-Fig. 1. 1-4). Apical bar attached to the cephalic wall and its place marked on the dorsal side of the cephalis by a straight outline or even a very weakly visible concavity. Collar suture marked by a circumferential row of pores on the surface or a slight constriction or indistinct. Inside the shell cavity it is well marked by a circular depression, trace of the collar ring. Cephalothorax bell-shaped or short conical and partly hidden in the abdominal cavity; its wall is slightly perforated and its surface usually costate; costae very irregular, usually more or less longitudinal or derived from the poral frames. Sutural pore absent. Abdomen very large, spherical or subspherical, sometimes with slightly flattened distal end. Wall very thick, perforated by narrow cylindrical pores with funnel-shaped external end, which are commonly hexagonally framed and quincuncially disposed. Both lumbar and postlumbar boundaries marked by deep constrictions. Postabdominal segment, that covers the distal abdominal aperture, is more or less inverted conical, closed distally and with a few large pores.



Text-fig 1. Inner mould of 3 specimens of *Hemicryptocapsa capita* Tan from a Valanginian sample of the Batain Plain, Oman, showing the inner structure of its skeleton. 1-3 lateral view, 4 apical view of specimen from fig. 1: **c** - cephalis, **t** - thorax, **a** - abdomen, **pa** - postabdomen, **V** - ventral side, **D** - dorsal side, **Ll** - left lateral side, **Lr** - right lateral side. On cephalis one can see the imprint of apical ray and, on thorax, the imprints of primary left lateral ray and primary right lateral ray.

Dimensions. Length of shell 152-246 μm , of cephalothorax outside abdomen 32-46 μm , of abdomen 86-180 μm , of postabdominal part 16-24 μm , diameter of abdomen 104-196 μm .

Remarks. The abundance of this species in the Sardinian samples allows knowing the variability of this species concerning both size and shape of the specimens or different segments of the shell. Fig. 3 shows only 5 specimens in order to demonstrate the morphological variability of the species concerning size of specimens, shape of cephalothorax and its superficial ornamentation, size and shape of the abdomen and postabdominal segment. The very small specimens (Fig. 9c) are very rare, most specimens having a big abdomen and well-marked constrictions between it and thorax and postcephalic segment. A similar specimen was illustrated by Matsuoka (1983, pl. 4, fig. 2) as *Willriedellum* sp. A.

Hemicryptocapsa capita resembles very much *Syringocapsa agolarium* Foreman, 1973, by having the shell formed of three parts: a hemispherical cephalothorax partly included in the abdominal cavity, a large spherical abdomen without sutural pore, and a small inverted conical postabdominal segment. Briefly, one can suppose that this species could have its origin in the uppermost Tithonian to upper Hauterivian species *Syringocapsa agolarium* Foreman, 1973 (see Baumgartner et al., 1995, p. 542 for comparison), whose FAD precedes the FAD of *H. capita*, and from which it differs by only the loss of the apical and distal spines. Goričan (1994) illustrated three specimens of this species. We consider that the specimen illustrated on her pl.12, fig. 5, coming from a Hauterivian-Barremian sample, does not belong to this species because it is younger and has a different morphology: abdominal pores are much smaller and the last distal postabdominal segment has very small pores and a terminal spine. Also, the specimen with tuberculate abdomen illustrated by Baumgartner et al. (1995, p. 249, fig. 5) probably should not be included in this species. This morphotype seems to be a very short ranged Valanginian species occurring also in the Murguceva section from Svinița, Romania.

Range and occurrence. Upper Valanginian to lowermost Hauterivian, cosmopolitan and very abundant in the Valanginian.

Hemicryptocapsa* (?) *bellireticulum (Wu & Li, 1982)

Figs. 10a-c1

?1927 *Theocapsa curata* Tan, p. 47, pl. 8. Figs. 50, 51.

1982 *Zhamoidellum bellireticulum* Wu & Li, p. 67, pl. 1, figs. 12, 13.

Description. Test three segmented. Cephalothorax bell-shaped with only the lowermost part of thorax included in the abdominal cavity. Cephalis very small, hemispherical externally, without apical horn, practically poreless or with very rare and very small pores, its collar suture marked by a row of pores and an evident constriction due to the fast increase of the diameter of thorax. Thorax much larger than cephalis, cylindrical and rough-surfaced, with ornamentation resulting from filling of a porous structure of which only rarely pores are visible. Its lower part is included in abdominal cavity and its apertural border bears three diverging needle shaped spines. Sutural pore very narrow, almost indistinct in the vicinity of thorax. Abdomen ovoid or cordate with acute part distally positioned. Distal end with a very narrow circular larger pore with protruding rim that could be an aperture (Fig. 10 c1). Abdominal wall thick perforated by numerous and irregularly disposed circular or subcircular pores. Its surface wrinkled resulted from an irregular network of sharp crests of different lengths and positions with pyramidal elevation at junctions.

Studied material. Seven photographed specimens in coll. MGP-PD, stub PD120, samples: OZ824 (stub PD120-OZ824-R13-15, R13-26, R13-27, R13-29; OZ825 (stub PD120-OZ825-R12-23), OZ836 (stub PD120-OZ836-R07-10), and OZ838 (stub PD120-OZ838-R04-06).

Dimensions. Length of shell 172-180 μm , of cephalothorax outside abdomen 40-48 μm , of abdomen 124-132 μm , diameter of cephalothorax 52-56 μm , of abdomen 124-132 μm .

Remarks. Almost all illustrated specimens resemble the holotype. The specimen with elongated abdomen (Fig. 10c) is the only one with such a morphology, suggesting that it could be an anomaly. The superficial abdominal ornamentation of this species resembles somehow that of the lower Aptian *Cryptamphorella gilkeyi* Dumitrică 1972, from which it differs in having the superficial polygonal areas partly open on at least one side and especially in having the cephalothorax very little hidden in

abdominal cavity and well separated from the latter, and in not having a sutural pore and distal aperture. The species is questionably assigned to the genus *Hemicryptocapsa* because it has no relict postabdominal chamber.

By its shape, this species is very close to *Theocapsa curata* Tan (1927, pl. 8, figs. 50, 51) from which it only differs by having much denser pores and a different superficial ornamentation.

Range and occurrence. Upper Valanginian of Sardinia, and in Tibet, in a block of the Zonghuo Formation (Wu & Li, 1982).

Genus *Kozurium* Pessagno, 1977

Type species. *Kozurium zingulai* Pessagno, 1977

Remarks. When Pessagno erected the genus *Kozurium* he compared it with *Diacanthocapsa* Squinabol, 1903, emend. Dumitrică, 1970. It is true that, externally, it looks rather close to Squinabol's genus, but this resemblance is quite superficial, not structural. *Diacanthocapsa* is a tricyrtid with cephalis partly or completely inclosed in a big, external thorax, that represents usually the most important and thickest part of shell, whereas *Kozurium* has the thorax very small and included in the abdomen and, as noted by Dumitrică (1970) for the Williriedellidae, it forms with the cephalis a unitary body, the cephalothorax, that moves together as an independent body in the relation with the abdomen.

By having a postabdominal chamber, *Kozurium* is intermediary between *Williriedellum* and *Hiscocapsa* O'Dogherty. From *Williriedellum* it has also the sutural pore that gives the shell a bilateral symmetry. This symmetry is much more advanced in *Kozurium hindei* (Tan, 1927) by the presence of the flat or concave area of the abdominal wall in the vicinity of the cephalothorax.

Range. Late Valanginian to late Cenomanian so far as known.

Kozurium hindei (Tan, 1927)

Figs. 9l-o, t, t1

1927 *Holocryptocapsa hindei* Tan Sin Hok, p. 53, pl. 10, fig. 75.

1970 *Holocryptocapsa* cf. *hindei* Tan – Dumitrică, p. 74, pl. 15, figs. 100a-d.

1994 *Holocryptocapsa hindei* Tan – O'Dogherty, p. 212, pl. 35, figs. 9-17.

2001 *Holocryptocapsa hindei* Tan – Dumitrică in De Wever et al., fig. 165.8.

2014 *Holocryptocapsa hindei* Tan – Robertson et al., fig. 10(A), 32.

Description. Shell commonly three-segmented, but originally four-segmented. Cephalothorax bell-shaped, partly to almost completely hidden in the abdominal wall and cavity. Cephalis imperforate and bearing usually an extremely short conical apical horn. Abdomen ovoid or subspherical with distal end flat. Lateral parts of the wall smooth with circular and irregularly disposed pores. Pores are very small on the inner part of wall and larger and cylindrical on the middle and external parts. Near the cephalothorax a wide depression is always present, corresponding to the sutural pore, but a true sutural pore is just a larger pore situated near the cephalis (see Dumitrică, 1970, pl. 15, fig. 100d). Distal part of abdomen completely flat or slightly convex and thinner-walled than the lat-

eral sides. Aperture circular, a little larger than the normal pores, simple or with protruding margins (Figs. 9l-11). Postabdominal segment absent in the Sardinia assemblages, but present in a Valanginian pyritized specimen from the Murguceva Formation, from Svinița (Romania) (see De Wever et al., 2001, fig. 165.8). It is a thin-walled tureen-shaped segment that covers the distal part of the abdomen.

Studied material. Numerous specimens in samples OZ824-826, OZ834, OZ836, OZ837 and OZ839 (see Table 1).

Dimensions. Length 115-138 µm, diameter of abdomen 95-126 µm.

Remarks. All specimens assigned to this species have a smooth surface, whereas the original drawing of the holotype illustrated by Tan Sin Hok (1927) shows a faint lineation suggesting a slightly rough surface. Such a surface resembles that of the specimen illustrated on Fig. 9l of the present paper, which, in our opinion, characterizes a younger ontogenetic stage of skeletogenesis, when the superficial layer of skeleton that narrows the diameter of pores was not completely built.

The large flat base of the abdomen differentiates this taxon from all other species of the Williriedellidae. As mentioned above, Dumitrică (1970, pl. 15, fig. 100a) has also shown that this distal part is not only flat but also thinner and its borders are rather sharp suggesting the initial presence of a fourth segment that was either absorbed during the life of the specimens or very easily dissolved after death. A single specimen with this supposed postabdominal segment was found in the upper Valanginian of the Svinița section (Romania) [see description in Dumitrică, 1995, and the illustrated specimen in De Wever et al. (2001, fig. 165.8)]. This specimen is comparable with the two species of the Albian-Cenomanian genus *Kozurium* Pessagno, 1977 [*K. corningensis* Pessagno 1977 (recte *corningense*), and *K. zingulai* Pessagno 1977]; this suggests that these two taxa are not diacanthocapsids. In conclusion, the genus *Kozurium* Pessagno 1977 is a williriedellid and not a diacanthocapsid as supposed by Pessagno.

Range and occurrence. Upper Valanginian of Sardinia to upper Cenomanian of Romania, but O'Dogherty (1994, p. 213) recorded more than 200 specimens in the early Aptian.

Genus *Williriedellum* Dumitrică, 1970

Type species. *Williriedellum crystallinum* Dumitrică, 1970.

Remarks. We use this genus in its original meaning, not in the emended one by O'Dogherty et al. 2017 because we do not find normal to include *Praezhamoidellum buekkensis* Kozur near the species of the genus *Hemicryptocapsa*.

Williriedellum buekkense (Kozur, 1984)

Figs. 9j, ja-jb

1984 *Praezhamoidellum buekkensis* Kozur, p. 54, pl. 3, figs. 1a-b.

1988 *Theocorys renzae* Schaaf – Thurow, p. 407, pl. 8, fig. 1, non Schaaf, 1981.

1998 *Tricolocapsa buekkense* (Kozur) – Cordey, p. 128, pl. 27, fig. 9.

2006 *Williriedellum buekkense* (Kozur) – O’Dogherty et al., p. 24, pl. 9, figs. 1-6.

2006 *Praezhamoidellum buekkense* Kozur – Auer et al., p. 42, fig. 31.

2016 *Hemicryptocapsa buekkensis* (Kozur) – O’Dogherty et al., p. 24, Fig. 9.1-9.6.

Studied material. Three specimens in coll. MGP-PD, stub PD120 as follows: PD120-OZ834-R09-17, PD120-OZ834-R10-19, and PD120-OZ839-R03-09.

Description. Shell three-segmented, ovoid and smoothed-faced with sparse and irregularly distributed very small circular pores. Sutural pores very small and sieve structured (fig. 9j1). Aperture very small and simple. Intersegmental boundaries generally not marked by constrictions.

Dimensions. Height of test 92-101 µm, of abdomen 67-77 µm, diameter of abdomen 71-81 µm.

Remarks. Despite its smooth surface, the assignation of this species to the genus *Hemicryptocapsa* (O’Dogherty et al., 2017) is erroneous, in our opinion, because this genus has a very small fourth segment and no sutural pore.

Range and occurrence. A long-ranged species, known from Middle Jurassic to Hauterivian.

***Williriedellum occultithorax* Dumitrică n. sp.**

Figs. 10s-s1

Description. Shell with abdomen practically spherical, smooth surfaced with dense and small circular pores arranged quincuncially. Cephalothorax with thorax hidden in the abdominal chamber. Cephalis small imperforated and thorax practically completely hidden in abdominal wall and cavity. Sutural pore not visible; it is probably situated on the other side of the shell. Aperture large, circular with rounded border.

Studied material. A single specimen in sample OZ826.

Holotype. Figs. 10s-s1, coll. MGP-PD, stub PD120-OZ826-R11-08a-c.

Dimensions. Diameter of abdomen 124 µm.

Etymology. From the Latin verb *occultus*, - a, - um = hidden, and *thorax*, as the thorax is hidden in the abdomen.

Remarks. This species differs from the other syngeneric taxa by the large distal aperture with rounded borders, very small abdominal pores, smooth surface, and hidden thorax.

Occurrence. A single specimen in sample OZ826.

***Williriedellum cordiforme* Dumitrică n. sp.**

Fig. 10r

?1981 *Cryptamphorella conara* (Foreman) – Schaaf, pl 9, figs. 15a-b.

Description. Cephalothorax typical for the genus with spherical and imperforate cephalis and thorax partly sunk in the abdominal cavity. Abdomen heart-shaped with irregular surface and circular pores arranged more or less quincuncially. Sutural pore with protruding rim. Distal aperture at the end of acute distal part.

Studied material. A single specimen in OZ837.

Holotype. Fig. 10r, coll. MGP-PD, stub PD120-OZ837-R06-17.

Dimensions. Height of shell 136 µm, diameter of abdomen 128 µm.

Etymology. From the Latin *cordiformis* – e = heart-shaped, due to its heart-shaped abdomen.

Remarks. This specimen resembles partly the specimen assigned questionally to *Cryptamphorella conara* illustrated by Schaaf due to its cordate abdomen and the absence of the inverted conical distal segment.

Occurrence. A single specimen in sample OZ837.

***Williriedellum gilkeyi* Dumitrică, 1972**

Figs. 10i, i1

1972 *Williriedellum* (?) *gilkeyi* Dumitrică, p. 841, pl. 3, figs. 4, 6; pl. 4, figs. 1, 2.

1981 *Williriedellum gilkeyi* Dumitrică – Schaaf, p. 440, pl. 2, figs. 6a-c.

1988 *Wiliriedellum gilkeyi* Dumitrică (pars) – Thurow, p. 408, pl. 8, figs. 10, 13, non fig. 14.

1991 *Wiliriedellum gilkeyi* Dumitrică – Aguado et al., text-fig. 7.17.

1993 *Wiliriedellum gilkeyi* Dumitrică – Aguado et al., pl. 3, fig. 5.

1994 *Cryptamphorella gilkeyi* (Dumitrică 1972) – O’Dogherty, p. 210, pl. 34, figs. 9-14.

Studied material. A single specimen in sample OZ838, coll. MGP-PD, stub PD120-OZ838-R05-04 and 04a.

Dimensions. Length of shell 140 µm, of abdomen 103 µm, diameter of abdomen 123 µm.

Remarks. As remarked in the original description (Dumitrică, 1972), this species was questionably assigned to the genus *Williriedellum* due to the lack of a distal view in order to see whether the holotype has or not an aperture. O’Dogherty (1994) mentioned that the abdomen has no aperture and, consequently, assigned the taxon to the genus *Cryptamphorella* Dumitrică, 1970. Moreover, this author initially established the age of the species as Albian on the basis of foraminifera, but later he ascertained the range as Barremian-lower Aptian. The specimen illustrated in the present paper (Fig. 10i1) proves that the aperture exists, and that the species belongs to the genus *Williriedellum*. Its aperture is a distal circular opening with a short protruding rim.

Range and occurrence. Upper Valanginian to lower Aptian, Tethys.

***Williriedellum labeosum* Dumitrică n. sp.**

Figs. 10d-f, j-j2

Description. Shell three-chambered, globular with tuberculate abdomen. Tubercles interconnected by simple or double costae forming a network of triangular surfaces. Pores of abdomen dense, circular and quincuncially arranged. Apex of most tubercles with a larger pore. Cephalothoracic body enclosed with lower half of thorax in abdominal cavity. Surface of cephalothorax with a network of thin ribs forming very small irregular polygonal surfaces with one small pore in each polygonal depression. Sutural pore with protruding rim and closed inside by a sieve structure (Fig. 10e). Aperture funnel-shaped bordered by a large protruding rim and closed, at the level of the inner side of wall, by a very thin network of very small pores (Fig. 10f, j2).

Studied material. Three illustrated specimens in samples OZ834 and 837.

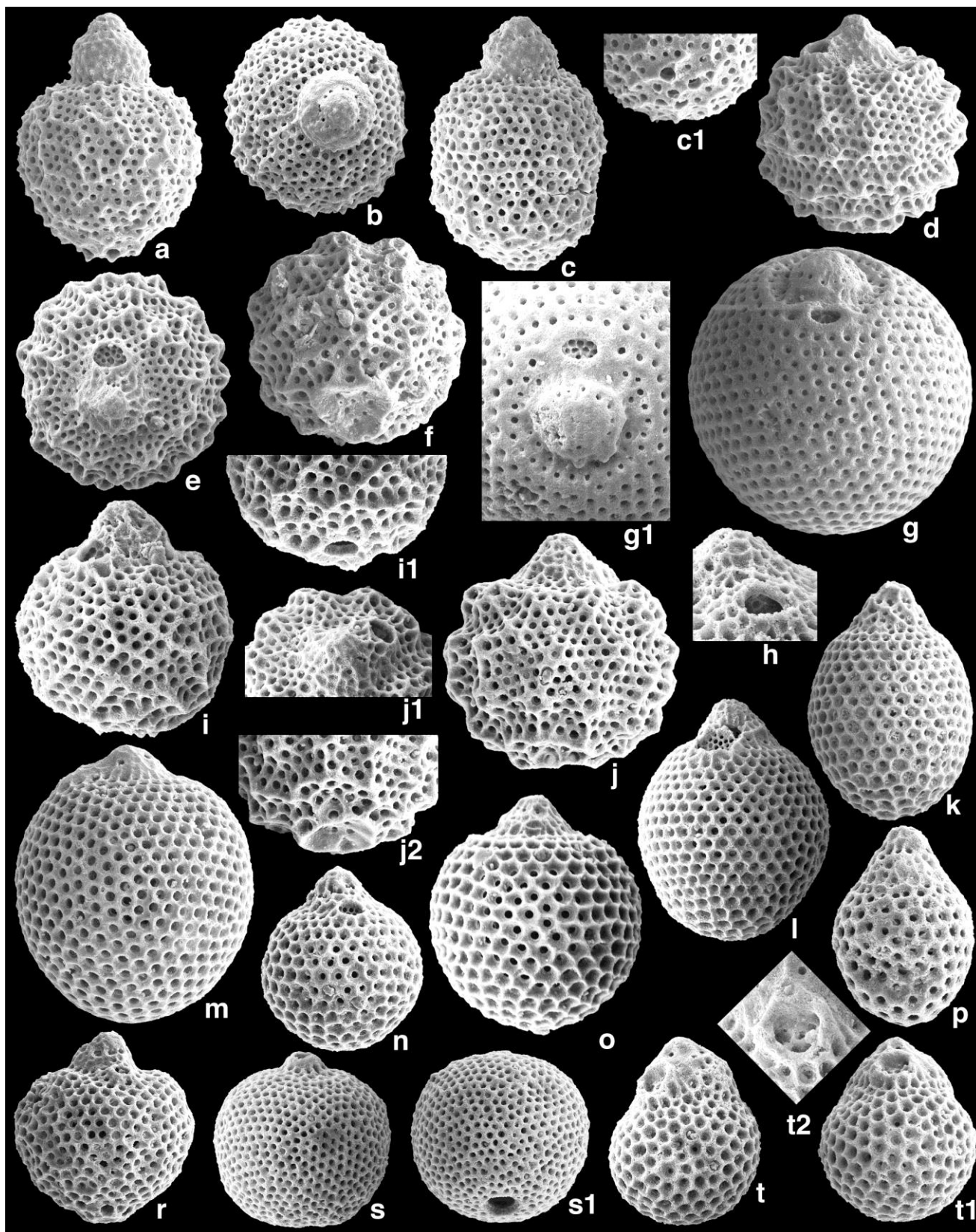


Fig. 10 a-c1 - *Hemicryptocapsa* (?) *bellireticulum* (Wu & Li): **a** - OZ825, **b** - OZ836. **c** - OZ838, **c1** - OZ824. **d-f, j-j2** - *Williriedellum labeosum* Dumitrică n. sp.: **d, e, j-j2**, OZ837, **f** - OZ834. **g, g1** - *Cryptamphorella circumthoracica* Dumitrică n. sp., OZ838; **g1** - view of apical part. **h, k-o** - *Cryptamphorella dimitricai* Schaaf: **h** - detail of sutural pore, **k** - OZ825, **l** - OZ 824, **m** - OZ838, **n-o**, OZ839. **i, i1** - *Williriedellum gilkei* Dumitrică, OZ838. **p** - *Zhamoidellum ovum* Dumitrică, OZ839. **r** - *Williriedellum cordiforme* Dumitrică n. sp., OZ837. **s, s1** - *Williriedellum occultithorax* Dumitrică n. sp. in lateral and obliquely apical views, OZ826. **t-t2** - *Cryptamphorella crassilabrosa* Dumitrică n. sp., OZ837: **t, t1** - holotype in two positions, **t2** - sutural pore much magnified showing inside the wall of the hidden thorax. Figs. **a-f, i, h, k-o, r** x250; **g, gi, h, t, t1** x300.

Holotype. Specimen illustrated on Fig.10 j-jb, coll. MGP-PD, stub PD120-OZ837-R06-07.

Dimensions. Length 152-164 μm , diameter of abdomen 152-166 μm .

Etymology. From the Latin *labeosus*, -a, -um = thick-lipped, due to the distal aperture with thick and protruding border.

Remarks. This species is very close to the Lower Cretaceous species *W. gilkeyi* Dumitrică, 1972, by having the surface costate and cephalothoracic body partly enclosed in the abdominal cavity; however, it differs from it by having a funnel-shaped aperture with opening closed by a sieve structure. From the Upper Jurassic species *W. crystallinum* Dumitrică it also differs by its distal aperture, which is not simple.

Occurrence. Upper Valanginian, Sardinia.

***Williriedellum petersmittae* Schaaf, 1981**

Fig. 6e

1972 *Hemicryptocapsa* (?) *nodosa* (Tan) – Dumitrică, p. 841, pl. 1, fig. 6; pl. 2, figs. 1, 2.

1981 *Williriedellum petersmittae* Schaaf, p. 440, pl. 1, figs. 3a, 3b; pl. 9, figs. 3a, 3b.

1991 radiolari – Dieni & Massari, fig. 23e.

2017 *Hiscocapsa* sp. aff. *kaminogoensis* (Aita) – Xu & Luo, fig. 5h.

Dimensions. Length of shell 196 μm , diameter of thorax 174 μm .

Remarks. This species was already illustrated from the S'Ozzastru section by Dieni & Massari (1991); another specimen was found in sample OZ837 but not illustrated with SEM image.

Range and occurrence. Barremian of Mid Pacific Mountains (Schaaf, 1981) and upper Valanginian of S'Ozzastru section, Sardinia.

Genus ***Cryptamphorella*** Dumitrică, 1970

Type species. *Hemicryptocapsa conara* Foreman, 1968.

Cryptamphorella circumthoracica Dumitrică n. sp.

Figs. 6i; 10 g, g1

1988 *Cryptamphorella* sp. B – Thurow, p. 401, pl. 8, fig. 22.

1989 *Cryptamphorella* sp. – Matsuoka, fig. 2.11.

1991 radiolari – Dieni & Massari, fig. 23i = Fig. 6i in the present article.

2009 *Cryptamphorella clivosa* (Aliev) – Ishii et al., p. 348, pl. 21, fig. 20.

2009 *Cryptamphorella conara* (Foreman) – Ishii et al., p. 348, pl. 21, fig. 21.

Description. Abdomen large, spherical, with small pores arranged quincuncially on most part of its surface and slightly polygonally framed externally. Distal part closed. Cephalothorax with cephalis exposed outside with only its apical half and bearing very small sparse pores, and thorax bell-shaped and enclosed in the abdominal cavity. Cephalothorax situated in a slightly depressed circular area bordered by a circular ridge. Sutural pore open on the trajectory of this ridge. Its margin is thick and it is closed on the inner side by a sieve plate with small pores representing a portion of the thoracic wall. Pores of abdomen very small and usually regularly arranged.

Studied material. A single specimen in sample OZ838, and others from the Masirah Island (Oman), and Murguceva Formation, Svinița (Romania).

Holotype. The illustrated specimen, coll. MGP-PD, stub PD120-OZ838-R05-15, 15a.

Dimensions. Diameter of abdominal shell 198 μm , of collar 90 μm .

Etymology. From the Latin *circum* = around and *thorax* = thorax.

Remarks. The species is very characteristic by bearing a circular ring on the abdomen around the cephalothoracic structure and on the level of the sutural pore, and a large abdomen with hexagonally framed small pores. The specimen illustrated by Thurow (1988, see synonymy) from the upper Hauterivian-lower Aptian is surely conspecific with the holotype. A similar specimen was found but not published in the Valanginian of the Svinița section, Murguceva Formation, Romania (see Dumitrică, 1995, for the section). The specimens illustrated by Ishii et al. (2009, see synonymy) seem also to be close to this new species although the peri-cephalothorax circular ring is not too much pronounced. The specimen illustrated by Matsuoka (1989) as *Cryptamphorella* sp. could represent this taxon because it has a sutural pore with protruding rim similar to that of the holotype, but the perithoracic circumferential crest is not too well marked.

Range and occurrence. Very rare in sample OZ838, in the Valanginian of Svinița (Romania), in the upper Valanginian-Hauterivian of Maghilah Unit, Masirah Island (Oman), and in the Barremian of Fayah Unit (Masirah Island).

Cryptamphorella dimitricai Schaaf, 1981

Figs. 6f; 10, h, k-o

1981 *Cryptamphorella dimitricai* Schaaf, p. 433, pl. 1, figs. 5a-c; pl. 9, figs. 5a, b, 13a, b.

1981 *Cryptamphorella* sp. indet. – Schaaf, pl. 2, figs. 4a, b.

1981 *Cryptamphorella* gen. et sp. indet. – Kanie et al., pl. 1, fig. 11.

1981 *Hemicryptocapsa pseudopilula* Tan Sin Hok – Schaaf, p. 434, pl. 2., figs. 4a, b.

1988 *Cryptamphorella* sp. cf. *C. conara* (Foreman) – Thurow, p. 399, pl. 8, fig. 20.

1988 *Cryptamphorella dimitricai* Schaaf – Thurow, p. 400, pl. 8, figs. 20, 23.

1988 *Cryptamphorella* sp. A. – Thurow, p. 400, pl. 9, fig. 2.

1999 *Zhamoidellum ovum* Dumitrică – Hori, p. 73, fig. 6.8.

2009 *Cryptamphorella clivosa* (Aliev) – Ishii et al., p. 348, pl. 21, fig. 20.

2009 *Cryptamphorella conara* (Foreman) – Ishii et al., p. 348, pl. 21, fig. 21.

2017 *Cryptamphorella conara* (Foreman) – Xu & Luo, Figs. 7E, F.

Description. Shell with large spherical to ellipsoidal or ovate abdomen of variable size. Pores dense and commonly quincuncially disposed. They are small, circular on the inner side of wall and larger and polygonally, commonly hexagonally framed on the outer surface. Frames generally with acute or slightly rounded crests. Pores funnel-shaped but with a sudden narrowing on the inner

side. Cephalothorax with thorax partly sunk in the abdominal wall and cavity, its surface irregularly ribbed due to the presence of crests around the very small pores. Cephalis without apical horn, small, with costate ornamentation and collar boundary very poorly marked. Thorax bell-shaped, partly included in the abdominal cavity and perforated by very small pores. The part of thorax sunk in abdominal cavity is thin-walled and has dense and small circular pores (fig. 10l). Lumbar boundary marked by a stricture resulting from the sudden development of the abdomen. Abdomen very variable in shape and size, from spherical (Figs. 10n, o) to elongate ellipsoidal (Fig. 10k), and from small (Fig. 10n) to rather big (Fig. 10m), suggesting that all belong to the same species. Sutural pore rather large, always with protruding rim and thin margins. No distal aperture.

Studied material. Many illustrated specimens.

Dimensions. Total length of shell 130-198 μm , of abdomen 104-172 μm , diameter of abdomen 114-168 μm .

Remarks. The assemblage occurring in the S'Ozzastru section contains a whole variety of abdominal forms of this species, from spherical (Figs. 10n, o) to elongate ellipsoidal (Fig. 10k) and from small (Fig. 10n) to big (Fig. 10m) suggesting that all belong to one and the same species. All have a different degree of sinking of the cephalis in the thorax and of the thorax in the abdomen, and a similar test structure. This species differs from *C. conara* (Foreman) by the variability of the shape of the abdomen and, especially, by the sharp and protruding borders of the sutural pore. Its abdominal variability may be compared with that of the early Campanian species *Cryptamphorella macropora* Dumitrică, 1970, from which it differs by the protruding and sharp rim of the sutural pore and its smaller size.

Range and occurrence. Valanginian so far as known.

***Cryptamphorella crassilabrosa* Dumitrică n. sp.**

Fig. 10 t-t2

1997 *Zhamoidellum parva* (Tan Sin Hok) – Meyerhoff Hull, p. 47, pl. 37, figs. 1, 2.

Description. Shell small, ovoid. Cephalis small, rounded conical externally, its distal half included in the thoracic wall and cavity. Thorax much larger than cephalis, truncate conical, with small and irregularly distributed pores, and strongly asymmetrical in dorso-ventral direction. Collar boundary marked by a small constriction resulted from the brusque enlargement of thorax. Sutural pore large and protruding, with relatively thick and rounded border and migrated on the middle part of thorax. Judging from external morphology, it is impossible to see how much of its distal part is included in the abdominal cavity. Abdomen spherical with slightly polygonally framed circular pores of variable size and irregularly quincuncially arranged. Lumbar boundary well marked externally by a change of outline resulted by the difference between the diameters of thorax and abdomen. Abdomen without distal aperture.

Studied material. A single specimen in the sample OZ837.

Holotype. The illustrated specimen, coll. MGP-PD, stub PD120-OZ837-R06-13, 13a, 13b.

Dimensions. Height of shell 110 μm , height of external part of thorax 27 μm , of abdomen 73 μm , diameter of thorax at base 67 μm , diameter of abdomen 93 μm .

Etymology. From the Latin *crassus*, -a, -um = thick and *labrosus*, -a, -um = lip-shaped, namely with big lips, due to the well-developed protruding margins of the sutural pore.

Remarks. This species differs from many other congeneric species from the late Valanginian Sardinian radiolarian assemblage by having the thorax rather large by comparison with the abdomen and the sutural pores displaced up to the level of the upper part of the thorax. Morphologically, it resembles very much the species illustrated by Meyerhoff Hull (1997, p. 132, pl. 37, figs. 1, 2) as *Zhamoidellum parva* (correct *parvum*) (Tan Sin Hok), generic translation from *Tricolocapsa parva* Tan Sin Hok, 1927, p. 47, pl. 9, fig. 55 and erroneous determination. Or, the Sardinian species has in common with Tan's species only the larger size of the thorax, but differs from it by the size and disposition of pores (in Tan's species the pores are rare, smaller, irregularly scattered and the surface is smooth), and the absence of the large sutural pore. It is possible that the upper Valanginian species shows an evolution of the position of this pore because in the upper Tithonian species illustrated by Meyerhoff Hull, it is on the upper part of the abdomen and just a little above the level of the lumbar constriction.

Range and occurrence. Upper Tithonian of western north America to upper Valanginian of Sardinia. Species very rare.

Genus *Zhamoidellum* Dumitrică 1970

Type species. *Zhamoidellum ventricosum* Dumitrică, 1970

***Zhamoidellum ovum* Dumitrică, 1970**

Fig. 10p

1970 *Zhamoidellum ovum* Dumitrică, p. 79, pl. 9, figs. 52-54.

1981 *Zhamoidellum ovum* Dumitrică – Baumgartner et al., p. 656, pl. 4079, figs. 1-6.

1982 *Zhamoidellum ovum* Dumitrică – Dumitrică & Mello, pl. 3, fig. 13.

1988 *Zhamoidellum ovum* Dumitrică – Ozvoldova, pl. 7, fig. 3.

1991/92 *Zhamoidellum ovum* Dumitrică – Kiessling & Zeiss, p. 191, pl. 2, fig. 7

non 1999 *Zhamoidellum ovum* Dumitrică – Hori, p. 73, Fig. 6. 8 = *Cryptamphorella dimitricai* Schaaf, 1981.

2017 *Zhamoidellum ovum* Dumitrică – O'Dogherty et al., p. 26, Figs. 10.31-10.40.

Studied material. A single specimen in sample OZ839, coll. MGP, stub PD120-OZ839-R03-06.

Dimensions. Length 117 μm , maximum diameter 83 μm .

Remarks. This species is rather long-ranged; it was described from the Oxfordian radiolarites of the Eastern Carpathians and was cited up to Tithonian; its occurrence in the upper Valanginian seems to be the youngest.

The genus *Complexapora* Kiessling & Zeiss 1991/92 (type species *Complexapora tirolica* Kiessling & Zeiss) resembles externally *Zhamoidellum ovum* Dumitrică 1970, from which it differs by having a large sutural pore with a sieve structure.

Range and occurrence. Upper Jurassic to Upper Valanginian of Tethys.

Family **Minocapsidae** O'Dogherty, Goričan & Gawlick 2017

Type genus. *Minocapsa* Matsuoka, 1991

Remarks. O'Dogherty et al. (2017) included in this family nassellarians with pyriform shell consisting usually of four segments with or without distal aperture and lattice shell composed of small rounded to polygonal pore frames. There was no mention on the cephalic structure that has, as it is well known, a primary value in nassellarian taxonomy at generic level. Or, besides the genera *Minocapsa* Matsuoka 1991, *Doliocapsa* O'Dogherty, Goričan & Gawlick 2017, *Hiscocapsa* O'Dogherty 1994, *Praewilliriedellum* Kozur 1984, and *Quarkus* Pessagno, Blome & Hull 1993, that have a simple cephalis, they also included the genus *Crococapsa* O'Dogherty, Goričan & Gawlick 2017, that has a two-chambered cephalis, as we shall show in this article, and for which we erect the new family *Crococapsidae* Dumitrică n. fam.

Range. Middle Jurassic to early Cretaceous

Genus ***Hiscocapsa*** O'Dogherty, 1994

Type species. *Cyrtocapsa grutterinki* Tan Sin Hok, 1927

Diagnosis. Usually spindle shaped Upper Jurassic? to Lower Cretaceous Nassellaria consisting of 4 chambers, the last one thinner-walled and sometimes missing due to fossilization or dissolution after the death of specimens.

Remarks. In the original diagnosis, this genus was invalid because O'Dogherty had included in it *Gongylothorax verbeeki* (Tan, 1927), the type species of the genus *Gongylothorax* Foreman, 1968. Although O'Dogherty considered that the upper Maestrichtian species illustrated and described by Foreman under this name was not the same as the one described and illustrated by Tan Sin Hok, both specimens are dicyrtids and congeneric and the type species of the genus *Gongylothorax* remains the species illustrated by Tan Sin Hok. Besides this species, that is a dicyrtid, and the type species of the genus *Hiscocapsa*, that is a tetracyrtid, O'Dogherty included in *Hiscocapsa*, among other species, the species *Theocapsa uterculus* Parona, 1890, and *Cyrtocapsa asseni* Tan, 1927, both belonging to another genus and family by having, as proved below, two chambered cephalis. Later O'Dogherty et al., (2017, p. 41), emended this genus, that will be restrained to tetracyrtid nassellarians having a globose postabdominal segment with tubercles. According to them, the species without tubercles belong to another genus. In the present paper we do not consider the morphology of the postabdominal segment (tuberculate or nontuberculate) as having a generic value because there are species whose tubercles are so weakly marked that they seem to be intermediary between the two morphologies (*Hiscocapsa lagunculoides* n. sp. and *H. tuberculata* n. sp.).

Range. Middle Jurassic to early Cretaceous.

Hiscocapsa aitai Dumitrică n. sp.

Figs. 11 i, i1

1982 *Sethocapsa* sp. Foreman – Okamura & Uto, pl. 7, fig. 5.

Description. Shell four-segmented morphologically consisting of two distinct parts: a proximal conical part and a spherical distal part. Proximal conical part made up of a smooth poreless cephalis with an extremely small apical spine and some very small circular pores, a short trapezoidal outlined thorax and abdomen both perforated by pores separated by irregularly longitudinally disposed costae. Collar and lumbar intersegmental separations not evident externally but the lumbar one very well marked by the sudden inflation of the postabdominal chamber. The latter has large circular pores usually hexagonally framed externally and quincuncially disposed. Here and there some very small nodules can appear at some nodal points of the frame. Distal part a little pointed and containing a relatively large circular aperture with sharp border.

Studied material. A single specimen in sample OZ824.

Holotype. The illustrated specimen, coll. MGP-PD, stub PD120-OZ824-R13-07.

Dimensions. Height of specimen 149 µm, of conical part 60 µm, diameter of base of conical part 53 µm, of post-abdominal segment 108 µm, of distal aperture 23 µm.

Etymology. The species is dedicated to Dr. Yoshiaki Aita who was the first to examine some radiolarians from the Ozzastru section (see Dieni et al., 1987b, p. 148).

Remarks. The specimen from Sardinia resembles rather well the species illustrated by Okamura & Uto (1982) by external morphology and the presence of rare nodules on the surface of the postabdominal segment.

Range and occurrence. Very rare in the Sardinian samples and the probably Valanginian from Japan.

Hiscocapsa grutterinki (Tan, 1927)

Figs. 11 a, a1, b, b1

1927 *Cyrtocapsa grutterinki* Tan Sin Hok, p. 64, pl. 13, fig. 110.

1981 *Cyrtocapsa grutterinki* Tan Sin Hok – Schaaf, p. 433, pl. 6, figs. 6a-b.

1982 Gen. et sp. indet. – Okamura & Uto, pl. 3, fig. 13.

1983 *Williriedellum* sp. 1 – Origlia-Devos, p. 214, pl. 24, fig. 15, non 16.

1988 *Cyrtocapsa* sp. cf. *C. grutterinki* Tan Sin Hok – Thurow, p. 400, pl. 8, figs. 2, 3.

1989 *Cyrtocapsa grutterinki* Tan Sin Hok – Tumanda, p. 36, pl. 5, fig. 6.

1992 *Cyrtocapsa grutterinki* Tan Sin Hok (pars) – Ozvoldova & Petercakova, pl. 3, fig. 13, non 11.

1994 *Hiscocapsa grutterinki* (Tan, 1927) – O'Dogherty, p. 201, pl. 31, figs. 14-16; pl. 32, figs. 1-3.

Studied material. Two specimens in samples OZ834 and OZ839 as follows: stub PD120-OZ834-R10-11 and PD120-OZ839-R02-07.

Dimensions. Total length of shell with 3 segments 126-152 µm, diameter of abdomen 105-138 µm.

Remarks. By its shape, *Hiscocapsa grutterinki*, without the postabdominal segment, as it usually occurs, resembles the williriedellid nassellarians from which it differs by having no sutural pore and by the shape of the distal end of the abdomen, that is flat and has angular borders, suggesting that, normally, it should have a thin-walled postabdominal segment.

Range and occurrence. Upper Valanginian to Aptian of Tethys so far as known.

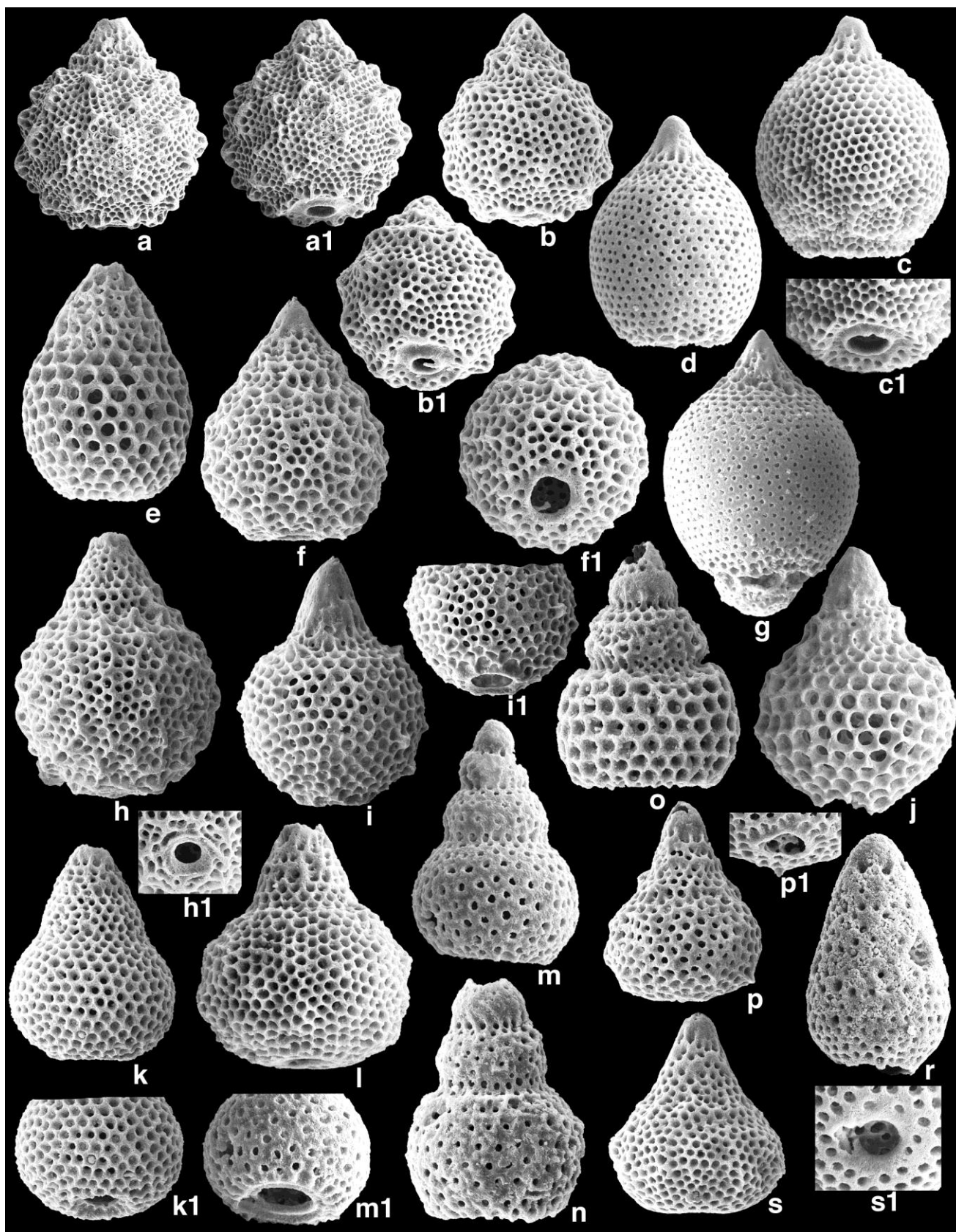


Fig. 11 a-b1 - *Hiscocapsa grutterinki* (Tan): a, OZ834, b, OZ839. c, c1, d, g - *Hiscocapsa* (?) *ventriosa* Dumitrică n. sp.: b, OZ839, c, OZ836, c1, aperture, g - complete specimen, V40, Sviña, Romania. e - *Doliocapsa utoi* Dumitrică n. sp., OZ824. f, f1, h, h1 - *Hiscocapsa rugosacutis* Dumitrică n. sp., OZ826. i-i1 - *Hiscocapsa aitari* Dumitrică n. sp., OZ824. p, s - *Hiscocapsa lagunculoides* Dumitrică n. sp., OZ834, OZ838; p1, s1 - distal apertures of both specimens. j - *Squinabollum* cf. *elegans* Dumitrică n. sp., OZ826. k, k1 - *Doliocapsa weisserti* Dumitrică n. sp., OZ834. l - *Hiscocapsa tuberculata* Dumitrică n. sp., OZ826. m, m1, n - *Doliocapsa erbae* Dumitrică n. sp., OZ834. o - *Doliocapsa favopora* Dumitrică n. sp., OZ834. r - *Doliocapsa mediterranea* Dumitrică n. sp., OZ834. Figs. a-d, j x250; figs. c1, e, e1, f, f1, g, h, i, il, k, k1, l, p, r x300, m-o, p1 x400.

Hiscocapsa lagunculoides Dumitrică n. sp.

Figs. 11 p, p1, s, s1

Description. Shell of four segments, wide conical, with smooth surface and lateral borders slightly concave. Cephalis small, globular, smooth surfaced and without apical horn. Collar boundary marked by a circle of thoracic pores. Thorax and abdomen form together a conical body with almost indistinct external marker of the lumbar boundary. Their surface is smooth but showing a slightly visible tendency to become nodular. Abdomen globular developed more lateral than in length. Its distal end flat, with a constricted aperture with a smooth border or a slightly protruding rim. Pores of thorax, abdomen and postabdominal segments very small, circular and arranged irregularly or with partly quincuncial disposition. Surface of postabdominal segment tending to become nodular; nodules scarcely marked.

Studied material. Two specimens in samples OZ834 and OZ838.

Holotype. Fig. 11p, p1, coll. MGP-PD, stub PD120-OZ838-R05-14a.

Paratype. Fig. 11i, i1, sample OZ 834, coll. MGP-PD, stub PD120-OZ834-R10-05.

Dimensions. Total length 118-120 µm, maximum diameter of postabdominal segment 95-113-µm, diameter of distal aperture 17 µm.

Etymology. From the Latin *laguncula* - small bottle.

Remarks. The specimens, coming from the same sample differ from one another by the density of pores, outside expression of the boundaries between segments, and shape of distal aperture, and resemble each other by the shape of test, number of segments and slightly marked tubercles.

Occurrence. Upper Valanginian so far as known.

Hiscocapsa rugosacutis Dumitrică n. sp.

Figs. 11 f, f1, h, h1

Description. Shell conical, tetracyrtid with last chamber large, spherical with wrinkled surface and open distally. Cephalis poreless, subspherical with a very thin and short apical spine. Collar boundary marked by the appearance of thoracic pores. Thorax and abdomen forming together with cephalis the conical proximal part of the skeleton, difficult to separate from each other. Their wall has small circular pores arranged in more or less circular rows. Postabdominal chamber very large, subspherical with small circular and dense pores arranged in groups of short rows of different orientations. Surface wrinkled, here and there with small nodules interconnected by thin ribs with different directions. Base of postabdomen slightly flattened with narrow funnel shaped circular aperture (Fig. 11fa) or a larger aperture with protruding rim.

Studied material. Two specimens in the sample OZ826.

Holotype. Figs. 11h, h1, OZ826, coll. MGP-PD, stub PD120-OZ826-R11-02 and 02a.

Paratype. Figs. 11f, f1, OZ826, coll. MGP-PD, stub PD120-OZ826-R11-19 and 19a.

Dimensions. Length 145-175 µm, diameter of last chamber 113-125 µm.

Etymology. From the Latin *rugosus*, - a, - um, wrinkled and *cutis* - crust, bark.

Remarks. The two specimens resemble generally to one another by having a rather similar ornamentation of the

postabdominal segment, but differ by having a different distal aperture and arrangement of pores and wrinkles.

Occurrence. Rare in the upper Valanginian of S'Ozzastru section.

Hiscocapsa tuberculata Dumitrică n. sp.

Fig. 11 l

Description. Shell composed of four segments of which the first three form a narrow conical body whereas the last one is large, spherical, slightly tuberculate and open distally. Cephalis partly preserved: it should have been poreless and smooth. Thorax and abdomen trapezoidal, bearing small circular pores which are hexagonally framed and arranged in 3 or 4 circumferential rows especially in the abdominal segment. Collar and lumbar strictures virtually indistinct but the post-lumbar one very well marked by the sudden inflation of the postabdominal segment. This segment is slightly nodose and has larger circular pores disposed in a quincuncial manner. Distal end of postabdominal segment slightly flattened and bearing a smooth bordered and narrow aperture without protruding rim.

Studied material. A single specimen.

Holotype. The illustrated specimen from sample OZ826, coll. MGP-PD, stub PD120-OZ826-R11-05.

Dimensions. Height of test approximately 145 µm, of cephalo-abdominal segment 56 µm, of postabdominal segment 92 µm, diameter of postabdominal segment 128 µm, of distal aperture 20 µm.

Etymology. From Latin *tuberculatus*, - a, - um, by having a tuberculate postabdominal segment.

Remarks. Morphologically, this species is very close to *Doliocapsa aitai* n. sp. (Fig. 11h), from which it differs in having a tuberculate postabdominal segment and a flatter distal end.

Occurrence. Very rare in the Sardinian section.

Hiscocapsa ventriosa Dumitrică n. sp.

Figs. 11c, c1, d, g

1982 Gen. et sp. indet. - Okamura & Uto, pl. 5, fig. 12.

Description. When entire, shell consists of three external morphological parts: a short proximal conical part, a big spherical or ovoid central part, and a distal cap-shaped part. Inner structure not known but supposed to be four-segmented. The proximal conical part consists of a simple cephalis and thorax. Boundary between them and between thorax and abdomen difficult to trace because usually it is not marked by any change in outline. Cephalis smooth-surfaced and generally imperforate. Thorax trapezoidal in outline and short, its pores irregularly disposed. Abdomen large, ovoid with pores of honeycomb structure (fig. 11c). With mature specimens, surface of abdomen is smooth and opening of pores is small and circular due to an external layer of silica that narrows the diameter of pores (fig. 11b, g). For most specimens the abdomen represents the last segment of shell, and its distal part is straight, as if transversally cut. The distal opening of this part is rather large with protruding rim. Complete specimens (fig. 11g) have a hemispherical or inverted cupola-shaped fourth segment that is closed distally; it is thin-walled and easily dissolved or broken off, or not yet built in most specimens.

Studied material. Three specimens in OZ836 and OZ839 and many in the Valanginian of Svinița, Romania.

Holotype. Fig. 11c, OZ839, coll. MGP-PD, stub PD120-OZ836-R08-13.

Paratype. Fig. 11b, OZ839-coll. MGP-PD, stub PD120-OZ839-R03-02.

Dimensions. Length of shell without the fourth segment 164-180 μm , with fourth segment 205-220 μm , maximum diameter of abdomen 124-142 μm .

Etymology. From the Latin adjective – *ventriosus*, -a, -um – round-bellied.

Remarks. All specimens from the Ozzastru section, although very well preserved, have the last segment dissolved or broken off. To have a complete image and description of the species we included on Fig. 11 the pyritized specimen **g** from the Valanginian of the Murguceva Formation, Vodinițki valley, Svinița (Romania), where complete specimens are not rare and very well preserved in pyrite.

Range and occurrence. Valanginian of Sardinia, Japan and Romania.

Genus *Doliocapsa* O'Dogherty, Goričan & Gawlick, 2017

Type species. *Stichomitra* (?) *stecki* O'Dogherty, Goričan & Dumitrică, 2006.

Remarks. According to the original diagnosis, we include in this genus species with small, hornless, simple and usually poreless spherical cephalis, and conical shell consisting usually of four or maximum five segments, the last one larger than the others and with a large terminal aperture. Aperture is either funnel-shaped (11k1) or has a protruding circular rim separated from the shell of the distal segment by a circular depression (Fig. 11m1). This type resembles the segmental partitions of many multicystid nassellarians (see, for example, Pessagno 1977b, pl. 7, figs. 19, 21, 26), suggesting that the distal segment should have had a small, or a very thin-walled terminal inverted conical or cap-shaped fifth segment usually dissolved after the death of the organism, or some distal projections.

The species included in this genus can be assembled into 2 groups:

- a) one group is similar to the type species and consists of conical species with chambers increasing regularly in diameter as added and with a large distal aperture. This group can include: *Stichomitra* (?) *stecki* O'Dogherty, Goričan & Dumitrică, 2006, *Doliocapsa erbae* Dumitrică n. sp., *D. favopora* Dumitrică n. sp. and *D. mediterranea* Dumitrică n. sp.
- b) the second group includes species with the last segment much greater and the distal aperture simple, without a protruding rim surrounded by a circular depression. It would comprise the following species: *Doliocapsa aitai* Dumitrică n. sp., *D. lagunculoides* Dumitrică n. sp., *D. tuberculata* Dumitrică n. sp., *D. weisserti* Dumitrică n. sp. and *D. utoi* Dumitrică n. sp.

Doliocapsa erbae Dumitrică n. sp.

Figs. 11m, m1, n

1986 *Stichomitra* sp. A – Aita & Okada, p. 122, pl. 3, fig. 3.

Description. Shell conical consisting of four segments well distinct due to their convex outline and well-marked constrictions. Cephalis globular, smooth without apical horn. Thorax, abdomen and postabdominal segments increasing regularly in length and diameter as added. Their surface relatively smooth and wall perforated by small circular pores which are irregularly disposed and increase in diameter distally. Each constriction is marked by a circle of pores. Aperture represented by an intersegmental type partition with protruding margin.

Studied material. Two rather similar specimens.

Holotype. Fig. 11m, ma, sample OZ834, coll. MGP-PD, stub PD120-OZ834-R09-23a.

Paratype. Fig. 11n, sample OZ834, coll. MGP-PD, stub PD120-OZ834-R09-35.

Dimensions. Total length 145-146 μm , diameter of last segment 100-106 μm , diameter of distal aperture 31 μm .

Etymology. The species is dedicated to Prof. Elisabetta Erba for her contribution to the knowledge of the Lower Cretaceous calcareous nannofossils.

Remarks. This new species resembles rather well *Stichomitra* sp. A of Aita & Okada (1986), from the upper Tithonian of Komikuchi Formation, Kaminogo, Japan, by having small and irregularly distributed pores, smooth surface and quite similar morphology, and differs only by having deeper intersegmental constrictions.

Occurrence. Upper Tithonian of Japan and upper Valanginian of S'Ozzastru section, Sardinia, Italy.

Doliocapsa favopora Dumitrică n. sp.

Fig. 11o

Description. Conical shell consisting of four segments increasing regularly in length and diameter as added. Cephalis spherical, smooth-surfaced and probably without apical horn. Following three segments with inflated outline. Thorax a little larger than cephalis, with smooth surface and practically poreless, except a circle of very small pores at the contact with the cephalis. Abdomen trapezoidal in lateral view with 4 circumferential rows of small pores. Postabdominal segment with 6-7 circumferential rows of pores. Pores quincuncially disposed with thin intervening bars. Aperture large, circular with protruding rim. This rim and the slightly serrate margin of the test suggest a possible thin distal segment dissolved after the death of the specimen.

Studied material. One specimen from sample OZ834.

Holotype. The illustrated specimen, coll. MGP-PD, stub PD120-OZ834-R09-34.

Dimensions. Total length 146 μm , diameter of last segment 110 μm .

Etymology. From the Latin *favus* - honeycomb, and *porus* - pore, due to the characteristic distribution of pores on the postabdominal segment.

Remarks. *Doliocapsa favopora* n. sp. is morphologically quite close to *Doliocapsa erbae* n. sp. by the general shape and number of segments, but differing by having larger postabdominal pores distributed in transversal circles.

Occurrence. A single specimen in the Ozzastru section, upper Valanginian.

Doliocapsa mediterranea Dumitrică n. sp.

Fig. 11r

Description. Shell conical, smooth surfaced, without apical horn and consisting probably of four or five segments. Except for the collar boundary, marked by a few larger pores, boundaries between segments are difficult to identify being not marked outside by constrictions or other morphological or structural characters, except probably some circumferential rows of larger pores. Cephalis imperforated with rounded apex. Collar boundary marked by 3 or 4 pores visible on half the perimeter. Thorax and the following segments trapezoidal, constantly increasing in diameter up to the last but one segment, which is the widest. Last segment inverted trapezoidal, decreasing in diameter rapidly. Distal end open, with more or less regular border represented by the margin of the last circumferential row of pores. Pores distributed in circumferential rows, interrupted or irregular in some places.

Studied material. A single specimen in sample OZ834.

Holotype. Fig. 11r, coll. MGP-PD, stub PD120-OZ834-R09-29.

Dimensions. Length 143 μm , diameter of last chamber 87 μm .

Etymology. From its occurrence in the Mediterranean area.

Remarks. This species differs from the other congeneric taxa occurring in the Sardinian material by having a smooth-surfaced shell and segmentation not marked outside by constrictions.

Occurrence. A single specimen from the upper Valanginian of S'Ozzastru.

***Doliocapsa utoi* Dumitrică n. sp.**

Fig. 11d

1982 Amphipyndacid gen. et sp. indet. – Okamura & Uto, pl. 2, fig. 11, non 12.

Description. Shell ovoid, probably four segmented and opened distally. Cephalis, incompletely preserved, should have been imperforated, smooth-surfaced and slightly pointed. Thorax and abdomen hardly to separate from each other; they are trapezoidal in lateral view and their pores irregularly disposed on the proximal part of this segment and in circumferential rows on the distal portion. Last segment higher and larger with convex outline; pores larger in the middle part, decreasing in size distally and arranged quincuncially in circumferential rows

Studied material. A single specimen.

Holotype. The illustrated specimen, coll. MGP-PD, stub PD120-OZ824-R13-18.

Dimensions. Length 172 μm , maximum diameter 122 μm .

Etymology. The species is dedicated to Hideyuki Uto who, together with M. Okamura, illustrated this radiolarian from the Lower Cretaceous of Japan.

Remarks. A perfectly similar species was illustrated by Okamura & Uto (1982) from the probably coeval sample YK-546 from the Lower Cretaceous chert sequence in the Yokonami Mélange of Shimanto Belt, Shikoku (Japan). This new species resembles somehow *D. favopora* n. sp., from which it differs in having smaller postabdominal pores and less marked intersegmental constrictions.

Occurrence. Upper Valanginian of Sardinia and probably of Japan.

***Doliocapsa weisserti* Dumitrică n. sp.**

Figs. 11k, k1

2017 aff. *Doliocapsa matsukoi* (Yeh) – O'Dogherty, Goričan & Gawlick, p. 17, figs. 8.33-?34.

Description. Shell composed of four segments, conical with the postabdominal chamber much larger than a normal cone. Cephalis small, poreless, separated from thorax by a circumferential row of pores. Thorax and abdomen truncate-conical with vaguely convex margin and dense circular pores arranged alternately in circumferential and oblique rows. Postabdominal chamber much larger than the abdominal one, subglobular, with smooth surface. Its pores are circular, larger than the abdominal ones, polygonally framed and quincuncially arranged. Distal end with a rather large aperture with truncate-conical opening and costate inner contour suggesting a possible very thin terminal cap dissolved after the death.

Studied material. The illustrated specimen.

Holotype. Fig. 11k, k1, coll. MGP-PD, stub PD120-OZ834-R09-03a.

Dimensions. Length 130 μm , diameter of last chamber 100 μm , inner diameter of aperture 17, outer diameter of distal aperture 33 μm .

Etymology. Dedicated to Prof. Helmut Weissert for his contribution to the knowledge of the anoxic events of the Early Cretaceous.

Remarks. The shape of this species is rather similar to that of the Middle Jurassic (Bajocian to Bathonian) species *Hiscocapsa matsukoi* Yeh (2009, 2011) from the Snowshoe Formation of east-central Oregon, transferred to the genus *Doliocapsa* by O'Dogherty et al. (2017). It has in common with this species the number of segments, general shape and the type of the distal aperture. However, the specimens from the Middle Jurassic of Oregon have deep constrictions and much larger last segments. Other specimens with which it can be compared have been illustrated by O'Dogherty et al. (2016, pl. 8, fig. 33) under the same species name (*Doliocapsa matsukoi*) from the Bathonian-Oxfordian from the Hallstatt Mélange. These specimens differ from the Sardinian specimen by having the first three segments of shell forming a thin and longer conical part without intersegmental constrictions. In our opinion, these different morphotypes of different ages represent different species of the same genus. It is for this reason that we erect a special species for the late Valanginian specimen from Sardinia. No species could traverse such a long period without change of taxonomic identity.

Occurrence. Very rare in Upper Valanginian of S'Ozzastru section.

Family *Crococapsidae* Dumitrică n. fam.

Type genus. *Crococapsa* O'Dogherty, Goričan and Gawlick, 2017.

Diagnosis. Conical and distally closed tetracyrtid, exceptionally tricyrtid nassellarians with cephalic cavity divided into two chambers by a transversal septum, and the last chamber without a distal aperture. First three, or two chambers in case of tricyrtid shell, forming a cylindrical or conical body well distinct from the last chamber, which is much larger.

Remarks. This new family is erected for the genera *Crococapsa* O'Dogherty, Goričan & Gawlick 2016, *Ocelli-*

capsa n. gen. and *Squinabolum* Dumitrică 1970, that differ from the members of the family Minocapsidae O'Dogherty, Goričan & Gawlick 2017 by having the cephalis divided into two chambers by a transversal septum rather similar to that of the family Amphipyndacidae or to the genus *Squinabolum*.

The family Crocopsidae, as defined herein, includes only the cited genera. The genera *Doliocapsa* O'Dogherty, Goričan & Gawlick, 2017, *Hemicryptoccephalis* Li 1988 and its related genus, *Quarkus* Pessagno, Blome & Hull in Pessagno et al. 1993, are excluded from this new family because their cephalis is simple and the last segment has an aperture.

The amphipyndacid structure of the cephalis is very easily visible in the Text-fig. 2, which represents an inner cast of *Crocopsa uterculus* (Parona, 1890) from a Lower Cretaceous chert of Turkey. It shows also that the abdomen of this species is also partly encased in the post-abdominal chamber and, for this reason, the ocelli are opened in apical direction and, consequently, they are better seen in apical or obliquely apical positions (see Fig. 12f1). The two-chambered cephalis was also well illustrated by Tan Sin Hok (1927, pl. 14, figs. 118-120), with drawings of his Lower Cretaceous species *Cyrtocapsa asseni* Tan and *Cyrtocapsa houwi* Tan (that should be assigned to the genus *Crocopsa*), and probably also of *Stichocapsa pseudoornata* (Tan, 1927, pl. 15, fig. 134). The lower chamber of the cephalis is easily recognizable by its shorter height and narrower diameter compared with the respective size of the upper chamber (see also Foreman, 1966, text-figs. 7-11). Other good images of the two-chambered cephalis are very well visible in *Sethocapsa uterculus* (Parona) illustrated in transmitted light by Schaaf (1981, pl. 26, figs 5a, b), and also in *Siphocampium davidi* Schaaf (1981, pl. 27, figs. 10a, b) and *Siphocampium ruteni* (Tan, 1927, pl. 27, figs. 11a, b). Consequently, *S. davidi* becomes a species of *Crocopsa*, and *S. ruteni* of *Ocellicapsa* nov. gen. (see below) due to its tuberculate postabdominal segment.

A short mention deserves the genus *Siphocampium* Haeckel, 1881, adopted by Schaaf for the species *S. davidi* and *S. ruteni* and also for *Dicolocapsa macropora* Rüst, 1888). As Schaaf himself (1981, p. 438) mentioned, he used questionably this genus because its type species (*Siphocampium accrescens* Rüst, 1885 figured on pl. 13, fig. 11, from the Upper Jurassic radiolarian cherts of Riggli, Switzerland) "has a cephalis sufficiently elongated to accommodate two chambers, and that this name is used to avoid or postpone the necessity of establishing a new genus". This type species has a cylindrical cephalis and a scalariform skeleton formed of 4 short cylindrical chambers that increase in diameter very fast, and the last chamber has the distal border frayed suggesting that it represents an apical fragment of an entire specimen. For this reason, O'Dogherty (2009, p. 441, fig. 542), in his inventory of Mesozoic radiolarian species, considered this species a *nomen dubium* nassellarian. This fragment resembles perfectly the apical part of the upper Middle to lower Upper Jurassic species *Palinandromeda podbielensis* (Ozoldova, 1979) and its probable synonym *Andromeda violae* Baumgartner 1980, a Bathonian to Oxfordian nassellarian species well illustrated in Baumgartner et al. (1980, 1995). Consequently, we can now con-

sider with sufficient certainty that *Siphocampium accrescens* Rüst 1885 is nothing else than a proximal fragment of *Palinandromeda podbielensis* (Ozoldova 1979).

Genus ***Crocopsa*** O'Dogherty, Goričan and Gawlick, 2017, emended herein.

Type species. *Sethocapsa hexagona* Hori, 1999.

Emended diagnosis. Conical tetracyrtid nassellarians having two-chambered cephalis and globose postabdominal segment. Cephalis without apical horn and, generally, poreless, and postabdominal segment not tuberculated, distally closed or having a discrete number of smaller pores grouped on the distal end. Collar and lumbar segmentation well recognizable or indistinct externally. Post-lumbar boundary well distinguished by a well-marked stricture with or without a circumferential row of larger pores (ocelli).

Remarks. This genus, initially assigned to the family Minocapsidae, includes four-segmented species with last segment without tubercles, such as: *Sethocapsa hexagona* Hori, 1999, *Sethocapsa accincta* Steiger, 1992, *Sethocapsa* (?) *subcrassitestata* Aita, 1986, *Sethocapsa* (?) *ruteni* Tan, 1927, *Cyrtocapsa asseni* Tan, 1927, *Sethocapsa horokanaiensis* Kawabata, 1988, *Sethocapsa uterculus* Parona, 1890, *Sethocapsa pseudouterculus* Aita, 1986, *Sethocapsa zweilii* Jud, 1994, *Sethocapsa kitoi* Jud, 1994, *Sethocapsa lagenaria* Wu and Li, 1982, *Sethocapsa* sp. B and *Sethocapsa* sp. C of Aita & Okada (1986), *Stichocapsa pseudoornata* Tan, 1927, *Cyrtocapsa houwi* Tan, 1927, *Cyrtocapsa asseni* Tan, 1927, *Minocapsa aitai* Hull, 1997, *Minocapsa* (?) *tansinhoki* Hull, 1997, and probably *Minocapsa* (?) sp. of Hull (1997). The ocelli, characteristic of the stratigraphically younger species (uppermost Jurassic and Lower Cretaceous), are smaller in the Upper Jurassic species or not differentiated from the pores of the postabdominal segment, and larger in the Lower Cretaceous ones. The type species does not seem to have large ocelli but smaller ones, well visible on the fig. 6.13 of Hori (1999) as a circle of small pores around the postlumbar boundary. A similar circle of small pores is visible in the specimen illustrated as *Sethocapsa* sp. A by Inose et al. (2018, fig. 6.20).

Range. Late Jurassic to Late Cretaceous.

Crocopsa* cf. *horokanaiensis (Kawabata, 1988)

Fig. 12b

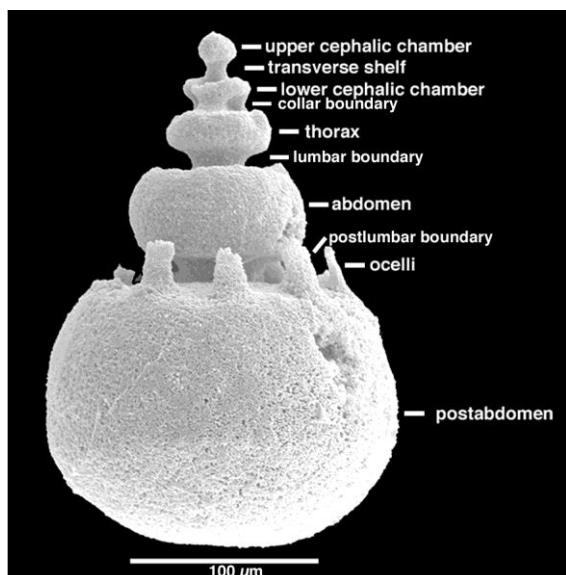
1982 *Sethocapsa* (?) sp. – Matsuyama et al., p. 377. pl. 1, fig. 6.

1988 *Sethocapsa horokanaiensis* Kawabata, p. 4, pl. 1, fig. 10, non 9, 11, 12.

1997 *Sethocapsa horokanaiensis* Kawabata – Ishida & Hashimoto, pl. 3, fig. 9.

2009 *Stichocapsa* sp. B – Ishii et al., pl. 17, fig. 12.

Description. Shell narrow conical with 5 ocelli well visible in lateral view on half a perimeter. Cephalis practically imperforate with rounded apex and separated from thorax by a circumferential row of pores. Thorax and abdomen trapezoidal in lateral view with irregularly distributed very small pores. They increase in diameter distally, and those of thorax have protruding rims. Post abdominal segment hemispherical, a little higher than its ray and separated from abdomen by a circumferential row of



Text-fig. 2 Inner mould of a specimen of *Crococapsa uterculus* (Parona) from a Valanginian sample of the Batain Plain, Oman.

wide ocelli, five on half a perimeter. Pores of postabdominal segment circular, polygonally framed and larger than those of the abdomen.

Studied material. A single specimen in sample OZ834, coll. MGP-PD, stub PD120-OZ834-R10-14.

Dimensions. Length 137 μm , diameter of last segment 77 μm .

Remarks. The illustrated specimen differs from the holotype of *Stichocapsa horokanaiensis* by not having the pores of the thorax and abdomen polygonally framed. It differs from *Crococapsa zwellii* (Jud, 1994), to which it seems also close, by being slimmer and also by having the postabdomen much smaller. Two specimens quite similar to the studied one were illustrated by Ishii et al. (2009) from north-western Pacific, and Ishida & Hashimoto (1997) from the East Shikoku, Japan. It can be inferred that this morphology could correspond to an independent species which, however, we do not dare to describe herein.

Occurrence. Upper Valanginian of Sardinia.

Crococapsa uterculus (Parona, 1890)

Figs. 12e-h, ha; text-fig. 2

1890 *Theocapsa uterculus* Parona, p. 168, pl. 5, fig. 17.

1975 *Sethocapsa* sp. cf. *Theocapsa uterculus* Parona – Foreman, p. 617, pl. 21, figs. 21, 22.

1978 *Sethocapsa* sp. cf. *Theocapsa uterculus* Parona – Foreman, p. 749, pl. 2, fig. 8.

1981 *Sethocapsa* sp. cf. *Theocapsa uterculus* Parona – Kanie et al., pl. 1, fig. 12.

1981 *Sethocapsa uterculus* (Parona) – Schaaf, p. 437, pl. 5, figs. 8a, b; pl. 26, figs. 5a, 5b.

1981 *Sethocapsa* sp. cf. *Theocapsa uterculus* Parona – Kanie et al., pl. 1, fig. 12-

1982 *Sethocapsa uterculus* (Parona) – Okamura & Uto, pl. 3, fig. 15.

1984 *Sethocapsa uterculus* (Parona) – Baumgartner, p. 784, pl. 8, fig. 15.

1984 *Sethocapsa uterculus* (Parona) – Schaaf, p. 150, figs. 1a, b, 3a, b, 4, non 2a-c.

1984 *Sethocapsa uterculus* (Parona) – Yao, pl. 4, fig. 1.

1985 *Sethocapsa uterculus* (Parona) – Kiminami et al., pl. 2, fig. 12.

1986 *Sethocapsa uterculus* (Parona) – Suyari, pl. 4, figs. 1, 2.

1987 *Sethocapsa uterculus* (Parona) – Kito, pl. 2, fig. 1.

1989 *Sethocapsa uterculus* (Parona) – Tumanda, p. 39, pl. 5, fig. 7.

1991 *Sethocapsa uterculus* (Parona) – Aguado et al., text-fig. 7.12.

1992 *Sethocapsa uterculus* (Parona) – Matsuoka, pl. 1, fig. 4, non pl. 2, fig. 9 = *Crococapsa kitoi* (Jud, 1994).

non 1992 *Sethocapsa uterculus* (Parona) – Steiger, p. 63, pl. 17, fig. 14 = *Crococapsa kitoi* Jud, 1994.

1992 *Sethocapsa uterculus* (Parona) – Taketani & Kanie, text-fig. 5.4.

1994 *Sethocapsa uterculus* (Parona) – Jud, p. 106, pl. 20, figs. 15, 16.

1994 *Sethocapsa uterculus* (Parona) – Goričan, p. 87, pl. 15, figs. 11-15.

1994 *Sethocapsa uterculus* (Parona) – O'Dogerty, p. 198, pl. 30, figs. 12-16.

1995 *Sethocapsa uterculus* (Parona) sensu Foreman – Baumgartner et al., p. 504, pl. 5462.

2002 *Hiscocapsa uterculus* (Parona) – Suzuki et al., p. 60, fig. 4.5.

2003 *Hiscocapsa uterculus* (Parona) – Zyabrev et al., fig. 3.27.

2009 *Hiscocapsa uterculus* (Parona) – Ishii et al., pl. 20, fig. 15.

2014 *Hiscocapsa uterculus* (Parona) – Robertson et al., fig. 10(A).

2017 *Hiscocapsa uterculus* (Parona) – Xu & Luo, fig. 5.I.

Studied material. Seven illustrated specimens in OZ825, OZ834 and OZ836, coll. MGP-PD, stub PD120-OZ825-R12-13 and 24, PD120-OZ834-R09-10 and 36, PD120-R10-18 and 21, and PD120-OZ836-R08-29.

Dimensions. Length of shell 154-184 μm , of postabdomen 92-116 μm , diameter of postabdomen 104-142 μm .

Remarks. As one can see from the specimens published to date, this species presents a rather wide variability. The most variable is the abdomen. It can be a simple segment, a little larger in diameter than the thorax, forming a conical body together with the cephalis and thorax (Fig. 12e), but usually it expands very much laterally, forming a flat ring-shaped segment (Fig. 12g, h) similar to the segment illustrated by Rüst (1898, p. 46, pl. 14, fig. 10) in *Sethocapsa crucigera*, that seems to be a junior synonym of *C. uterculus* (see Jud, 1994, p. 106). A special characteristic of this taxon is also represented by the postabdominal segment that, in lateral view, is very well separated from the abdomen by a deep constriction. In oblique apical view this constriction can be seen to correspond to the ring of ocelli at the contact of the postabdominal segment with the abdominal one (Figs. 12f, fa). The cast of this species (Text-fig. 2) shows that the ocelli are vertically opened because the abdomen is partly submerged in the postabdominal cavity and the real contact between the two segments is at the base of the abdomen. As a consequence, the ocelli form a rather long tube between the wall of the partly hidden abdomen in the postabdominal

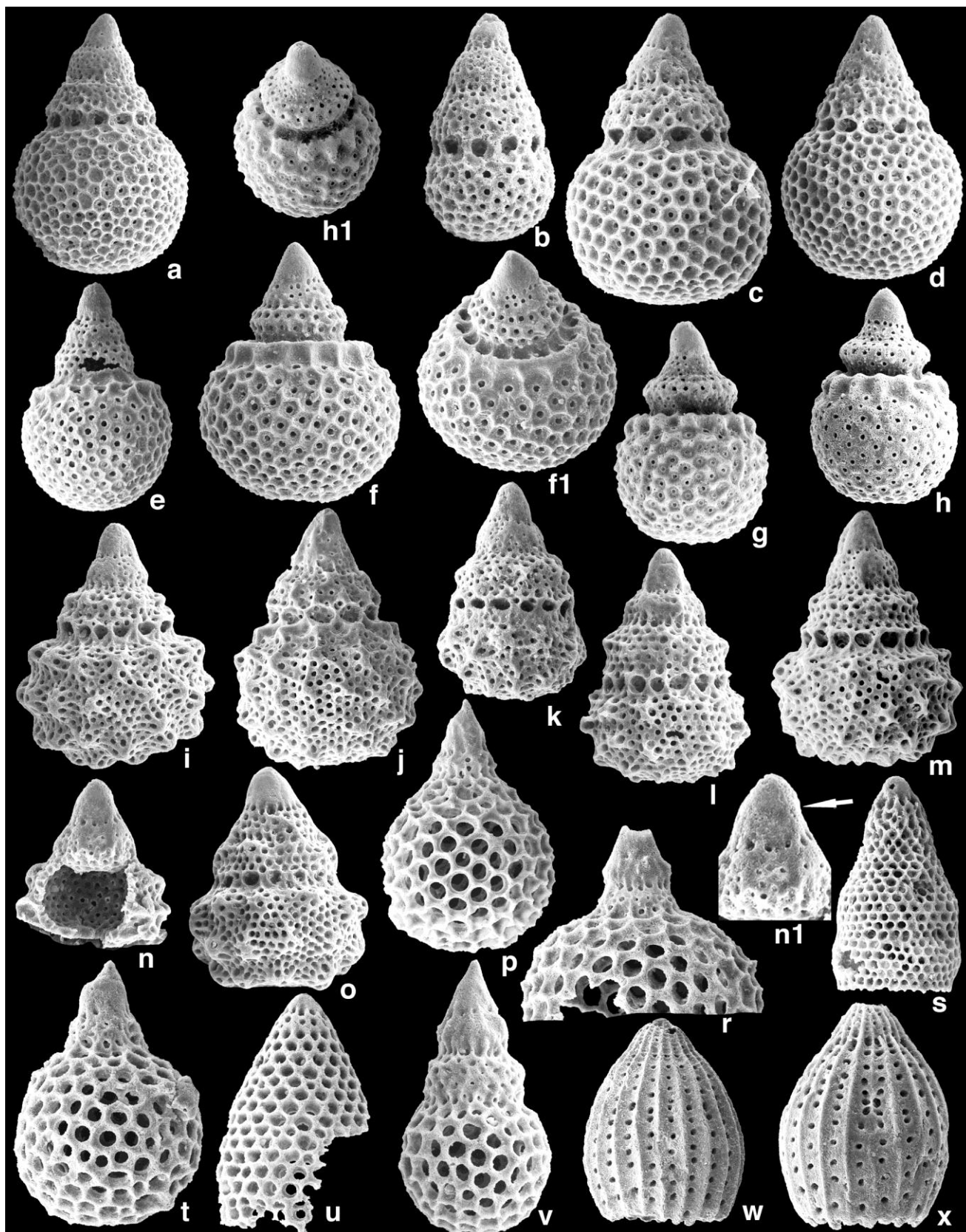


Fig. 12 b - *Crococapsa* cf. *horokanaiensis* (Kawabata), OZ834. **a, c, d** - *Crococapsa zweilii* (Jud): **a**, OZ826; **c**, OZ836; **d**, OZ825. **e-h** - *Crococapsa uterculus* (Parona): **e, f, h** - OZ834, **g** - OZ825. **i-o** - *Ocellicapsa ruthae* Dumitrică n. sp.: **i** - OZ837, **j** - OZ837, **k** - OZ836, **l** - OZ834, **m** - OZ824, **n** - OZ838, **n1** - detail of cephalothoracic body, arrow shows the place of very small pores at the boundary between the two parts of cephalic cavity, **o** - OZ825. **p, r, t, v** - *Squinabolum elegans* Dumitrică n. sp.: **p** - OZ824, **r** - OZ826, **t** - OZ836, **s** - *Amphipyndax zybrevi* Dumitrică n. sp. - OZ825. **u** - *Campanomitra pulchella* (Rüst), OZ836. **v** - OZ834. **w, x** - *Archaeodictyomitra inflata* Dumitrică n. sp.: **w** - OZ839, **x** - OZ834. Figs. **a, c-h, u** x250, all the others x300.

cavity and the postabdominal wall. In lateral view the length of these tubes is well marked on the surface of the shell by large frames of a circumferential row of small pores characteristic of this species.

Range. Abundant from Berriasian to lower Aptian, UAZ 6-35 of Jud (1994), cosmopolitan.

Crococapsa zweilii (Jud, 1994)

Figs. 6h; 12a, c, d

?1982 *Sethocapsa lagenaria* Wu & Li, p. 70. pl. 2, fig. 9. 1991 radiolari – Dieni & Massari, fig. 23h.

1994 *Sethocapsa* (?) *zweilii* Jud, p. 106, pl. 20, figs. 12-14.

2017 *Hiscocapsa zweilii* (Jud) – Xu & Luo, fig. 5J.

Description. The last (postabdominal) segment is much larger than the cephalo-abdominal body, resulting in a sphero-conical shell with relatively well marked intersegmental constrictions. Cephalis conical, imperforate with rounded apex separated from thorax by a circle of very small pores. Thorax trapezoidal in lateral view with very small circular pores. Abdomen trapezoidal too, with pores larger than those of the thorax and polygonally framed. Postabdominal segment very large, globular with 5-6 large, laterally opened ocelli on half a perimeter. It has small circular pores on the inner side of wall separated by large polygonal, commonly hexagonal, frames on the surface. Size of frames becomes smaller distally.

Studied material. Three specimens in OZ825, OZ826 and OZ836, coll. MGP-PD, stub PD120-OZ825-R12-03 and 33, PD120-OZ826-R12-03, and PD120-OZ836-R07-15.

Dimensions. Total length 188-208 µm, diameter of post-abdomen 128-148 µm

Remarks. This species is very close to *C. horokanaiensis* (Kawabata, 1988) and probably *Crococapsa accincta* (Steiger, 1992). However, the latter species has practically no intersegmental constrictions; its last segment has a smaller diameter by comparison with the other species and, above all, its apical end is rather acute and very small that does not suggest a two-chambered cephalis. *C. horokanaiensis* differs from *C. zweilii* by being much longer, by having well marked intersegmental constrictions and circular pores with polygonal frames. All these three species have laterally opened ocelli. Another species similar to *C. zweilii*, and probably its senior synonym, is *Sethocapsa* (?) *lagenaria* Wu & Li, 1982. Unfortunately, its figured position is oblique, and the ocelli are difficult to see; they seem to be apically oblique instead of laterally directed.

Range. Berriasian to lower Hauterivian, UAZ 6-26 of Jud (1994).

Genus ***Ocellicapsa*** Dumitrică n. gen.

Type species: *Ocellicapsa ruthae* nov. sp.

Diagnosis. Closed tetracyrtid nassellarians with imperforated two-chambered cephalis without apical horn. First three segments form a conical body, and the last one is larger than the others, has no distal aperture, and its boundary with the abdominal chamber is marked by a characteristic circumferential row of wide openings (ocelli). Last segment with tuberculate surface, a morphology that can invade also the abdomen or even the thorax.

Remarks. This new genus is proposed because O'Dogherty et al. (2016), in describing *Crococapsa*, ex-

cluded from it the species with tuberculate last segment. The taxa assigned to this new genus are the following: *Ocellicapsa ruthae* n. sp., *Sethocapsa kaminogoensis* Aita 1986, *Sethocapsa* (?) aff. *kaminogoensis* Aita, 1986, *Sethocapsa* (?) *subcrassitestata* Aita 1986, *Sethocapsa* cf. *clava* (Parona) in Aita & Okada 1986, *Sethocapsa* (?) *rutteni* (Tan) in Aita & Okada (1986), *Sethocapsa* (?) sp. B in Aita & Okada 1986, *Sethocapsa* (?) sp. C in Aita & Okada 1986, *Stichocapsa pseudoornata* (Tan, 1927), *Sethocapsa* cf. *kaminogoensis* Aita and *Sethocapsa* sp. (in Kato & Iwata, 1989, illustrated in pl. 2, figs. 10 and 11; pl. 4, fig. 9).

This new genus is very close to *Crococapsa* O'Dogherty, Goričan & Gawlick (2017), from which it differs only by having a tuberculate postabdominal segment and almost always a circumferential row of wide ocelli at the postabdominal boundary with the abdominal one, a structural feature very well visible in almost all species of this genus. *Ocellicapsa* could also be considered as a subgenus of *Crococapsa* if the tuberculate morphology is considered of lower taxonomic value.

Etymology. From the Latin *ocellus*, plural *ocelli* = small eyes and *capsa* = capsule.

Range. Berriasian to Barremian or younger.

Ocellicapsa ruthae Dumitrică nov. sp.

Figs. 12i-o

1982 *Sethocapsa* sp. – Okamura & Uto, pl. 3, fig. 12.

1982 *Tricolocapsa* sp. – Okamura & Uto, pl. 9, figs. 1a-b.

1982 unnamed nassellarinid C – Wu & Li, pl. 2, fig. 16.

1989 *Sethocapsa kaminogoensis* Aita – Tumanda, p. 39, pl. 4, figs. 13, 14; ? pl. 10, fig. I12

1994 *Sethocapsa* sp. aff. *kaminogoensis* Aita – Jud, p. 104, pl. 19, fig. 15; pl. 20, figs. 1, 2.

1994 *Sethocapsa kaminogoensis* Aita – Goričan, p. 87, pl. 15, fig. 7.

2003 *Hiscocapsa kaminogoensis* (Aita) – Zyabrev et al., fig. 3.25.

2009 *Hiscocapsa kaminogoensis* (Aita) – Ishii et al., pl. 20, fig. 11.

2017 *Hiscocapsa* sp. aff. *H. kaminogoensis* (Aita) – Xu & Luo, fig. 5H.

Description. Shell tetracyrtid, conical and tuberculate. Cephalis conical and smooth with rounded apex and imperforate. Thorax about as long as cephalis but much wider. Its wall perforated by very small and irregularly distributed pores, and its distal part constricted and plunged in the abdominal cavity (Fig. 12n). Collar boundary usually marked by a shallow constriction and by the presence of pores. Shell has usually about four or five tubercles on half the perimeter. Abdomen higher and much wider than thorax, with wall perforated by circular pores wider than those of thorax, and surface covered with a circumferential row of tubercles. Lumbar boundary marked by an evident constriction resulted from the fast increase of the diameter of abdomen. Postabdominal chamber globular and much wider than the other segments. It bears numerous tubercles arranged irregularly and commonly interconnected at the surface of the shell by ribs. Pores dense, circular, arranged in irregular rows of different orientations. At the boundary with abdomen the postabdominal chamber bears a circumferential row of large ocelli open in lateral direction. Their number

varies from 6 to 8 on half the perimeter. Distal part of the abdomen rather flat or convex and closed.

Studied material. 14 figured specimens from samples OZ824, OZ825, OZ834, OZ836, OZ837 and OZ838.

Holotype. Fig. 12i, coll. MGP-PD, stub PD120-OZ837-R06-22.

Paratype. Fig. 12l, coll. MGP-PD, stub PD120-OZ824-R13-22.

Dimensions. Total length 153-174 μm , length of the first three chambers 89-90 μm , of cephalis 23-24 μm , diameter of base of cephalis 26-28 μm , of thorax 44-48 μm , of abdomen 70-84 μm , of postabdominal segment 106-140 μm ,

Etymology. The species is dedicated to Ruth Dumitrică-Jud who first described the morphology of this species and remarked that, in spite of its resemblance with *Sethocapsa kaminogoensis* Aita, 1986, it differs from this taxon by the lateral opening of the large pores (= ocelli) between the abdomen and the postabdominal segment.

Remarks. *Ocellicapsa ruthae* nov. sp. is very similar to *O. kaminogoensis* (Aita) by having a tuberculate skeleton but differs by having the ocelli opened in lateral directions, so that they are well visible in lateral view, whereas in *O. kaminogoensis* they are visible in apical or obliquely apical view (see Aita & Okada, 1986, pl. 5, figs. 3, 6; Takahashi & Ishii, 1995, pl. 2, fig. 26), as in *Crococapsa uterculus* (Parona, 1890). It is strange that Jud (1994), who studied also the Berriasian radiolarian fauna from Breggia, type locality of *O. kaminogoensis*, did not illustrate specimens of this species. The three specimens illustrated and considered by her as having affinities with this species, came: one from the upper Valanginian of the Fiume Bosso section, and two from the Barremian of the Presale and Fiume Bosso sections, respectively. Even the specimen illustrated by Goričan (1994) as *O. kaminogoensis*, and that is in fact *O. ruthae*, comes from the upper Valanginian-Hauterivian of her zonation. This situation could have a single explanation: the sample in which Aita & Okada founded their species *O. kaminogoensis* came from a level of the Berriasian lower than that from which Jud collected her Berriasian fauna. Therefore, *O. kaminogoensis* could be considered as the forerunner of *O. ruthae* and the transition between the two species could have taken place during the late Berriasian or earliest Valanginian.

Range. Valanginian to Barremian so far as known.

Genus *Squinabollum* Dumitrică, 1970

Type species: *Clistophaena fossilis* Squinabol, 1903 = *Squinabollum fossile* (Squinabol)

Remarks. The species from the upper Valanginian of Sardinia here referred to *Squinabollum* is the oldest known member of this genus. According to O'Dogherty (1994), *Squinabollum* has its origin in *Hiscocapsa asseni* (Tan, 1927), a four-chambered species originated in early Barremian or Hauterivian and disappeared in the Turonian. However, its occurrence in the upper Valanginian of Sardinia proves that the origin of this genus is older, and that *H. asseni* cannot be its probable forerunner, although the two species seem to be closely related: both have a two-segmented cephalis and the morphology of the abdomen of *H. asseni* resembles somehow the morphology of what is here considered as the thoracic collar

in *S. elegans* n. sp. (see below). What differentiates the two species and genera is that *S. elegans* has a short apical horn present always in the species of the genus *Squinabollum*, and absent in *H. asseni*, but present in the type-species of *Hiscocapsa* O'Dogherty, 1994. Later, O'Dogherty et al. (2017) included *Squinabollum* in the family *Arcanicapsidae* Takemura, 1986. As concerns the stratigraphic range of the genus *Squinabollum* new data from the radiolarian fauna of the Coniacian sample DV54 from the Deva Beds, Romania (see Dumitrică & Carter, 1999; Dumitrică, 2004 for the locality of this sample), prove that it is still present and rather common at this level where it is represented by a species with the last globose segment characterized by having an additional cortical layer around its distal half.

Range. Valanginian to Coniacian.

Squinabollum elegans Dumitrică n. sp.

Figs. 12p, r, t, v

?1982 *Theocapsa* sp. – Okamura & Uto, pl. 3, fig. 14.

1982 *Sethocapsa* sp. – Okamura & Uto, pl. 6, fig. 9.

Description. Shell conical, three-chambered, each chamber of different morphology. Cephalis imperforated, two-chambered, armed with a short or very short conical horn, with chambers separated usually from one another by a circumferential circle of extremely small pores, and sometimes by a shallow constriction. Thorax ring- or collar-shaped with parallel or subparallel margins, larger and a little higher than cephalis, and with distal part submerged in the abdominal cavity. Its wall is perforated by very small, sparse and irregularly distributed pores, sometimes with a somehow spongy structure. Due to its spongy structure, the thorax of some specimens appears brighter than the other segments on scanning electron micrographs. Abdominal chamber spherical, large, with wide circular pores. On the inner side, the pores have smaller diameter and on the outer side they are larger, cylindrical and polygonally (hexagonally or pentagonally) framed on the surface. Interporal bars with relatively sharp crests and rarely with one or two very short spines. Distal end of postabdomen without aperture.

Studied material. The description is based on 8 specimens from samples OZ824, OZ825, OZ826, OZ836, plus the two specimens illustrated by Okamura & Uto (1982) from the Lower Cretaceous (probably Valanginian) chert sample YK-546 from the Yokonami Mélange of Shiman-to Belt, Japan.

Holotype. The specimen of figure 12v, sample OZ836, coll. MGP-PD, stub PD120-OZ836-R08-19.

Paratype. Fig. 12t, sample OZ836, coll. MGP-PD, stub PD120-OZ836-R08-12.

Dimensions. Length of shell 143-192 μm , of cephalis with apical horn 43-83 μm , of thoracic collar up to 27 μm , diameter of collar-shaped thorax 38-60 μm , of abdomen 90-144 μm .

Etymology: From the Latin *elegans* = elegant, due to the perfect and beautiful shape of the holotype.

Remarks. This new taxon is very well distinguished from other congeneric species by the special shape of its thorax resembling a necklace or a comforter. The specimens from Sardinia resemble very well the probably coeval specimens illustrated by Okamura & Uto (1982).

Range and occurrence. Upper Valanginian, S'Ozzastru section, and Valanginian from the Yokomani Mélange of Shimanto Belt, Japan.

***Squinabollum* cf. *elegans* Dumitrică n. sp.**

Fig. 11j

1988 *Siphocampium* (?) *davidi* Schaaf – Thurow, p. 408, pl. 7, fig. 25.

Material. A single specimen in sample OZ826.

Remarks. This specimen, very similar to the specimen illustrated by Thurow (1988) from what he considered Hauterivian-lower Aptian, differs from *S. elegans* n. sp. by not having a conical apical horn, by having the thorax much broader and the abdomen with distal end a little irregular.

Fam. **Xithomitridae** O'Dogherty, Gorican & Gawlick 2017

Type genus. *Xitomitra* O'Dogherty, Gorican & Gawlick 2017

Genus ***Campanomitra*** O'Dogherty, Gorican & Gawlick 2017

Type species. *Stichocapsa praepulchella* Hori, 1999

***Campanomitra pulchella* (Rüst, 1898)**

Fig. 12u

1898 *Archicorys pulchella* Rüst, p. 40, pl. 13, fig. 6.

1981 *Stichocapsa cribata* Hinde – Schaaf, p. 439, pl. 6, fig. 4; pl. 25, fig. 6.

1984 *Stichocapsa cribata* Hinde – Schaaf, p. 156, fig. 6.

1991 *Stichocapsa cribata* Hinde – Ishida & Hashimoto, p. 51, pl. 2, fig. 4.

1992 *Archicorys pulchella* Rüst – Steiger, p. 90, pl. 27, fig. 1.

1994 *Stichocapsa pulchella* (Rüst) – Jud, p. 108, pl. 21, figs. 6, 7.

1997 *Stichocapsa pulchella* (Rüst) – Dumitrică et al., p. 67, pl. 15, fig. 19.

1999 *Stichocapsa praepulchella* Hori, p. 88, fig. 8. 13-16; fig. 11. 2.

2017 *Aitaum* (?) *pulchella* (Rüst) – Xu & Luo, Fig. 7G.

Studied material. Only the illustrated specimen from the sample OZ836, coll. MGP-PD, stub PD120-OZ836-R08-22.

Remarks. In our opinion, *A. pulchella* Rüst and *S. praepulchella* Hori are synonym, although Hori (1999) and O'Dogherty et al. (2017) considered that they are different. Since the shape is similar and the age is not too different, the fewer number of transversally arranged pores is not a reason to separate them.

Range. Tithonian-late Barremian/early Aptian.

Family **Amphipyndacidae** Riedel, 1967

Genus ***Amphipyndax*** Foreman, 1966

Type species: *Amphipyndax enesseffi* Foreman, 1966.

***Amphipyndax zybrevi* Dumitrică n. sp.**

Fig. 12s

1996 *Amphipyndax stocki* (Campbell & Clark) – Zybrev, pl. 2, figs. 11, 12.

Description. Shell bottle-shaped consisting of five or more segments difficult to distinguish from the external

shape, with a conical proximal half and a cylindrical distal half. Cephalis spherical outside imperforate, without apical horn and with distal part covered by the proximal part of the thoracic skeleton. Thorax, abdomen and probably first postabdominal segment form a conical part with no intersegmental constriction outside. Following segments form a cylindrical body with one visible constriction in the middle part and another one on the distal part. The latter is not preserved but marked by a fast-decreasing trend in diameter. Wall of post-cephalic test perforated by dense cylindrical pores with dense honeycomb shape arranged quincuncially in transverse and oblique rows. They are hexagonally framed in the distal half and tend to be gradually elongate in proximal direction so that in the vicinity of cephalis they become long-elliptical.

Studied material: Only one specimen.

Holotype. Fig. 12s, sample OZ825, coll. MGP-PD, stub PD120-OZ825-R12-15.

Dimensions. Length of preserved test 127 µm, maximum diameter 76 µm.

Etymology. The species is dedicated to Dr. Sergey V. Zybrev, from the Institute of Tectonics and Geophysics, Habarovsk (Russia), who illustrated a similar species.

Remarks. The specimen found in the Sardinian sample preserves most part of the test and resembles almost perfectly the specimens determined by Zybrev (1996) as *Amphipyndax stocki* and coming from what he considered as an Albian-Cenomanian assemblage from an accretionary complex of the Russian continental Far East. The specific determination is erroneous because *A. stocki* (Campbell & Clark, 1944) has another morphology: larger pores and, usually, boundary between segments marked by constrictions.

Range and occurrence. Late Valanginian to probably Aptian or Albian if we consider correct the age determined by Zybrev for his *Amphipyndax stocki*.

Family **Archaeodictyomitridae** Pessagno, 1976

Type genus: *Archaeodictyomitra* Pessagno, 1976

Genus ***Archaeodictyomitra*** Pessagno, 1976

Type species. *Archaeodictyomitra squinaboli* Pessagno, 1976.

Remarks. We follow here the original definition of the genus *Archaeodictyomitra* Pessagno 1976 not the emended one (Pessagno, 1977b) that permitted the author to assign to it the species *Lithocampe apiarium* Rüst 1885. This species, for which we erect a new genus (*Apiaromitra*, see below), strongly differs from *A. squinaboli* and has roots in the Middle Jurassic radiolarians. The type species of *Archaeodictyomitra* suggests that the constrictions, when they exist, correspond to the intersegmental boundaries, and the pores are usually disposed in longitudinal rows.

***Archaeodictyomitra inflata* Dumitrică n. sp.**

Figs. 12w, x

1997 *Thanarla* aff. *brouweri* (Tan) – Dumitrică et al., p. 43, pl. 8, figs. 7, 79.

1997 *Thanarla pacifica* Nakaseko & Nishimura – Dumitrică et al., p. 43, pl. 8, fig. 6, non 2, 4, 5.

Description. Shell small, bell-shaped with 9-10 costae on half the perimeter. Apical part, consisting probably only of cephalis and thorax, narrow conical, pointed. Rest of shell much inflated up to the middle or more, then slowly narrowing. Distal part with costae prolonged a little downward without forming lamellar feet. Pores circular or elongated, very small on the conical apical part, then increasing rapidly on the inflated part. Boundary between the two parts marked by a concavity in outline.

Studied material. Two specimens from Sardinia samples and one from Masirah Island sample I-215.

Holotype. Figure 12x, OZ 834, coll. MGP-PD, stub PD120-OZ834-R10-26.

Paratype. Figure 12w, OZ839, coll. MGP-PD, stub PD120-OZ839-R01-12.

Dimensions. Length 123-140 μm , maximum diameter 100-128 μm .

Etymology. From the Latin *inflatus*, -a, -um = inflated.

Remarks. This species differs from other species of this genus by having an inflated body and from *Archaeodictyomitra robustovum* n. sp. (see below) by having the cephalothoracic conical segment narrower and separated from the rest of the body by a slight constriction.

Range and occurrence. Upper Valanginian of S'Ozzastru section.

***Archaeodictyomitra dienii* Dumitrică nov. sp.**

Figs. 13n, t

Description. Shell long subcylindrical to subconical consisting of four or five relatively long segments with slightly convex outline and separated by very weakly marked constrictions. Cephalis probably very thin-walled, its top not preserved in the studied specimens. Its base has the surface with 9 costae visible on half a diameter. Collar boundary well marked by a sudden widening of the thorax. Thorax difficult to separate externally from abdomen and abdomen from postabdominal segment. In fact, the number of post cephalic segments is difficult to establish because they are separated by very weakly marked constrictions. It seems that there are only two constrictions in the post cephalic portion of the skeleton, this signifying that there are only three post cephalic segments. Irrespective of their number, the test increases very slowly in diameter from cephalis to the distal end, which is slightly constricted. Costae very well marked and continuous from the base of thorax to the distal end of the test. Intercostal space has a single row of very small pores, usually elliptical and irregularly spaced. Distal end of test irregular, with costae not prolonged or very slightly prolonged beyond the intercostal areas.

Studied material. Two almost identical specimens.

Holotype. Figure 13n, coll. MGP-PD, stub PD120-OZ838-R04-07.

Paratype. Figure 13t, coll. MGP-PD, stub PD120-OZ836-R08-11.

Dimensions. Maximum length preserved (without cephalis) 185-200 μm , maximum diameter of test 80 μm .

Etymology. The species is dedicated to Dr. Iginio Dieni for his contribution to the knowledge of the geology of eastern Sardinia.

Remarks. Based on the two specimens one can suppose that this species has a rather constant morphology. By its general morphology, *Archaeodictyomitra dienii* n. sp.

resembles the very variable and probably polyphyletic Albian to basal Turonian species *Dictyomitra montisserei* (Squinabol, 1903) as emended by O'Dogherty (1994). Despite this resemblance, its absence in the fossil record of the Hauterivian to Aptian stratigraphic interval suggests that it is an independent species and probably the forerunner of *Dictyomitra montisserei*.

Occurrence. Rare in OZ838, late Valanginian, Sardinia, Italy.

***Archaeodictyomitra longipora* Dumitrică nov. sp.**

Figs. 13l, p

Description. Shell long spindle-shaped consisting of six or seven segments and 10 longitudinal costae visible on half a perimeter. Cephalis thin-walled, probably rounded at its top but not preserved. It is separated from thorax by a circumferential row of very small pores. Thorax and two or three post-thoracic segments increasing slowly in diameter and length and trapezoidal in lateral projection. The following two segments are slowly decreasing in diameter but not in length. Distal end without costal projections and perpendicular to the axis of shell. Costae well marked and intercostal zones broad, each one with one row of circular to, mostly, elongate or very elongate pores. What is interesting in this species is that the middle part of grooves, wherein the pores are open, is raised, so that the deepest zones of the intercostal areas are situated on both sides of the line of pores (Fig. 13l). Intersegmental boundaries very weakly marked externally by wide and shallow constrictions.

Studied material. A single specimen in sample OZ836.

Holotype. The illustrated specimen, coll. MGP-PD, stub PD120-OZ836-R08-20.

Dimensions. Preserved length 193 μm , maximum diameter, at approximately the middle of the shell 75 μm .

Etymology. From its elongate pores.

Remarks. This very rare species differs from *Archaeodictyomitra sardoa* nov. sp., to which it is morphologically very close, by slightly ellipsoidal shape and elongate pores in the raised central part of grooves.

Occurrence. A single specimen in S'Ozzastru samples.

***Archaeodictyomitra massarii* Dumitrică nov. sp.**

Figs. 13g-k, ?14l

1982 *Archaeodictyomitra* sp. – Okamura & Uto, pl. 1, figs. 16-19; pl. 5, fig.7; pl. 6, fig. 2.

1989 *Mita* sp. A – Tumanda, p. 8, pl. 3, fig. 13.

Description. Shell long ovoid with usually 6-8 segments and about the two apical thirds conical with slightly convex sides, and the distal third narrowing. Surface with 9 to 11 continuous and deep costae from top to distal end on half the perimeter. Wall thick, of commonly cavernous structure, with rather deep intercostal areas, each one with a row of dense circular pores on the inner side of wall, and oval or transversally elongated and usually very complicated sculpture on the outer surface. Sculptures resulted from the cavernous structure of wall. Distal part without a neck.

Studied material. Six illustrated specimens.

Holotype. Figure 13i, coll. MGP-PD, stub PD120-OZ839-R02-12.

Dimensions. Length of shell 140-200 μm , maximum diameter 86-96 μm .

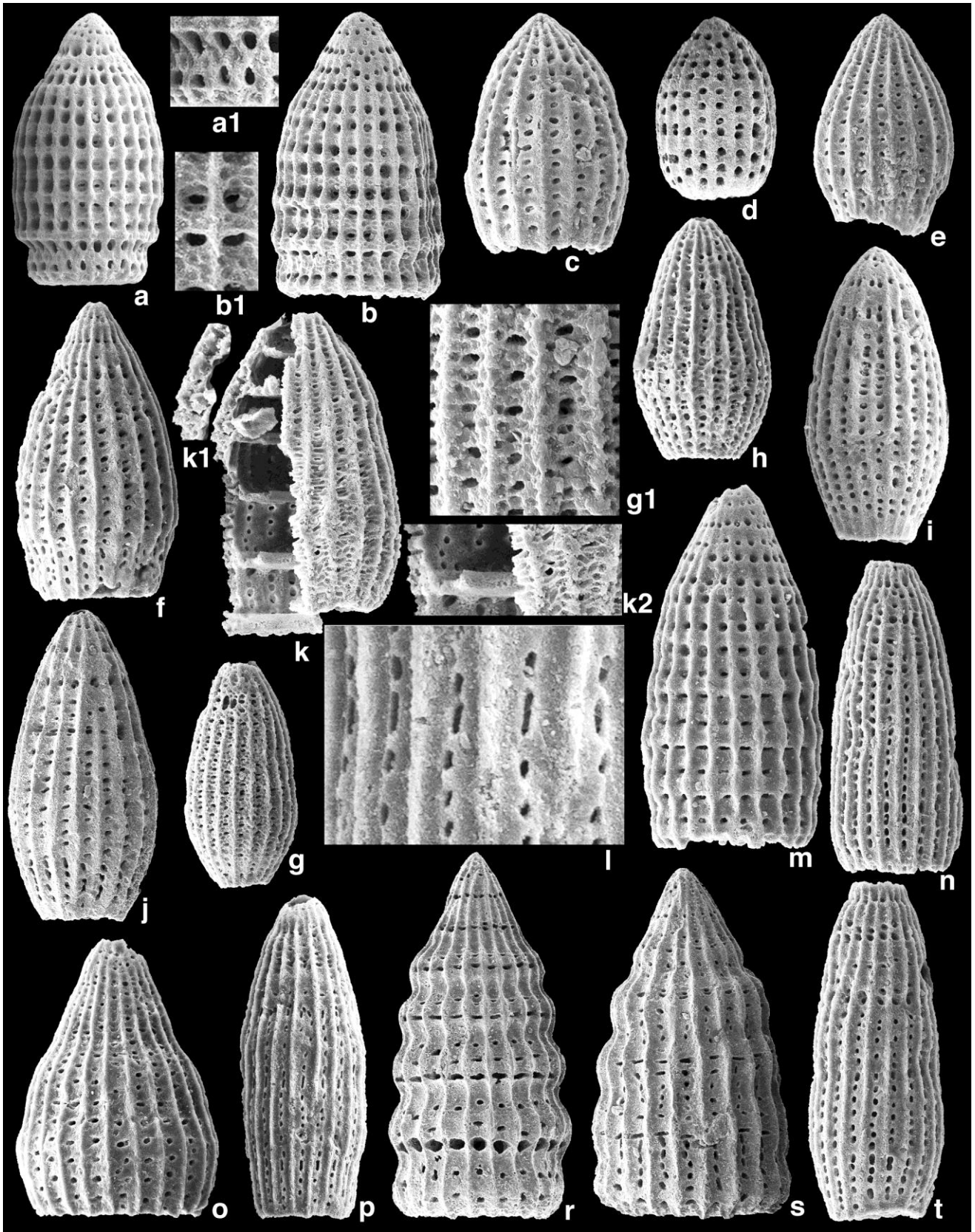


Fig. 13 **a, b** - *Apiaromitra apiarium* (Rüst): **a** - OZ836, **b** - OZ839, **a1** - detail of ornamentation of last segment, **b1** - detail of ornamentation of penultimate segment. **c** - *Archaeodictyomitra robustovum* Dumitrică n. sp., OZ837. **d** - *Archaeodictyomitra* sp., OZ839. **e, f** - *Archaeodictyomitra mitra* Dumitrică: **e** - OZ838, **f** - OZ824. **g-k** - *Archaeodictyomitra massarii* Dumitrică n. sp.: **g** - OZ834, **g1** - detail of surface x1000. **h** - OZ834, **i** - OZ839, **j** - OZ834, **k** - OZ839; **k1** - detail of wall showing the cavernous structure, **k2** - detail of surface. **l, p** - *Archaeodictyomitra longipora* Dumitrică n. sp., OZ836; **l** - portion of surface of **p** much magnified showing the elevated intercostal area. **m** - *Apiaromitra tyaghtonensis* (Cordey), OZ837. **n, t** - *Archaeodictyomitra dienii* Dumitrică n. sp.: **n** - OZ836, **t** - OZ837. **o** - *Thanarla* cf. *pulchra* (Squinabol), OZ824. **r** - *Archaeodictyomitra judae* Dumitrică n. sp., OZ839. **s** - *Archaeodictyomitra humerosa* Dumitrică n. sp., OZ839. Figs. **a, b** x250, **k1** and **k2** x450, all the others x300.

Etymology. The species is dedicated to Prof. Francesco Massari for his contribution to the knowledge of the geology of eastern Sardinia.

Remarks. What is interesting in the population of this new species is that most pores of some specimens are slit-shaped and transversally positioned on the surface of shell, and the surface is sculptured (Figs. 13g1, k2) whereas on the inner side of the wall the pores are circular (Fig. 13k). This difference is the result of the cavernous structure of wall (Figs. 13k, k1), which seems to be original, not secondary, resulted from a differential dissolution of the shell. The same kind of superficial sculpture and transversally or obliquely directed slit-like pores are present in some specimens of *Archaeodictyomitra mitra* Dumitrică 1997, a species quite close morphologically to this new species, from which it differs by having a slightly spindle-shaped shell and the distal end without a neck, and also in the specimens of *Eucyrtidium brouweri* illustrated by Tan (1927) in pl. 11, figs. 90 and 91. The cavernous structure of shell, that was never mentioned in Radiolaria, seems to be characteristic of several Lower Cretaceous archaeodictyomitrid species or only specimens illustrated by Thurow (1988, pl. 6, figs. 18-22; pl. 7, figs. 7), O'Dogherty (1994) on his pl. 5, figs. 4-6, 12, 23, 25-27, 31-33; pl. 6, figs. 1-4, 10, 15, Jud (1994) on *Thanarla guta* Jud (1994, pl. 23, figs. 4, 5, *Thanarla pulchra*, pl. 23, figs. 6, 7) or other authors. Some specimens of these species in his pl. 5, figs. 4, 23, 26), to cite only the most visible, have also pores on the top of costae. We do not know whether this cavernous structure has a taxonomic meaning or a palaeobiological one. All these specimens are archaeodictyomitrids. Anyway, it is interesting to mention it, radiolarian skeleton being known to be compact, by comparison with that of Phaeodaria, that has an alveolar or porous structure (Takahashi & Hurd, 2007; Dumitrică, 2016).

Range and occurrence. Berriasian to Barremian of Masirah Island, Oman, and upper Valanginian of Sardinia.

Archaeodictyomitra mitra Dumitrică, 1997

Figs. 13e, f

1973 *Dictyomitra* sp., Foreman, pl. 10, fig. 7.

1981 *Archaeodictyomitra* sp., Schaaf, pl. 4, fig. 1.

1981 *Archaeodictyomitra vulgaris* Pessagno – Schaaf, p. 447, pl. 4, fig. 2.

1981 *Archaeodictyomitra brouweri* var. a – Schaaf, p. 432, figs. 3a, b.

1982 *Thanarla*, various types – Okamura & Uto, pl. 1, figs. 16, 20-22, 24.

1988 *Thanarla conica* (Aliev) – Thurow, p. 406, pl. 6, fig. 20, non pl. 7, figs. 5, 1.

1994 *Thanarla brouweri* (Tan) – O'Dogherty, p. 86, pl. 5, figs. 4-6, 12.

1994 *Thanarla pulchra* (Squinabol) – O'Dogherty, p. 91, pl. 5, fig. 28.

1997 *Archaeodictyomitra mitra* Dumitrică in Dumitrică et al., p. 40, pl. 7, figs. 8, 13-15, 19-21, 23.

2009 *Thanarla brouweri* (Tan) – Ishii et al., pl. 12, fig. 3.

Studied material: Several illustrated specimens of which only two included on the plates.

Dimensions. Total length of shell of our specimens 130-175 µm, length of ogival shell without distal neck 106-138 µm, maximum diameter 83-93 µm.

Remarks. This species is characterized by an ogival shape and the sharp narrowing of the distal segment forming a kind of distal neck. This neck is just a thinner and narrower wall with intercostal pores. Although it has the same distal position on shell, it does not resemble the blade-like feet of the genus *Thanarla* Pessagno, 1977. As noted before (Dumitrică et al., 1997), pores are either circular or slit-like, in the last case disposed obliquely or transversally. Structure of shell wall usually cavernous and surface sculptured similar to that of the *A. massarii* Dumitrică n. sp. (see discussion under this species). Such a structure is also visible on the specimens illustrated by Dumitrică in Dumitrică et al. (1997, pl. 7, figs. 15, 21).

Range. Valanginian to upper Hauterivian-lower Aptian according to Thurow (1988)

Archaeodictyomitra robustovum Dumitrică n. sp.

Fig. 13c

1994 aff. *Thanarla conica* (Squinabol) – O'Dogherty, p. 90, pl. 5, fig. 25, non 23, 24, 26, 27.

Description. Shell short, ovoid, with 8-9 costae visible on half the perimeter. Apical end rather rounded, not prolonged into a small conical body distinct from the rest of the shell. Costae robust and intercostal grooves wide with circular or slightly transversally elongated pores. Apical end with an angle a little wider than 90°. Distal end not prolonged into a narrow and thinner distal neck or in lamellar projections.

Studied material. A single specimen from sample OZ837.

Holotype. Fig. 13c, coll. MGP-PD, stub PD120-OZ837-R06-21.

Dimensions. Length 142 µm, maximum diameter 98 µm.

Etymology. From its ovoid shape (*ovum* in Latin) and *robustus* - robust body.

Remarks. This species differs from all the other congeneric taxa of the studied assemblages by its robust shell, not acute apical end and the absence of a distal neck. The middle Aptian species illustrated by O'Dogherty (1994) on his fig. 25 resembles very well this species, the other specimens he illustrated under this species from middle Albian being much longer.

Occurrence. A single specimen in the sample OZ837 and one from the middle Aptian illustrated by O'Dogherty (l. cit.).

Archaeodictyomitra judae Dumitrică n. sp.

Fig. 13r

1927 aff. *Stichomitra pseudoscalaris* Tan Sin Hok, p. 56, pl. 11, fig. 84.

1981 aff. *Archaeodictyomitra pseudoscalaris* (Tan Sin Hok) – Schaaf, p. 432, pl. 4, fig. 5; pl. 21, figs. 13a, b.

1988 aff. *Archaeodictyomitra pseudoscalaris* (Tan Sin Hok) – Thurow, p. 398, pl. 7, fig. 14.

1989 aff. *Archaeodictyomitra pseudoscalaris* (Tan Sin Hok) – Tumanda, p. 36, pl. 3, fig. 12.

1994 *Dictyomitra pseudoscalaris* Tan sensu Schaaf – Jud, p. 75, pl. 9, figs. 6, 7.

1994 aff. *Dictyomitra communis* (Squinabol) – O'Dogherty, p. 71, pl. 1, figs. 3, 4, non 5-11.

2009 aff. *Archaeodictyomitra leptocostata* Dumitrică – Ishii et al., p. 343, pl. 11, fig. 1.

Description. Shell conical of 8-11 segments and 11-12 costae visible on half a perimeter. Apical part, consisting of three and a half segments, conical with straight outline and intersegmental boundaries marked by a row of pores. Starting from the distal half of the fourth segment and proximal part of the fifth one, the test increases rapidly in diameter and becomes strongly undulated. On this part the rows of intersegmental pores are at first on the highest parts of undulations and then move gradually distally below them. Diameter of segments increases slowly up to the seventh segment and decreases a little in the last one.

Studied material. The figured specimen from sample OZ839, coll. MGP-PD, stub PD120-OZ839-R01-09, and other 12 specimens in OZ838 and 10 in OZ839, not illustrated.

Dimensions. Length of test 216 µm, maximum diameter of the seventh segment 106 µm.

Etymology. The species is dedicated to Ruth Dumitrică-Jud who illustrated a specimen similar to the holotype of this species.

Remarks. This species has affinities with *Archaeodictyomitra pseudoscalaris* (Tan Sin Hok, 1927) in which it probably originated and from which it differs by having well lobular shell starting with the first postabdominal segment. It resembles perfectly the specimen illustrated by Jud (1994, pl. 9, fig. 7) from the upper Hauterivian of the Fiume Bosso section (Marche region, Italy), with the only difference that it is a little shorter. It seems that at the horizon OZ838 started the evolution of this species from *A. pseudoscalaris* because the specimens occurring in lower beds have the test very little constricted and with the proximal part difficult to separate from the rest of the skeleton. The holotype of *Archaeodictyomitra pseudoscalaris* (Tan) differs from this new species by having very slightly lobular segments and a convex outline, and more pores in each intercostal zone of segments. By having constrictions, the new taxon, as well as *A. humerosa* Dumitrică n. sp. (see above), resembles the genus *Dictyomitra* Zittel, 1876, emend. Pessagno, 1976. However, both species differ from the congeneric species because their constrictions do not completely coincide with the intersegmental boundaries, especially in the middle part of test. From *A. humerosa* Dumitrică n. sp., *A. judae* differs by being narrower, by having larger pores on the sutural row of pores and only one or maximum two pores per segment in each intercostal area, plus more advanced constrictions of test. Another similar species is *A. coniforma* Dumitrică 1997 that differs from *A. pseudoscalaris* by being perfectly conical and much slender.

O'Dogherty (1994, pl. 1, figs. 3-11) considered *A. pseudoscalaris* very variable and included it in a long list of synonyms of the species *Dictyomitra communis* (Squinabol). To prove this high variability he illustrated 9 specimens, all from the same locality and of the same age (late Aptian). We retain as *D. pseudoscalaris* only the first two specimens from his plate (figs. 3, 4) that differ from the other ones by having the last segment narrower and the lateral outline of test visibly convex, resembling the holotype. The other specimens are conical with rather straight lateral sides and resemble the holotype of *Dictyomitra communis* (Squinabol 1904).

Range and occurrence. Upper Valanginian to upper Aptian of Tethys according to Jud (1994) and O'Dogherty (1994).

***Archaeodictyomitra humerosa* Dumitrică n. sp.**

Figs. 13s; 14b, f

?1992 *Archaeodictyomitra pseudoscalaris* (Tan Sin Hok) – Matsuoka, pl. 1, fig. 8.

Description. Shell conical with three parts when complete: a narrow conical apical part consisting of 2-3 segments of which the distalmost has a convex outline, a wider truncated conical middle part consisting of 3-5 segments with convex outline and separated from one another by constrictions, and a last narrow distal cylindrical segment.

Studied material. Three illustrated specimens in OZ826 plus many others not figured (see Table 1).

Holotype. Figure 14b, coll. MGP-PD, stub PD120-OZ834-R10-27.

Paratype. Figure 13s, coll. MGP-PD, stub PD120-OZ839-R01-09

Dimensions. Length of complete test 216 µm, of apical conical part 66 µm, of complete middle part 123-133 µm, of distal neck-shaped segment 27 µm, maximum diameter of test 98-116 µm.

Etymology. From the Latin *humer* = shoulder, due to the shape of the test at the contact between the first and the middle part.

Remarks. This species, as here defined, has a rather wide variability. It comprises specimens with 6 to 10 segments and the entire test consists of three parts: a conical proximal part, a middle trapezoidal part, and a distal narrower part. The proximal part consists commonly of the first 3-4 segments, which are not separated by well-marked constrictions. The middle part consists of 3-5 segments with well-marked convex outline which gives this part an undulate aspect. On this part, the boundaries between segments are situated at the expanded portion of test and are usually marked by a circumferential row of larger, usually transversally elongated pores situated just below the boundary platforms (Figs. 13s, 14b, f). The third part, observed only in a single specimen (Fig. 14b), is represented by a cylindrical neck-shaped segment. The surface of the whole test comprises 10-11 narrow uninterrupted costae on half the perimeter separated by wide intercostal spaces. Pores are small and arranged in a single irregular row in each intercostal depression, rarely in two irregular rows (Fig. 14f).

Range. Berriasian to early Hauterivian.

***Archaeodictyomitra conica* (Aliev, 1965)**

Fig. 14d, e

?1965 *Cornutana conica* Aliev, p. 34, pl. 6, fig. 1.

1973 *Cornutana conica* Aliev – Moore, p. 830, pl. 14, fig. 1, non 2 = *Archaeodictyomitra lacrimula* (Foreman, 1973).

?1977b *Thanarla conica* (Aliev) – Pessagno, p. 45, pl. 7, figs. 1, 13, 15.

1994 *Thanarla brouweri* (Tan) – O'Dogherty, p. 86, pl. 5, fig. 2, non 1, 3-12.

Description. Shell very small, conical with ten costae in lateral view and probably 4 or, maximum, 5 segments. Distal part rounded in outline with narrowing margin.

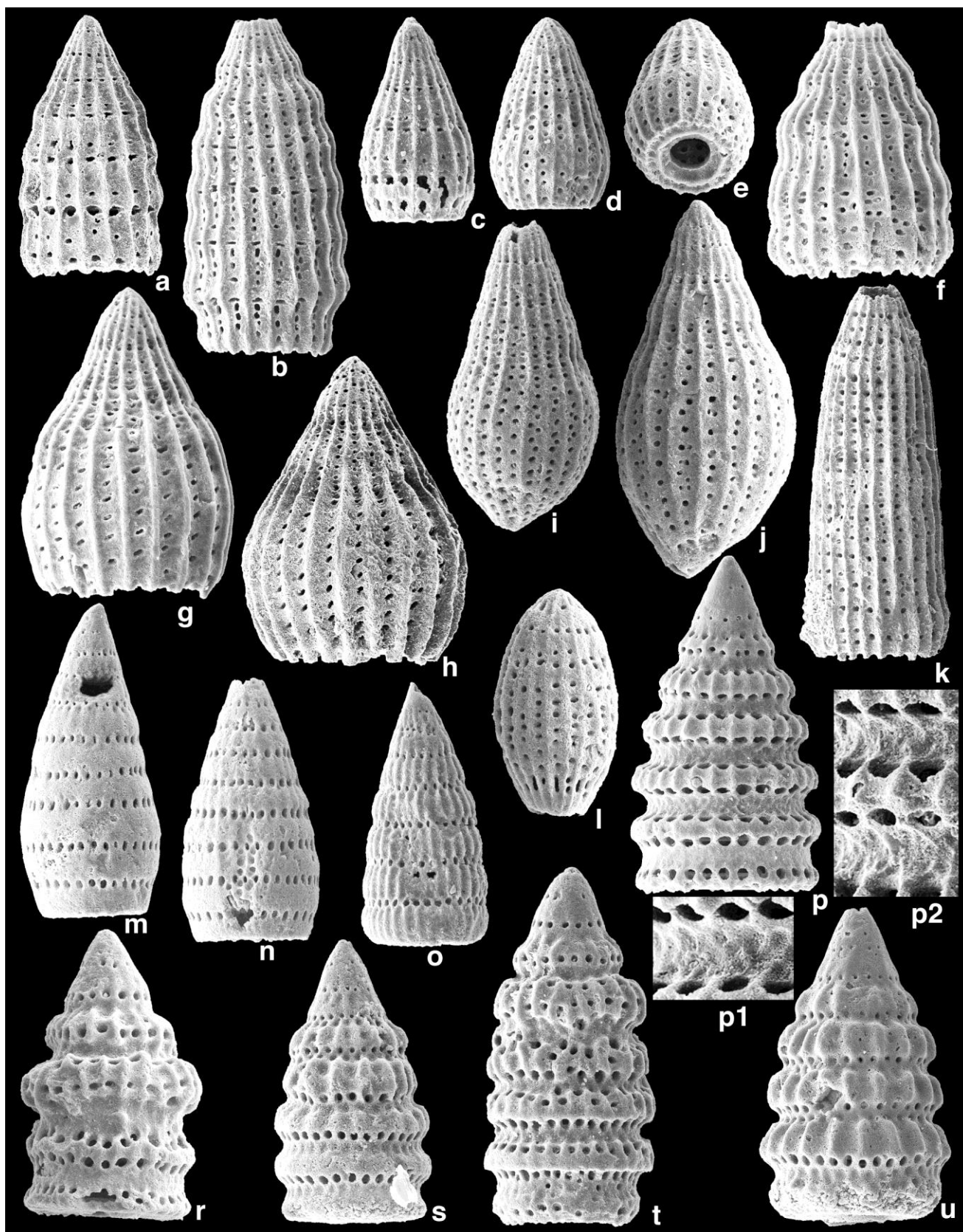


Fig. 14 a - *Archaeodictyomitra conicoscalaris* Dumitrică n. sp., OZ839. b, f - *Archaeodictyomitra humerosa* Dumitrică n. sp.: b - OZ834, f - OZ824. c - *Archaeodictyomitra pumila* Dumitrică n. sp., OZ834. d, e - *Archaeodictyomitra conica* (Aliev), OZ824. g - *Thanarla* cf. *pulchra* (Squinabol), OZ825. h - *Thanarla pulchra* (Squinabol), OZ839. i, j - *Mictyoditra thiensis* (Tan), OZ836. k - *Archaeodictyomitra excellens* (Tan), OZ839. l - *Archaeodictyomitra* sp., OZ836. m, n - *Loopus nudus* (Schaaf): m - OZ838, n - OZ834. o - *Loopus* cf. *primitivus* (Matsuoka & Yao), OZ834. p, p1, p2 - *Svinitzium depressum* (Baumgartner), p1, p2 - details of penultimate segmental band showing relic pores of parvicingulid type or other types, OZ824. Figs. r, t - *Svinitzium* (?) *irregulare* Dumitrică n. sp.: r - OZ 836, t - OZ834. s, u - *Pseudodictyomitra* cf. *carpatica* (Lozynyak): s - OZ834, u - OZ 824. Figs. b, n x250, the others x300.

Aperture large, circular, with protruding rim. Pores very small, circular, disposed in one longitudinal row in each intercostal groove.

Studied material. A single specimen in sample OZ 839, illustrated in lateral and obliquely basal views, coll. MGP-PD, stub PD120-OZ824-R13-08, 09.

Dimensions. Length 114 µm, maximum diameter 72 µm.

Remarks. This species resembles, in size and shape *A. pumila* n. sp. (see below), from which it only differs by having numerous small pores in each intercostal area. From the holotype of Aliev's species it differs in only being narrower.

Occurrence. Very rare in S'Ozzastru section, upper Valanginian.

***Archaeodictyomitra conicoscalaris* Dumitrică n. sp.**

Fig. 14a

1981 *Pseudodictyomitra formosa* Squinabol – Schaaf, p. 436, pl. 3, fig. 9.

1988 *Archaeodictyomitra pseudoscalaris* (Tan Sin Hok) – Thurow, p. 398, pl. 7, fig. 14.

1988 *Archaeodictyomitra* sp. cf. *A. puga* Schaaf – Thurow, p. 398, pl. 7, fig. 15, non pl. 6, fig. 18.

1995 *Dictyomitra pseudoscalaris* (Tan) sensu Schaaf – Baumgartner et al., p. 186, pl. 5927, fig. 4, non figs. 1, 3, 5.

Description. Shell of 7 or more segments consisting of two parts: a conical proximal part and a distal cylindrical one. Whole skeleton costate with 8-9 strong and uninterrupted longitudinal costae separated by large intercostal furrows and radiating from cephalis. On cylindrical part costae scalariform in lateral view. Nine costae visible on half perimeter. Boundaries between segments marked by a transversal row of larger pores situated between the base of a previous segment and the beginning of the new one. Sparse pores also on the constricted part of segments.

Studied material. A single specimen.

Holotype. Figure 14a, sample OZ839, coll. MGP-PD, stub PD120-OZ839-R01-13.

Dimensions. Total height with 7 segments 153 µm, maximum diameter 87 µm.

Etymology. From its conical shape and the scalariform outline of middle and distal segments.

Remarks. This species is part of a group of taxa with longitudinal, uninterrupted costae and a row of circumferential larger pores under each intersegmental internal wall and usually also a row of commonly smaller pores above this wall. It differs from *A. coniforma* Dumitrică, 1997 by being shorter and having two different outlines: rather widely conical in the proximal part and almost cylindrical in the last two to three segments.

Occurrence. A single specimen in OZ 839.

***Archaeodictyomitra pumila* Dumitrică n. sp.**

Fig. 14c

Description. Shell very small conical with nine continuous costae visible on half the perimeter in lateral view. Pores circular, increasing in size distally and arranged in two rows on each segment: one above the segment junctions and one below, separated by a wide imperforate transversal band in the middle of segments. Segmental junction marked by a narrow band between the two rows

of pores, one corresponding to the anterior chamber and one to the posterior chamber. Distal end without the appendage characteristic of *Thanarla*. Distal end open in a large circular aperture.

Studied material. A single specimen in sample OZ834.

Holotype. Fig. 14c, coll. MGP-PD, stub PD120-OZ834-R09-12.

Dimensions. Length 122 µm, maximum diameter 70 µm.

Etymology. From the Latin *pumilus*, -a, -um = dwarf.

Remarks. By its conical shape, this species has the morphology of the genus *Thanarla* and the wall with pore disposition as in *Apiaromitra* n. gen.

Occurrence. A single specimen in the upper Valanginian sample OZ 834.

***Archaeodictyomitra excellens* (Tan, 1927)**

Fig. 14k

1927 *Lithomitra excellens* Tan, p. 56, pl. 11, fig. 85.

1981 *Archaeodictyomitra apiara* (Rüst) – Schaaf, p. 450, pl. 18, figs. 2a, b.

1981 *Archaeodictyomitra apiaria* (Rüst) – Kanie et al., pl. 1, fig. 8.

1982 *Archaeodictyomitra apiara* (Rüst) – Okamura & Uto, pl. 2, figs. 1, 2.

1984 *Archaeodictyomitra excellens* (Tan Sin Hok) – Baumgartner, p. 758, pl. 2, figs. 7, 8.

1984 *Archaeodictyomitra apiarium* (Rüst, 1885) – Schaaf, p. 92-93, figs. 2, 4a, 4b.

1992 *Archaeodictyomitra excellens* (Tan Sin Hok) – Steiger, p. 88, pl. 25, figs. 10, 11.

1994 *Archaeodictyomitra excellens* (Tan) – Jud, p. 63, pl. 3, figs. 15, 16.

1994 *Archaeodictyomitra excellens* (Tan) – Goričan, p. 62, pl. 20, figs. 2-4.

2009 *Archaeodictyomitra excellens* (Tan) – Ishii et al., pl. 10, fig. 18.

Studied material. Species very rare in Sardinia material, only two specimens have been recorded: the illustrated one in sample OZ839 and another specimen in OZ833.

Dimensions. Total length of shell without cephalis 220 µm.

Range and occurrence. Late Kimmeridgian-early Tithonian to late Barremian-early Aptian (Baumgartner et al., 1995). Very rare in upper Valanginian of Sardinia.

***Archaeodictyomitra* spp.**

Figs. 13d, 14l

Dimensions. Height 106-135 µm, maximum diameter at the middle part of test 72-75 µm.

Remarks. Although different in length, the two specimens have two characters in common: rounded apical part and pores more or less arranged in imperfect circumferential rows. However, fig. 14l seems to be rather close to *A. massarii* n. sp.

Occurrence. Very rare in S'Ozzastru section.

Genus *Apiaromitra* Dumitrică n. gen.

Type species. *Lithocampe apiarium* Rüst, 1885.

Diagnosis. Multisegmented conical or conico-cylindrical nassellarians with continuous longitudinal costae and without apical horn. Segments separated by planiform partitions usually marked on the surface by more or less evident circumferential ridges. Pores arranged in longitu-

dinal and transversal rows; each intercostal longitudinal row has a single row of pores and each postabdominal segment has two rows, one above and one below planiform partitions, separated by a central imperforate circumferential band. Costae continuous along the test.

Etimology. From Latin *apiarium* = been hive and *mitra* = mitre

Remarks. The type species of this new genus was assigned in modern literature to the genus *Archaeodictyomitra* Pessagno, 1976, because of its continuous and longitudinal costae with a single intercostal row of pores. However, comparing it with the type species of *Archaeodictyomitra*, which is the Cretaceous *A. squinaboli* Pessagno, 1976, and with many other congeneric taxa, one can see that there is quite a big difference between them. Although *Apiaromitra* n. gen. has longitudinal costae as in *Archaeodictyomitra*, it has more or less expanded circumferential ridges as external expressions of the inner planiform partitions, and only two rows of pores in each segment, of which one above the planiform partition and one below it; conversely, *Archaeodictyomitra* has more pores on segments, not aligned in transversal rows, and the intersegmental partitions are either not marked outside or correspond to external constrictions.

By its wall structure *Apiaromitra* n. gen. seems to be close to the genus *Wrangellium* Pessagno & Whalen, 1982, to species like *Praecaneta mimetica* Dumitrică, 1997, *Tethysetta pygmaea* Dumitrică, 1997 and others, and to the genus *Svinitzium* Dumitrică, 1997. All these Upper Jurassic or Lower Cretaceous species have in common the following characters: nodose circumferential ridges with H-linked structure corresponding to intersegmental partitions, one row of pores on each side of these partitions, and a median transversal band that can be simple and smooth (*Svinitzium*), with depressed costae, or with a row of elongate pores on longitudinal ridges, *Pseudocrolanium puga* (Schaaf, 1981), *Praecaneta mimetica* Dumitrică, 1997, *Tethysetta pygmaea* Dumitrică, 1997, etc.). These pores seem to derive from the middle row of the characteristic porous bands of the Parvicingulidae.

If this disposition of pores is taken into account, this genus should probably include the following species assigned until present to *Archaeodictyomitra* Pessagno, or to *Svinitzium* Dumitrică: *Archaeodictyomitra apiarium* (Rüst, 1885), *A. cf. apiarium* (Rüst) of Ishida (1985, pl. 4, figs. 7, 8), *A. apiarium* of Dumitrică 1997, *A. minoensis* (Mizutani, 1981), *A. sp. cf. shengi* Yang (1993, p. 112, pl. 21, fig. 14), *A. masirahensis* Dumitrică, 1997, *A. leptocostata* (Wu & Li, 1982), *A. conica* Dumitrică, 1997, etc.

Range. Middle Jurassic to late Barremian-early Aptian.

***Apiaromitra apiarium* (Rüst, 1885)**

Figs. 13a, aa, b, ba

1885 *Lithocampe apiarium* Rüst, p. 314, pl. 39 (14), fig. 8.

1976 *Dictyomitra excellens* (Tan) – Baumgartner & Bernoulli, p. 615, fig. 12k.

1977b. *Archaeodictyomitra apiaria* (Rüst) – Pessagno, p. 41, pl., 6, figs 6, 14.

1981 *Archaeodictyomitra apiara* (Rüst) – Nakaseko & Nishimura, p. 145, pl. 6, figs. 2-4, non 1; pl. 15, figs. 2, 6, non 7.

1982 *Archaeodictyomitra apiara* (Rüst) – Nishizono et al., p. 323, pl. 3, fig. 4.

1982 *Archaeodictyomitra apiara* (Rüst) – Murata et al., p. 335, pl. 1, fig. 10.

1982 *Archaeodictyomitra apiara* (Rüst) – Matsuyama et al., p. 377, pl. 1, fig. 1.

1982 *Archaeodictyomitra apiara* (Rüst) – Wu & Li, pl. 1, figs. 15, 16.

1984 *Archaeodictyomitra apiara* (Rüst) – Baumgartner, p. 758, pl. 2, figs. 5, 6.

1984 *Archaeodictyomitra apiarium* (Rüst) – Schaaf, p. 92, fig. H.

1984 *Hsuum* (?) *savignanensis* (Neviani) – Schaaf, p. 152, pl. Berriasian, p. 153, fig. 1.

1986 *Archaeodictyomitra apiarium* (Rüst) – Aita & Okada, pl. 1, fig. 11.

1989 *Archaeodictyomitra apiaria* (Rüst) – Tumanda, p. 38, pl. 3, fig. 9.

1989 *Archaeodictyomitra apiarium* (Rüst) – Kito, p. 188, pl. 21, fig. 15.

1991 *Archaeodictyomitra apiaria* (Rüst) – Ishida & Hashimoto, p. 45, pl. 1, fig. 2.

1992 *Archaeodictyomitra apiaria* (Rüst) – Steiger, p. 88, pl. 25, figs. 8, 9.

1992 *Archaeodictyomitra apiara* (Rüst) – Kiessling, p. 193, pl. 1, figs. 4-5.

1994 *Archaeodictyomitra apiarium* (Rüst) – Jud, p. 62, pl. 3, figs. 10, 11.

1994 *Archaeodictyomitra apiarium* (Rüst) – Goričan, p. 61, pl. 20, figs. 5-8, 12, 13, 17, 18.

1995 *Archaeodictyomitra apiarium* (Rüst) – Baumgartner et al., p. 98, pl. 3263, figs. 1-7.

1996 *Archaeodictyomitra apiarium* (Rüst) – Suzuki, p. 662.

not 1997 *Archaeodictyomitra apiarium* (Rüst) – Dumitrică et al., p. 38, pl. 7, fig. 7.

1999 *Archaeodictyomitra apiarium* (Rüst) – Hori, p. 80, fig. 7.10.

2009 *Archaeodictyomitra apiarium* (Rüst) – Ishii et al., pl. 10, fig. 15.

2014. *Archaeodictyomitra apiarium* (Rüst) – Robertson et al., fig. 10(A).

2017 *Archaeodictyomitra apiarium* (Rüst) – Hsu & Luo, fig. 4. g, h.

Remarks. This species is very variable in morphology, with the main shell cylindrical, as in the original drawing of Rüst, or with sides more or less convex. There is also a great variation in the thickness and height of longitudinal costae relative to the transversal or circumferential bands. The latter are almost always of two different types: one higher, representing external expression of intersegmental wall, the other more internal, representing the imperforate central band between the two rows of pores, characteristic of the species, one above and one below. A detailed study of these differences would be probably interesting.

A characteristic of this species, when complete, is that the distal segment has a much smaller diameter than that of the previous chamber forming a neck. The same feature is typical of *A. excellens* (Tan, 1927) and other *Archaeodictyomitridae*. For this reason and for having continuous costae, without small nodes at the intersection with the transversal ribs, the specimen attributed to *A. apiarium* in Dumitrică et al. (1997, p. 38, pl. 7, fig. 7) is herein

considered an erroneous determination. It is probably interesting to make a study of the stratigraphic distribution of species with pores arranged not only in longitudinal rows but also in circumferential rows but without nodes at the meeting points of the two type of rows as in *Apiaromitra apiarium*.

Studied material. Four photographed specimens from OZ 836, 838, 839 of which two included in Fig. 13 as follow: fig. 13a = PD120-OZ836-R08-26 and fig. 13b = PD120-OZ839-R01-04.

Dimensions. Total length of shell 192-198 µm, maximum diameter 106-124 µm.

Range and occurrence. Mid Callovian-early Oxfordian to late Barremian-early Aptian, cosmopolitan.

***Apiaromitra tyaughtonensis* (Cordey, 1998)**

Fig. 13m

1982 *Archaeodictyomitra apiara* (Rüst) – Sato et al., p. 306, pl. 4, fig. 8.

1984 *Archaeodictyomitra apiarium* (Rüst 1885) – Schaaf, p. 92, figs. 5a, 5b, non 1, 3a, 3b, , 2, 4a, 4b = *Archaeodictyomitra excellens* (Tan).

1994 *Archaeodictyomitra* spp. – Goričan, pl. 20, figs. 11, 16.

1998 *Archaeodictyomitra tyaughtonensis* Cordey, p. 98, pl. 28, figs. 5, 6.

2017 *Archaeodictyomitra tyaughtonensis* Cordey – O’Dogherty et al., p. 55, figs. 7.38, 7.39.

2017 *Archaeodictyomitra minoensis* Mizutani – O’Dogherty et al., p. 54, fig. 7.41, non 7.40, 7.42.

Description. This species, represented by very few specimens in the Sardinia samples, differs from *A. apiarium* s. str. in being higher and having a conical skeleton, instead of a cylindrical or subcylindrical one, with a longer conical apical part. The shape of the specimen resembles very much the two specimens illustrated by O’Dogherty et al. (2017) from the Upper Jurassic of the Eastern Alps and the specimens from other Jurassic sections assigned to *A. apiarium*, or to other taxa.

Material. Rare in samples OZ806, OZ833 and OZ837 (PD120-OZ837-R06-23).

Dimensions. Height 220 µm, maximum diameter 110 µm.

Range. This species seems to occur in the Upper Jurassic to Lower Cretaceous, its last occurrence being recorded in the upper Valanginian.

Genus *Mictyoditra* Dumitrică, 1997 in Dumitrică et al., 1977

Type species. *Eucyrtidium thiensis* Tan Sin Hok, 1927.

***Mictyoditra thiensis* (Tan, 1927)**

Figs. 14i, j

1927 *Eucyrtidium thiensis* Tan Sin Hok, 1927, p. 95, pl. 11, fig. 95.

1981 *Eucyrtidium thiensis* Tan – Schaaf, p. 433, pl. 27, figs. 6a, b.

1997 *Mictyoditra thiensis* (Tan) – Dumitrică et al., p. 45, pl. 8, figs. 3, 8, 11, 13.

2014 *Mictyoditra curvata* Dumitrică – Robertson et al., fig. 10(A), 31.

Studied material. Two specimens in MGP-PD, stub PD120-OZ836-R07-17 and OZ836-R08-01.

Description. See Dumitrică et al., 1997, p. 45.

Remarks. The two illustrated specimens resemble rather well the specimens from Oman and the type specimen.

Range and occurrence. Berriasian - lower Valanginian of Masirah Island (Oman), and upper Valanginian of Sardinia.

Genus ***Thanarla*** Pessagno, 1977

Type species. *Phormocyrtis veneta* Squinabol, 1903.

Remarks. The genus was defined as having a multicyrtd costate shell with terminal blade-like feet and constrictions, when present, not occurring at joints. The problem with this genus is that the feet, which are distal projections of costae, are rarely preserved in fossil material. In this case it is difficult to assign some species to *Thanarla* or to *Archaeodictyomitra*. Pessagno (1977b) illustrated such blade-like feet in *Thanarla veneta* (Squinabol, 1904), *T. pulchra* (Squinabol, 1904), and *T. elegantissima* (Cita, 1964), whereas O’Dogherty (1994) assigned to this genus not only species with terminal blade-like feet but also species without such projections. We restrained the genus to *T. veneta*, *T. pulchra* and *T. elegantissima*, which are rather big species.

Range. Late Valanginian to Turonian.

***Thanarla pulchra* (Squinabol, 1904)**

Fig. 14h

1904 *Sethamphora pulchra* Squinabol, p. 213, pl. 5, fig. 8.

1973 *Sethamphora pulchra* Squinabol – Moore, p. 826, pl. 3, figs. 5, 6, non 4.

1975 *Dictyomitra pulchra* (Squinabol) – Dumitrică, p. 87, text-fig. 7.

1977b *Thanarla pulchra* (Squinabol) – Pessagno, p. 46, pl. 7, figs. 7, 21, 26.

1982 *Thanarla* cf. *pulchra* (Squinabol) – Okamura & Uto, pl. 5, fig. 6.

1984 *Thanarla pulchra* (Squinabol) – Baumgartner, p. 788, pl. 9, fig. 15,

1991 *Thanarla pulchra* (Squinabol) – Ishida & Hashimoto, p. 52, pl. 1, fig. 18.

1994 *Thanarla pulchra* (Squinabol) – Jud, p. 114, pl. 23, figs. 6-7.

?1994 *Thanarla pacifica* Nakaseko & Nishimura – O’Dogherty, p. 84, pl. 4, figs. 20-24.

1995 *Thanarla pulchra* (Squinabol) – Baumgartner et al., p. 570, pl. 5073 (p. 571).

Studied material. Several specimens in the studied samples (see Table 1).

Dimensions. Length of shell without distal projections 183 µm, maximum diameter 135 µm.

Remarks. Since there are two little different morphotypes of this species in the Valanginian of the S’Ozzastru section, also the specimens resembling those illustrated by Jud (1994) are included in this morphotype.

Occurrence. According to Jud (1994), the species is rather long-ranged, its FAD being recorded in her UA9 Zone, corresponding to the upper Berriasian and, according to O’Dogherty (1994), its LAD is as old as late Cenomanian.

***Thanarla* cf. *pulchra* (Squinabol, 1903)**

Figs. 13o, 14g

?1988 *Thanarla* sp. A – Thurow, p. 406, pl. 7, fig. 12.

Studied material. Two specimens in samples OZ825 and OZ834.

Dimensions. Length of shell without distal projections 180 µm, diameter 120-125 µm.

Remarks. This species is close in size and morphology to *T. pulchra*, from which it differs by having more or less marked constrictions on the inflates distal part of shell and a similarly deeper constriction between the proximal conical part and the distal inflated part. It is possible that this morphology evolved in time to originate the Albian *Thanarla* sp. A of Thurow where the undulations become much more marked.

Occurrence. Two specimens in the upper Valanginian of Sardinia.

Family **Pseudodictyomitridae** Pessagno, 1977

Type genus. *Pseudodictyomitra* Pessagno, 1977

Genus **Loopus** Yang, 1993

Type species. *Pseudodictyomitra primitiva* Matsuoka & Yao, 1985.

Loopus nudus (Schaaf, 1981)

Figs. 14m, n

1981 *Archaeodictyomitra nuda* Schaaf, p. 432, pl. 3, fig. 6.

1981 *Pseudodictyomitra blabla* Schaaf, p. 436, pl. 21, figs. 1a, b.

1994 *Pseudodictyomitra nuda* (Schaaf) – Jud, p. 99, pl. 18, figs. 12, 13.

1995 *Pseudodictyomitra nuda* Schaaf – Baumgartner et al., p. 452, pl. 5647, figs. 1-4.

1997 *Loopus blabla* Schaaf – Dumitrică et al., pl. 5, figs. 6, 23.

Material. Two specimens: one in OZ838, another one in OZ834.

Dimensions. Length 186 µm, diameter 83-98 µm.

Remarks. In Dumitrică et al. (1997), by a mistake, the species is mentioned as *Loopus blabla* in the text, whereas on the plate it is mentioned as *Loopus nudus*. Both species seem to be synonymous, one is viewed under electronic microscope, the other under light microscope. The specimens from the upper Valanginian of Sardinia differ from those from Oman (Dumitrică et al., 1997) in having a smooth surface, less inflates shell and more segments.

Range. Early Valanginian to late Barremian (Baumgartner et al., 1995).

Loopus cf. primitivus (Matsuoka & Yao), 1985

Fig. 14o

1985 *Pseudodictyomitra primitiva* Matsuoka & Yao, p. 131, pl. 1, figs. 1-6; pl. 3, figs. 1-4.

1993 *Loopus primitivus* (Matsuoka & Yao) – Yang, p. 125, pl. 23, figs. 5, 6, 13, 21.

1994 *Pseudodictyomitra primitiva* Matsuoka & Yao – Goričan, p. 84, pl. 22, fig. 16.

1995 *Pseudodictyomitra primitiva* Matsuoka & Yao – Baumgartner et al., p. 454, pl. 3189, figs 1-4.

Studied material. A single specimen from sample OZ834.

Dimensions. Length 156 µm, diameter 76 µm.

Range and occurrence. Upper Bathonian to Tithonian or Valanginian, worldwide.

Genus **Pseudodictyomitra** Pessagno, 1977

Type species: *Pseudodictyomitra pentacolaensis* Pessagno, 1977.

Pseudodictyomitra cf. carpatica (Lozyniak 1969)

Figs. 14 u, ?s

cf.1969 *Dictyomitra carpatica* Lozyniak, p. 38, pl. 2, figs. 11, 12.

cf.1981 *Pseudodictyomitra carpatica* (Lozyniak) – Nakaseko & Nishimura, p. 158, pl. 9, fig. 6, non 11.

cf. 1987 *Pseudodictyomitra carpatica* (Lozyniak) – Kito, pl. 3, fig. 4.

cf. 1991 *Pseudodictyomitra carpatica* (Lozyniak) – Ishida & Hashimoto, p. 49, pl. 2, fig. 2.

cf. 1992 *Pseudodictyomitra carpatica* (Lozyniak) – Steinger, p. 87, pl. 25, figs. 1-3, non 7.

cf.1994 *Pseudodictyomitra carpatica* (Lozyniak) – Jud, p. 97, pl. 18, figs. 3-5.

cf. 1994 *Pseudodictyomitra carpatica* (Lozyniak) – Goričan, p. 82, pl. 22, fig. 17.

cf. 1995 *Pseudodictyomitra carpatica* (Lozyniak) – Baumgartner et al., p. 446, pl. 3293, figs. 1, 2, 4-6, non 3, 7.

cf. 1995 *Pseudodictyomitra carpatica* (Lozyniak) – Matsuoka, figs. 4/4, 4/6-8, non 4/5.

cf. 1997 *Pseudodictyomitra carpatica* (Lozyniak) – Dumitrică et al., p. 32, pl. 6, figs. 10, 17.

cf. 2009 *Pseudodictyomitra carpatica* (Lozyniak) – Ishii et al., p. 343, pl. 10, fig. 5.

2017 *Loopus yangi* Dumitrică – Wu et al., p. 350, fig. 3.8.

Studied material. Only the illustrated specimens.

Remarks. The few specimens occurring in the upper Valanginian Sardinian samples differ from the older specimens by being shorter, by loosing the nodes on the distal part of shell and by having an ornamentation in the intercostal areas represented by depressions suggesting infilled pores. The specimen illustrated as *Loopus yangi* by Wu et al. (2017) does not represent this species but *Pseudodictyomitra carpatica*. The latter has the two rows of intersegmental pores very well visible whereas *Loopus* has only one row of pores and the ribs are thin and longitudinally arranged, whereas the specimen in Wu et al. 2017 has two rows of pores very well visible, and the ribs are short and thick.

Range and occurrence. Tithonian to lower Barremian, cosmopolitan.

Pseudodictyomitra nodocostata Dumitrică, 1997

Fig. 15a

1991 *Pseudodictyomitra lilyae* (Tan Sin Hok) – Ishida & Hashimoto, p. 50, pl. 2, fig. 14.

1997 *Pseudodictyomitra nodocostata* Dumitrică in Dumitrică et al., p. 35, pl. 6, figs. 2, 3, 15.

2009 *Pseudodictyomitra nodocostata* Dumitrică – Ishii et al., p. 343, pl.10, fig. 9.

Studied material. One specimen in OZ824 and another one in OZ839, coll. MGP-PD, stub PD120-OZ839-R01-07.

Remarks. By its morphology and stratigraphic range, this species seems to derive from *Pseudodictyomitra carpatica* (Lozyniak, 1969).

Dimensions. Total length 210 µm, maximum diameter 70 µm.

Range and occurrence. Upper Valanginian of Sardinia, Valanginian of North Pacific, lower Hauterivian of Svinița (Romania) and upper Barremian of Masirah Island (Oman).

Genus *Svinitzium* Dumitrică, 1997.

Type species. *Pseudodictyomitra depressa* Baumgartner, 1984.

Svinitzium depressum (Baumgartner, 1984)

Figs. 14p, pa, pb

1980 *Archaeodictyomitra carpatica* (Lozyniak) – Okamura & Uto, pl. 2, fig. 3.

1982 Unnamed nassellariid F – Wu & Li, pl. 2, fig. 19.

1982 *Pseudodictyomitra* sp. – Okamura & Uto, pl. 5, fig. 1.

1982 *Pseudodictyomitra carpatica* (Lozyniak) – Okamura & Uto, pl. 8, figs. 7a-b.

1984 *Pseudodictyomitra depressa* Baumgartner, p. 782, pl. 8, figs. 2, 7, 8, 11.

1989 *Pseudodictyomitra carpatica* (Lozyniak) – Tuman-da, p. 38, pl. 2, fig. 8.

1992 *Pseudodictyomitra depressa* Baumgartner – Taketani & Kanie, fig. 4.13.

1992 *Pseudodictyomitra depressa* Baumgartner – Steiger, p. 87, pl. 25, figs. 4, 5.

1994 *Wrangellium* (?) *depressum* (Baumgartner) – Jud, p. 117, pl. 23, fig. 18; pl. 24, fig. 1.

1995 *Wrangellium depressum* (Baumgartner) – Baumgartner et al., p. 632, pl. 3284 (p. 633), figs. 1-5.

2014 *Svinitzium depressum* (Baumgartner) – Robertson et al., fig. 10(A), 21.

1997 *Svinitzium depressum* (Baumgartner) – Dumitrică et al., p. 53, pl. 11, figs. 11, 17.

2017 *Svinitzium depressum* (Baumgartner) – Wu et al., p. 352, fig. 3.11.

Studied material. One specimen in sample OZ824, coll. MGP-PD, stub PD120-OZ824-R13-16 (figs. 14 p, p1) and another one in PD120-OZ839-R01-10 (fig. 14 p2). Many other specimens recorded in almost all samples but not illustrated (see Table 1).

Dimensions. Length 240 μm .

Remarks. What is interesting in this species is that the imperforate bands of the last segments show an ornamentation of infilled pores disposed in three circumferential rows with alternating pores (Fig. 14p1) (suggesting that the origin of the genus is in the family Parvicingulidae), or an ornamentation consisting of superficial ribs of variable directions and lengths (Fig. 14p2). These ribs are also visible, although less obvious, on the specimen of Fig. 14p1.

Range and occurrence. Berriasian to Valanginian, cosmopolitan.

Svinitzium irregulare Dumitrică n. sp.

Figs. 14r, t

Description. Shell multicyrtd conico-cylindrical consisting of 6-8 or probably more segments. First four segments increase in diameter as added forming a conical body without apical horn. Cephalis and thorax smooth-surfaced, and collar boundary marked by a circumferential row of small circular pores. Following two segments, representing abdomen and first postabdominal segment,

are well inflated, costate and separated by a deep post-lumbar constriction. The abdomen has a circumferential row of small circular pores, and the first postabdominal segment two parallel circumferential row of pores on the inflate portion. The following two to four segments, depending on the length of shell, have concave outline with a poreless circumferential band in the deep portion separated on both sides by high and slightly nodular circumferential crests and by a row of pores. Inner intersegmental platforms marked outside by the high circumferential and slightly nodular crest. Nodes may be separated by small shallow depressions. On the distal segments (Fig. 14t) the row of relict pores characteristic of the genus is not visible.

Studied material. Two specimens.

Holotype. Figure 14t, col. MGP-PD, stub PD120-OZ834-R10-10.

Paratype. Figure 14r, coll. MGP-PD, stub PD120-OZ836-R08-05.

Dimensions. Length of shell with 6 segments 171 μm , with 8 segments 212 μm , maximum diameter 103-108 μm .

Remarks. The two illustrated specimens, although different in length of test and number of segments, have similar proximal and distal parts. In the holotype, there is a transitional segment between these well distinct portions. The external strictures of the species do not correspond to the internal planiform partitions between segments but to their middle part, these partitions corresponding to the expanded parts of the segments like in the Parvicingulidae.

Etymology. From the Latin *irregularis*, -e = irregular.

Range and occurrence. Known only in the S'Ozzastru section.

Family **Parvicingulidae** Pessagno, 1977

Type genus. *Parvicingula* Pessagno, 1977

Genus *Ristola* Pessagno and Whalen, 1982, emend. Baumgartner 1984

Type species. *Parvicingula* (?) *procera* Pessagno, 1977.

Ristola (?) *nakatonbetsensis* Tumanda 1989

Fig. 6g

1989 *Ristola nakatonbetsensis* Tumanda, p. 31, pl. 4, figs. 7, 8.

1991 radiolari – Dieni & Massari, p. 36, fig. 23g.

Material. A single specimen illustrated by Dieni & Massari (1991).

Dimensions. Length 176 μm , maximum diameter 132 μm .

Remarks. By comparison with the holotype from the Lower Cretaceous Furebira Formation (Japan), the conical specimen illustrated by Dieni & Massari seems to represent only the proximal half of the shell. What is characteristic of this species is that the secondary outer layer of the proximal part of shell has continuous costae similar to those of the Archaeodictyomitridae.

Range and occurrence. Very rare in the upper Valanginian of Sardinia and also in the probable Hauterivian of the Furebira Formation, Japan.

Genus *Tethysetta* Dumitrică, 1997

Type species. *Tethysetta pygmaea* Dumitrică, 1997.

***Tethysetta cingulifera* Dumitrică, 1997**

Figs. 15j-l

1997 *Tethysetta cingulifera* Dumitrică in Dumitrică et al., p. 48, pl. 9, figs. 13, 14, 17.

Description. Shell very small, ovoid, consisting of about 8 segments. The first 4 segments increase constantly in diameter forming a conical portion of the test with no circumferential ridge between cephalis and thorax and between thorax and abdomen but with a possible shallow one between abdomen and first postabdominal chamber. The pores are irregularly disposed on thorax, but they start to show the characteristic disposition in 3 alternately disposed circumferential rows on the abdomen. Fifth and sixth chambers, which are the thickest, are well marked by their ring-shaped outline with concave shape, and by three well pronounced circumferential ridges that mark their boundary with neighbouring segments and between them. Ridges slightly nodular. Distal parts inverted conical but only partly preserved in the examined samples. Better preserved specimens from Oman (Dumitrică et al., 1997) prove that the last chambers decrease rapidly in diameter, and the last one is short, inverted conical and closed distally.

Studied material. Three illustrated specimens in sample OZ838 (coll. MGP-PD, stub PD120-OZ838-R04-02) and two in sample OZ839, coll. MGP-PD, stub PD120-OZ839-R02-04 and PD120-OZ839-R02-11.

Dimensions. Length of incomplete shell 143-156 µm, maximum diameter 93-106 µm.

Remarks. Hori (1999, p. 96) erroneously included this species, as well as *T. ovoidala* Dumitrică and *T. pygmaea* Dumitrică and many others in the synonymy list of what was considered before him as *Parvicingula boesii* (Parona, 1890). In such a way he extended the range of *P. boesii* from Kimmeridgian to Albian considering it a quite long-ranging and polymorphous species, and, therefore, biostratigraphically useless. Actually, in this stratigraphic interval the parvicingulids of the Tethys evolved rather quickly and diversified very much. In fact, the taxonomy of *Parvicingula boesii* is not perfectly known. Surely, it is not a *Parvicingula* but a *Tethysetta* because it has a different cephalic morphology. Under the name *Dictyomitra boesii*, Parona (1890, pl. 6, fig. 9) illustrated an elongate spindle-shaped species with 6 circumferential ridges. Until now almost no species illustrated in modern literature resembles perfectly Parona's drawing.

Range and occurrence. Upper Berriasian-lower Valanginian, Masirah Island, (Oman) and upper Valanginian of Sardinia.

***Tethysetta ovoidala* Dumitrică, 1997**

Figs. 15i

1974 *Dictyomitra boesii* Parona – Riedel & Sanfilippo, p. 778, pl. 4, fig. 6, ?5.

1982 *Parvicingula boesii* (Parona) – Okamura & Uto, pl. 5, figs. 5-7.

1985 *Parvicingula boesii* (Parona) – Kiminami et al., pl. 1, fig. 9.

1991 *Ristola boesii* (Parona) – Ishida & Hashimoto, p. 50, pl. 1, fig. 8.

1994 *Parvicingula boesii* (Parona) gr. – Jud, p. 91, pl. 16, fig. 1, non 2 = *T. hullae* Dumitrică.

1994 *Parvicingula boesii* (Parona) gr. – Goričan, p. 80, pl. 24, figs. 11, 14, 15.

1995 *Parvicingula boesii* gr. (Parona) – Baumgartner et al., p. 402, pl. 3185, figs. 1, 3-6.

1997 *Tethysetta boesii* (Parona) – Dumitrică et al., p. 48, pl. 10, fig. 19.

1997 *Tethysetta ovoidala* Dumitrică in Dumitrică et al., p. 50, pl. 10, figs. 21, 22.

2009 *Tethysetta boesii* (Parona) – Ishii et al., pl. 13, fig. 6.

2014 *Tethysetta boesii* (Parona) – Robertson et al., fig. 10(A), 28.

2017 *Tethysetta boesii* (Parona) – Xu & Luo, figs. 6N, 6O.

Remarks. Based on the very well-preserved illustrated specimen from Sardinia and on other similarly well-preserved specimens assigned in the literature to *Tethysetta boesii* (Parona, 1890), a more detailed description can be given of the species *T. ovoidala* which was erected on the basis of partly dissolved specimens from Oman (Dumitrică et al., 1997). This species has spindle-shaped test of about 9-10 segments consisting of two main parts: a proximal conical part and a cingulate middle and distal part. Proximal conical part is smooth-surfaced with small circular pores disposed in more or less circular rows. This regular disposition increases distally, and in the same direction also the size of pores increases. Apex of cephalis thin-walled, usually dissolved. This portion seems to comprise the first four segments. Boundaries between segments are not marked by any change in outside morphology excepted, in some cases, the appearance of very small nodes at the boundary between abdomen and postabdominal segments. The following 4-5 segments increase in diameter, whereas the following (last?) ones decrease forming an inflated spindle-shaped shell. The intersegmental boundaries are well marked by high circumferential ridges that may be smooth or more or less nodular. Segments of this part are very depressed, concave in outline, with three rows of alternatively disposed pores. Pores of middle part of segments are elliptical with protruding rims. These rims merge together at the proximal and distal ends of pores to join on the intervening bars of the proximal and distal circumferential rows of pores of each segment. In the middle row of pores this structure forms a circumferential band with elliptical pores separated by more or less disturbed(?) rectangular depressions. Last segments are rarely preserved due probably to dissolution because they are very thin.

Material. Only the illustrated specimen.

Studied material. Specimen of Fig. 15i, coll. MGP-PD, stub PD120-OZ834-R10-29.

Dimensions. Length more than 240 µm, maximum diameter 125-160 µm.

Remarks. By its shape, number of segments, type of middle row of pores with protruding rims at the segments with strong circumferential ridges, the specimen illustrated by Ishida & Hashimoto (1991) as *Ristola boesii* (Parona) from the Lower Cretaceous of the Chichibu Terrane

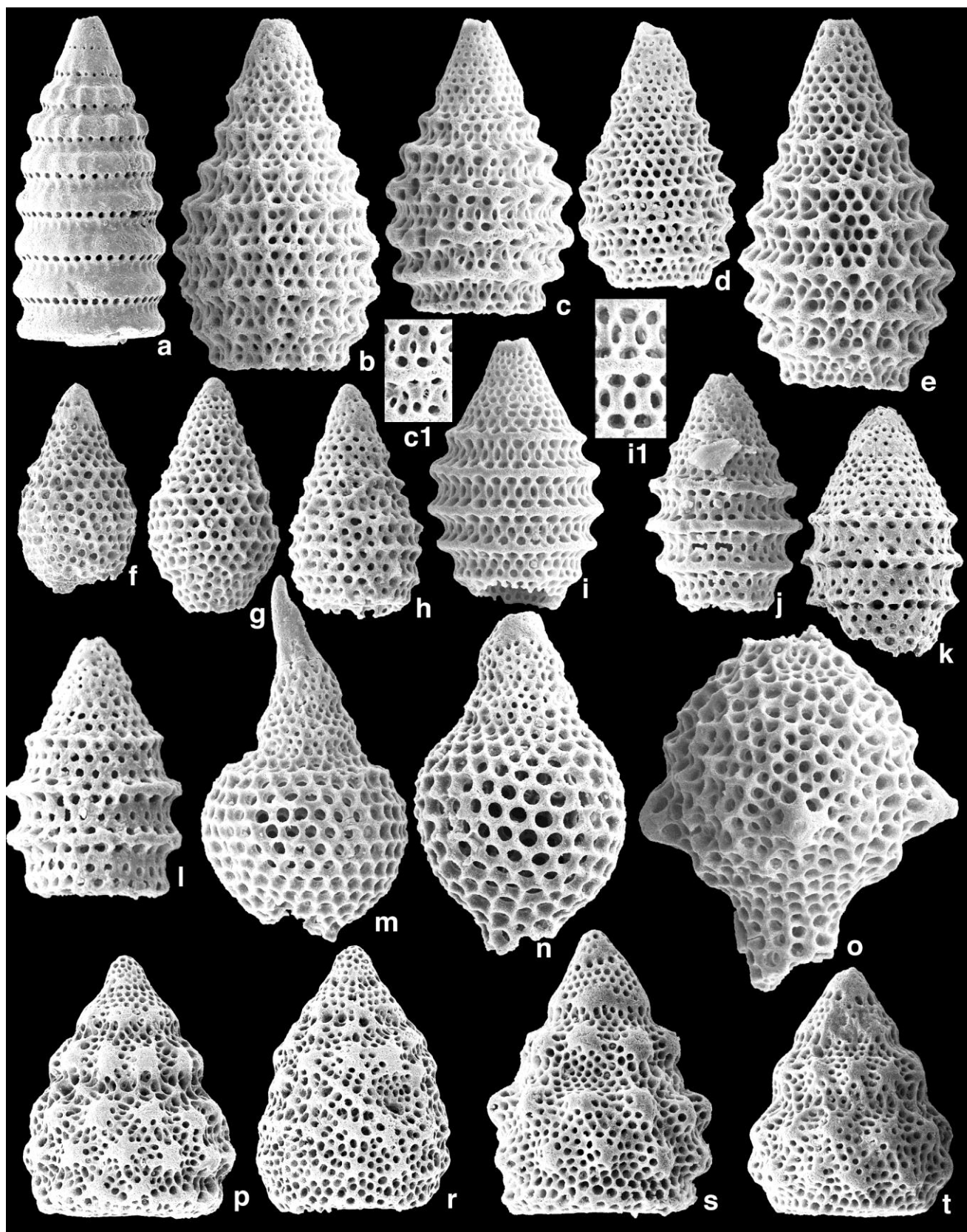


Fig. 15 a - *Pseudodictyomitra nodocostata* Dumitrică, OZ839. b-e - *Tethysetta usotanensis* (Tumanda): b - OZ837, c, d - OZ836, c1 - details of pore morphology, e - OZ838. f-h - *Tethysetta reducta* Dumitrică n. sp.: f - OZ836, g - OZ839, h - OZ834. i - *Tethysetta ovoidala* Dumitrică, OZ836, i1 - details of pore morphology. j-l - *Tethysetta cingulifera* Dumitrică: j - OZ838, k, l - OZ839. m - *Favosyringium affine* (Rüst), OZ834. n - *Favosyringium* cf. *affine* (Rüst), fragment of shell, OZ836. o - *Favosyringium quadriaculeatum* Steiger, fragment of shell, OZ838. p-t - *Pseudoxitus seriola* Dumitrică: p - OZ839, r-t - OZ836. Figs. a-l, m-t x250, figs. j-l x300.

in eastern Shikoku (Japan), belongs to this species. It differs from the specimen herein illustrated especially by having very thick circumferential ridges.

Morphologically, this species is very close to *Tethysetta boesii* (Parona, 1890) to which it was usually assigned, but differs by having a larger maximum diameter relative to its length. *T. boesii* is much slender and its intersegmental boundaries of proximal segments are also well marked by high circumferential rings.

Tethysetta ovoidala is also close to *T. usotanensis* (Tumanda, 1989), from which it differs by the regularity of disposition of pores and the quite perfect bilateral symmetry relative to a perpendicular plane passing through the middle of shell. *T. usotanensis* has the conical apical part of shell longer than the lower part and the maximum diameter is not at the middle part of the shell but at its third distal part.

Range and occurrence. Latest Tithonian to Hauterivian (see synonymy). Upper Valanginian of Sardinia, and probably Valanginian of Japan.

***Tethysetta reducta* Dumitrică n. sp.**

Figs. 15f-h

Description. Shell small, long-ovate to spindle-shaped of which about two proximal thirds are conical and the distal third inverted conical. Cephalis small, spherical, without apical horn and imperforate. Postcephalic segments increasing in diameter as added up to about two thirds of length forming a conical body, then decreasing gradually. Distal end incompletely preserved and probably open as the holotype suggests. Whole shell except cephalis with small and dense circular or subcircular pores disposed alternately and divided transversally by rather irregular circumferential ridges into about 10 segments. Circumferential ridges weakly marked, partly almost indistinct. Between them each segment has only two circumferential rows of pores. Surface of test rather irregular due to the circumferential ridges and shorter oblique or longitudinal ridges.

Studied material. Three illustrated specimens in OZ836 (PD120-OZ836-R08-08), OZ838 (holotype) and OZ839 (PD120-OZ839-R02-08).

Holotype. Figure 15g, coll. MGP-PD, stub PD120-OZ838-R04-01.

Dimensions. Length 149-169 µm, maximum diameter 82-94 µm.

Remarks. The assignation of this species to the genus *Tethysetta* is somewhat questionable because of the very weak outside expression of the circumferential ridges, of their irregularities and of the presence of only two rows of pores in each segment.

Etymology. From the Latin *reductus*, -a, -um, = reduced, due to the reduced number of circumferential pores in each segment from three (normal for the genus) to two.

Occurrence. Upper Valanginian of Sardinia as far as known.

***Tethysetta usotanensis* (Tumanda, 1989)**

Figs. 15b-e

1973 *Lithocampe ananassa* Rüst – Moore, p. 828, pl. 4, figs 7-9.

1977 *Lithocampe ananassa* Rüst – Muzavor, p. 99, pl. 8, fig. 6.

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1981 *Parvicingula boesii* (Parona) – Schaaf, p. 436, pl. 3, figs. 13a, b; pl. 18, figs. 6a, b.

?1982 *Parvicingula* sp. B – Aita, pl. 2, fig. 14.

1986 *Parvicingula* sp. – Suyari, pl. 3, fig. 2.

1987 *Eucyrtis* cf. *E. elido* Schaaf – Thurow, pl. 10, fig. 78.

1989 *Parvicingula usotanensis* Tumanda, p. 30, pl. 4, fig. 4; pl. 10, figs. 11a, b.

1994 *Parvicingula usotanensis* Tumanda – Jud, p. 92, pl. 16, fig. 8.

1995 *Parvicingula usotanensis* Tumanda – Baumgartner et al., p. 414, pl. 5712, figs. 1-6.

2003 *Parvicingula usotanensis* Tumanda – Zyabrev et al., fig. 3.32.

2014 *Tethysetta usotanensis* (Tumanda) – Robertson et al., figs. 10(A), 27; 10(B), 15.

2017 *Tethysetta usotanensis* (Tumanda) – Xu & Luo, fig. 6S.

Studied material. Four figured specimens.

Remarks. In the Sardinian samples there is a wide range of variations of this species, from smaller and simpler specimens (Fig. 15d) to bigger and normal ones similar to the holotype (Fig. 15b, e), or from the latter to specimens with robust shell and some segments with an ornamentation similar to the species of *Tethysetta ovoidalis* Dumitrică (Fig. 15i). This specimen has robust circumferential sutural circles and two segments with regular central bands of pores. These facts prove that the two species are very closely related.

Range: UA Zones 15-22 (Baumgartner et al., 1995), upper Berriasian-lowermost Valanginian to upper Barremian-lower Aptian.

Family **Favosyringiidae** Steiger, 1992, nom. corr. by O'Dogherty et al. (2009), pro Favocyrtidiinae Steiger, 1992.

Type genus. *Favosyringium* Steiger, 1992.

Syn. Syringocapsinae Foreman, 1973, type genus: *Syringocapsa* Foreman, 1973, non Neviani, 1900.

Remarks. The family Favosyringiidae comprises especially Middle Jurassic to Lower Cretaceous spindle-shaped nassellarians with test consisting of three parts: a conical apical part (with usually two segments: a simple cephalis and thorax), a bulbous middle part, which usually represents the abdomen, and a distal inverted conical tube of different lengths. Both the cephalis and the distal tube may be prolonged into a spine that may be conical or bladed, or missing.

Genus **Favosyringium** Steiger, 1992

Type species. *Eusyringium affine* (Rüst, 1898).

Remarks. The genus *Favosyringium* comprises nassellarians with a conical two chambered proximal part, a bulbous middle part and a long inverted conical distal tube. Apical horn conical, not bladed.

***Favosyringium affine* (Rüst, 1898)**

Figs. 6c, 15m

1898 *Eusyringium affine* Rüst, p. 60, pl. 17, fig. 8.

1973 *Podobursa triacantha* (Fischli) – Foreman, p. 266, pl. 13, figs. 2, 4, 6 non 1, 3, 5, 7.

1973 *Dibolachras apletopora* Foreman, p. 265, pl. 11, fig. 3, non 11.

1992 *Favosyringium affine* (Rüst) – Steiger, p. 79, pl. 21, fig. 10, non 11, 12.

1991 radiolari – Dieni & Massari, fig. 23c.

2009 *Eusyringium affine* (Rüst) – O’Dogerty et al., p. 332, fig. 460.

2009 *Sethocapsa* sp. – Ishii et al., p. 348, pl. 21, fig. 9.

2017 *Hiscocapsa* (?) *mirifica* Wu et al., p. 359, fig. 2-11, 12.

2017 *Spinocapsa* sp. aff. *S. quadriaculeata* (Steiger) – Xu & Luo, p. 166, fig. 5O, P

Description. Shell with a long conical apical horn, a porous cephalis, a thorax with small circular pores, and a bulbous abdomen with larger pores. Pores circular but hexagonally framed on the surface and disposed quincuncially in circumferential and oblique rows. All segments are separated from one another by evident collar and lumbar constrictions, respectively. Distal tube is inverted conical, usually rather long and open or prolonged in a spine. Pores of distal tube disposed usually in longitudinal rows.

Remarks. Steiger (1992) illustrated under this species 3 specimens: one (pl. 21, fig. 10) has a conical apical horn, the other two (pl. 21, figs. 11, 12) have bladed apical horns. We include in this species only the specimen with conical apical horn, as the specimens with bladed horns must belong to another genus or, at least, to another species. The specimen illustrated by Ishii et al. (2009) belongs to this species and not to *Sethocapsa*. It resembles very well the specimen from s’Ozzastru section and is nothing else than a specimen with broken off distal tube. The specimen described as *Hiscocapsa* (?) *mirifica* n. sp. by Wu et al. (2017) does not belong at all to *Hiscocapsa*. It is a specimen of *Eusyringium affine* with the apical part broken off and reversely mounted on the plate, with the apical part (partly broken off) and downwardly directed, and the distal tube apically directed.

Range. Berriasian to Valanginian as far as we know.

Favosyringium cf. *affine* (Rüst, 1898)

Fig. 15n

Remarks. This only specimen at disposal differs from *F. affine* (Rüst) by having an ellipsoidal abdomen and a less marked postlumbar constriction. It may be a member of this species, representing just a morphological variation of the holotype. The scarcity of specimens examined by Rüst does not allow any knowledge of the variability of the species. For example, the distal tube is open in the only entire specimen illustrated by Dieni & Massari (1991), whereas the holotype and the specimen illustrated by Steiger (1992, pl. 21, fig. 10) have a narrow tube with a very long distal spine.

Range. The same as the type species.

Favosyringium quadriaculeatum Steiger, 1992

Fig. 15o

1992 *Favosyringium quadriaculeatum* Steiger, p. 81, pl. 22, figs. 1-5.

Remarks. Although incomplete, the illustrated specimen can be well compared with this species, having a nodose abdomen with 4 short mammary equatorial spines and a rough surface. Similar and very well-preserved pyritized specimens occur in the Valanginian of the Murguceva Formation from Svinița, Banat, SW Romania.

Range and occurrence. Uppermost Tithonian or Berriasian to upper Valanginian, Tethys, so far as known.

Family **Xitidae** Pessagno, 1977b

Type genus. *Xitus* Pessagno, 1977b

Remarks. For generic assignation of the members of this family we follow Pessagno (1977b), with some critical remarks. This author erected the family Xitidae with three new genera: *Crolanium* Pessagno, 1977b (type species *Crolanium triquetrum* Pessagno 1977b), *Novixitus* Pessagno (type species *Novixitus mclaughlini* Pessagno 1977b) and *Xitus* Pessagno (type species *Xitus plenus* Pessagno 1977b) with well defined diagnoses and very good illustrations.

Crolanium was later (O’Dogerty, 1994) erroneously transferred to the family Parvingulidae Pessagno 1977b and its type species synonymised, also erroneously in our opinion, with *Stichocampe triangularis* Aliev, 1968, because the shape of the two species is not quite similar and also because it is very difficult to recognize in an old and simple drawing a species illustrated by electroscan microscopy. Concerning *Novixitus*, it was also synonymised, together with *Pseudoxitus* Wu and Pessagno in Wu, 1993, with the genus *Xitus* whose type species was synonymised with *Dictyomitra spicularia* Aliev, 1965, that became *Xitus spicularius* (Aliev). The reduction of the morphological diversity of this group to a single genus does not reflect the divergent evolution of these radiolarians during the Cretaceous.

Genus **Pseudoxitus** Wu and Pessagno, 1993

Type species. *Pseudoxitus inflatus* Wu, 1993.

Remarks. This genus is rather similar to *Neorelumbra* Kiessling, 1995, from which it differs by lacking longitudinally elongated tubercles or ribs. Both have short conical or ovoidal shell with four or maximum five segments and the fourth segment with maximum diameter. By this last character they differ from *Novixitus* Pessagno, 1977, that has a robust skeleton and the third segment tending to expand. It is possible that Aliev (1965, p. 60, pl. 11, fig. 4) illustrated a species of this genus as *Lithocampe tumulata* Aliev, but the specimen figured in its drawing is difficult to compare with those illustrated with electroscan technology. Moreover, the sizes he mentions for this species (length 308-354 µm, diameter 169-200 µm) are greater than those of all the congeneric species herein illustrated.

Range. Late Tithonian to late Barremian according to Kiessling (1995).

Pseudoxitus laguncula Dumitrică, 1997

Figs. 16f, j

1973 *Dictyomitra* sp. C. – Moore, p. 830, pl. 14, fig. 3.

1997 *Pseudoxitus laguncula* Dumitrică in Dumitrică et al., p. 60, pl. 13, fig. 19; pl. 14, fig. 1.

Dimensions. Length of shell 208 µm, diameter of shell 136 µm.

Remarks. This specimen is rather similar to the topotypes from Oman and partly to *X. gifuensis* illustrated by Tumanda (1989). Although the specimen illustrated by Moore (1973) from probably Berriasian-Valanginian of Site 167 of the Leg 17 of the DSDP is poorly preserved, it seems to belong to this species.

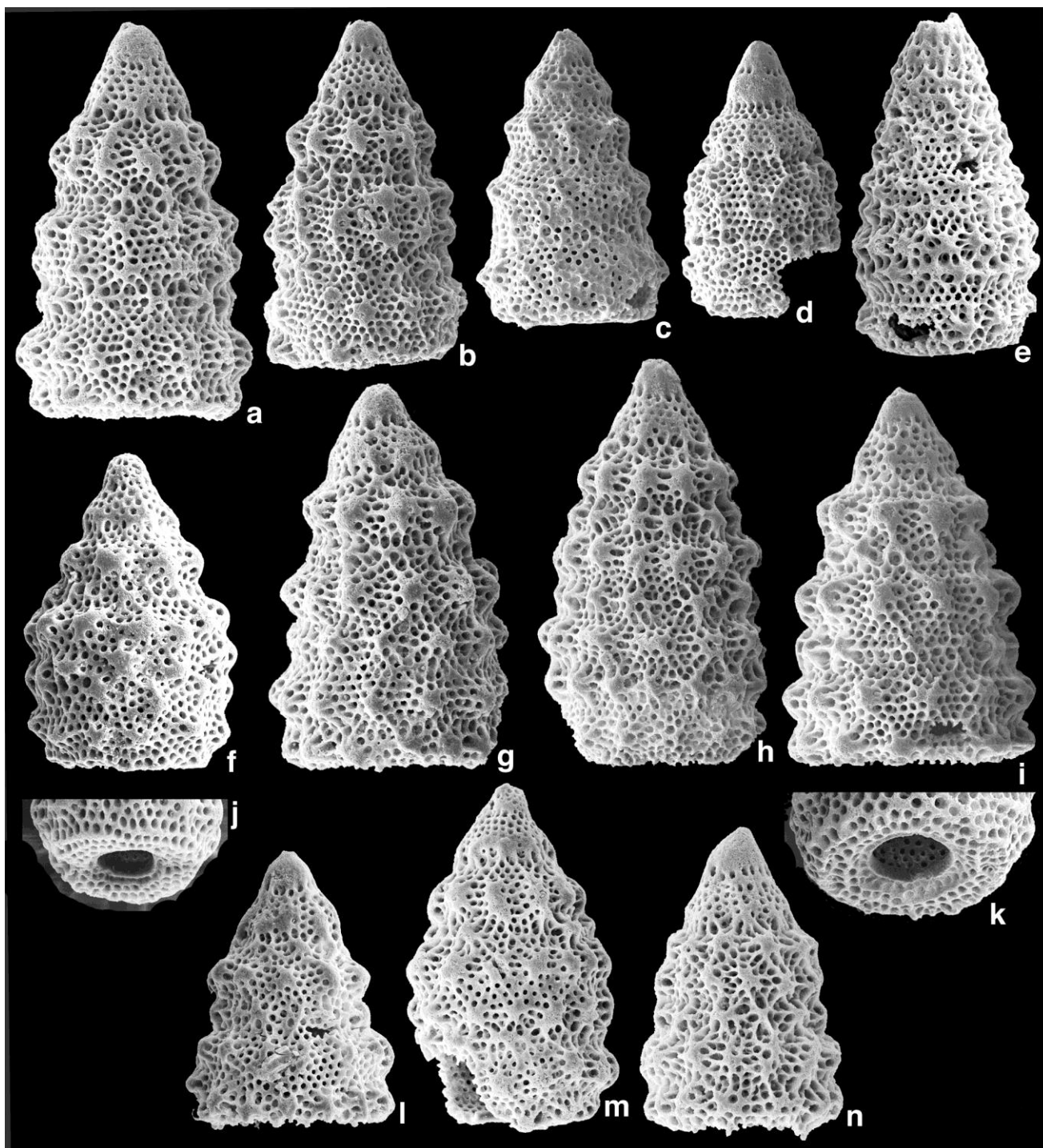


Fig. 16 a, b, m, n - *Novixitus quadripartitus* Dumitrică n. sp.: a - holotype, OZ836. b - paratype, OZ834. c?, g-i, k, l, - *Novixitus robustus* Wu, OZ825. d - *Pseudoxitus wui* Dumitrică n. sp., holotype, OZ836. e - *Xitus vermiculatus* (Renz), OZ838. f, j - *Pseudoxitus laguncula* Dumitrică, OZ836. i - OZ836, k - basal view, OZ839. All figures x250.

Ranged and occurrence. Known from early Valanginian to early Barremian. In S'Ozzastru section a single specimen was found in sample OZ836.

***Pseudoxitus seriola* Dumitrică, 1997**

Figs. 6d, 15p-t

1982 *Xitus gifuensis* Mizutani – Adachi, pl. 3, fig. 1, non 2.

1982 *Novixitus* sp. – Okamura & Uto, pl. 2, figs. 7, 9 non 8.

1989 *Xitus gifuensis* Mizutani – Tumanda, p. 40, pl. 4, fig. 5.

1991 radiolari – Dieni & Massari, fig. 23d.

1995 *Neorelumbra* (?) sp. B. – Kiessling, p. 338, fig. 8/10.

1997 *Pseudoxitus seriola* Dumitrică in Dumitrică et al., p. 61, pl. 13, figs. 12, 15.

1997 *Pseudoxitus omanensis* Dumitrică in Dumitrică et al., p. 61, pl. 12, figs. 13, 14, 18.

2009 *Pseudoxitus seriola* Dumitrică – Ishii et al., p. 347, pl. 17, figs. 13-15, non 11, 12.

2017 *Pseudoxitus angulatus* Dumitrică – Xu & Luo, Fig. 8A.

Description. Shell low conical of four to six segments. Cephalis hemispherical or rounded conical with very small pores or without pores, separated from the thorax by a circle of larger pores. Collar boundary marked by such larger pores or also by the change of the angle of the sides of the cone. Thorax is a truncated cone with wall perforated by very small circular pores and, at its base, with three or four tubercles visible on half the perimeter. Abdomen larger than thorax but not higher, consisting of a circumferential row of big tubercles, about five on half the perimeter. Tubercles with massive apex, without pores. Lumbar boundary marked by a constriction between the row of tubercles of thorax and that of the abdomen. Generally, the septal tubercles are not visible, but they are very rare and very small in some specimens. First postabdominal chamber larger and higher than the abdominal one, continuing in straight line the conical outline of the shell and having two circumferential rows of big tubercles with usually poreless apex. Tubercles of the two rows in intercalated position with respect to one another. Below the lowermost row of tubercles, the shell become inverted conical on a very short distance before stopping its growth or can bear a row of smaller septal tubercles. Base flat with circular pores and with a wide circular aperture. Rare specimens can have a distal chamber of small diameter and with a row of small tubercles (holotype).

Studied material. Many specimens.

Dimensions. Length 176–200 µm, diameter 138–160 µm.

Remarks. The taxonomy used by Dumitrică when he studied the fauna from Oman (Dumitrică et al., 1997) was purely morphological, due to the small number of specimens at disposal. In this group he recognized several species based on the shape of shell, number of segments and others. At present, combining the data from Oman with those from Sardinia and those published in the meantime, the variability and morphological boundaries of the species may be better understood. The specimen from Fig. 15r belongs to this species by size and shape of skeleton, although the two rows of nodes of the last segment and the deep postlumbar stricture are very weakly marked.

Occurrence. Valanginian of Sardinia, Oman, North Pacific and Japan.

***Pseudoxitus wui* Dumitrică n. sp.**

Fig. 16d

Description. Shell elongate ovoid consisting of five segments. Cephalis and thorax form a conical portion of shell with smooth surface, rounded apex and without apical horn. Both chambers separated by a circumferential row of small pores. Thorax perforated by very small pores irregularly disposed. Abdomen is truncate-conical and continues the conical shell above. It is a little more expanded, has larger pores, a circumferential row of very small tubercles at the lower part and an imperforated circle at the upper part, which is connected by a rib with each of the lower tubercles forming trapezoidal areas with rather regularly disposed pores. First postabdominal segment cylindrical with much larger diameter than abdomen and with surface divided into polygonal areas by differently oriented ribs which form very small tubercles

at their meeting points. Pores a little larger than those of the abdominal segment, circular and disposed in regular rows of various orientations. Postlumbar boundary more or less well marked by a constriction. Second postabdominal chamber sensibly shorter than the first postabdominal one and slightly inverted-trapezoidal in outline. Its superficial ornamentation similar to that of the first postabdominal chamber. Second postlumbar boundary marked by a circle of rare larger pores. Distal end with a large circular opening.

Studied material. The illustrated specimen and one specimen from Oman.

Holotype. Fig. 16d, coll. MGP-PD, stub PD120-OZ838-R05-07.

Dimensions. Length of test 180 µm, maximum diameter 104 µm.

Etymology. The species is dedicated to Haoruo Wu who described several species of the family Xitidae.

Remarks. *Pseudoxitus wui* n. sp. seems to belong to a small group of species with ovoid shell formed of five segments and having tuberculate surface such as *Pseudoxitus seriola* Dumitrică and *P. laguncula* Dumitrică. *Pseudoxitus wui* differs from the other species mentioned in this genus by lacking big tubercles but by having polygonal areas outlined by thin crests and very small tubercles at the meeting points of crests.

Range and occurrence. Upper Valanginian of Sardinia to Hauterivian of Oman.

Genus ***Novixitus*** Pessagno, 1977

Type species. *Novixitus mclaughlini* Pessagno, 1977 (= junior synonym of *Lithostrobos elegans* Squinabol 1903).

Remarks. An interesting discussion deserves *Lithostrobos elegans* Squinabol (1903, pl. 9, fig. 22) that was erroneously synonymised by O'Dogherty (1994) with *Xitus vermiculatus* (Renz, 1974). Squinabol's drawing is very small but rather significant. Looking carefully at the original drawing, this species appears rather big if compared to *Phormocyrtis veneta* (see Squinabol, 1903, pl. 9, fig. 30), that has the same magnification and that will become type species of the genus *Thanarla* Pessagno, 1977. At the middle and distal parts of its shell, this "*Lithostrobos*" has also two rows of bigger tubercles separated by circumferential rows of smaller tubercles. And, above all, this species has on the proximal part two rows of very big tubercles, one larger on the lower part and one smaller above it. This proves that it is nothing else than *Novixitus mclaughlini* Pessagno, 1977. Another argument for this assignation is the age of the two species. According to Pessagno (1977b), *N. mclaughlini* is early Cenomanian in age. *Lithostrobos elegans* is also Cenomanian in age occurring in an assemblage with *Thanarla veneta* (Squinabol), *Pseudodictyomitra pseudomacrocephala* (Squinabol, 1903) and many other coeval species.

***Novixitus quadripartitus* n. sp.**

Figs. 16a, b, n, ?m

1981 *Novixitus* sp. – Kanie et al., pl. 1, fig. 17.

1982 *Xitus* sp. – Okamura & Uto, pl. 5, figs. 4, 5.

1995 *Xitus* sp. aff. *X. spicularius* (Aliev) – Baumgartner et al., p. 646, pl. 3295, fig. 3, non 1, 2, 4, 5.

2014 *Xitus* sp. – Robertson et al., p. 12, Fig. 10(B), 6.

2017 *Pseudoxitus* (?) sp. – Xu & Luo, Fig. 8E, F.

Description. Shell large, cylindro-conical consisting of five to six segments separated by three deep constrictions. Cephalis and thorax form a usually smooth conical proximal part. Cephalis smooth, poreless or with very small, almost indistinct pores, with or without a small apical horn. Thorax is a truncate cone with dense and small circular pores and a beginning of some nodes at its base. Collar boundary marked by a shallow constriction resulted by the widening of the base of thorax and by the increase of thoracic pores. Abdomen much larger, with a row of circumferential nodes and also a beginning of some additional nodes. Nodes usually elongate on longitudinal direction and interconnected by radially disposed interporal bars. Lumbar boundary marked by a change in outline due to the development of abdominal tubercles and appearance of larger abdominal pores. Next segments increase very slowly in diameter so that the postabdominal part is virtually subcylindrical. First postabdominal segment almost as high as abdomen and a little larger in diameter than it, resembling the abdomen in surface structure but having two rows of tubercles disposed one under the other so that some of them may unite giving rise to longitudinally elongated tubercles. First postlumbar intersegmental boundary very deep with very small tubercles along it. Second postabdominal segment as high as the previous one and a little larger in diameter. It bears a row of circumferential tubercles and is separated from the previous segment by a deep intersegmental constriction with very small tubercles. Distal end of shell bearing one or two rows of big tubercles followed by a row of small intersegmental tubercles. A narrow cylindrical segment with thin wall and a circle of small tubercles may develop to close the building of complete shell.

Studied material. Two specimens in samples OZ 834 and OZ 836; other specimens are in the synonymy list.

Holotype. Fig. 16a, coll. MGP-PD, stub PD120-OZ836-R08-02.

Paratype. Fig. 16b, coll. MGP-PD, stub PD120-OZ834-R09-06.

Dimensions. Total length of shell with 5 segments 228-260 µm, maximum diameter of the last segment 134-154 µm, of abdomen 99-112 µm.

Etymology. From the Latin *quadri* – related to four, and *partitus* = divided, because the shell is divided into four parts by three deep constrictions.

Remarks. The specimen from fig. 16n, which has only 4 segments but the characteristic abdomen with two rows of tubercles, is considered an incomplete specimen, fact suggested by the ragged distal end. The species illustrated by Kanie et al. (1981, pl. 1, fig. 17) is perfectly similar to this new species which differs from *Xitus spicularius* (Aliev) by being much shorter and having some segments with two rows of tubercles and no horn. From *Xitus normalis* (Wu and Li, 1982), that has also 5 segments, it differs by not having all segments with only one circumferential row of tubercles.

Occurrence. Reported also in Japan, Oman and in the Valanginian of Svinița section, Romania (see synonymy).

Novixitus robustus Wu, 1993

Figs. 16c, g-i, k, l

1981 *Xitus spicularius* (Aliev) – Schaaf, p. 440, pl. 5, figs. 12a, b; pl. 19, figs. 2a, b.

1982 *Novixitus* sp. (pars) – Okamura & Uto, pl. 2, fig. 8, non 7, 9.

1983 *Novixitus* (?) *maclaughlini* Pessagno – Origlia-Devos, p. 211, pl. 25, figs. 2, 3.

1984 *Xitus* sp. cf. *X. spicularius* Aliev – Baumgartner, p. 792, figs. 16, 17.

1989 *Xitus* sp. cf. *X. spicularius* (Aliev) – Matsuoka, fig. 2. 2.

1992 *Xitus spicularius* (Aliev) – Steiger, p. 89, pl. 26, figs. 9?, 10, 11.

1992 *Xitus spicularius* (Aliev) – Ozvoldova & Petercakova, pl. 4, fig. 6.

1993 *Xitus robustus* Wu, p. 127, pl. 4, fig. 10.

1994 *Xitus clava* (Parona) – O'Dogherty, p. 124, pl. 11, figs. 1-8.

1995 *Xitus* sp. aff. *X. spicularius* (Aliev) – Baumgartner et al., p. 646, pl. 3295 (p. 647), fig. 2, non 1, 3-5.

1995 *Xitus* sp. cf. *X. spicularius* (Aliev) – Takahashi & Ishii, pl. 3, fig. 13.

1997 *Xitus robustus* Wu – Dumitrică et al., p. 57, pl. 13, figs. 4?, 10, 11.

2014 *Xitus robustus* Wu – Robertson et al., fig. 10(B), 21.

2017 *Xitus robustus* Wu – Xu & Luo, fig. G-K.

Description. Shell robust, wide conical consisting commonly of five segments. Cephalis and thorax form a short conical body with a practically imperforated and smooth hemispherical cephalis bearing or not an extremely short apical horn. Thorax truncate conical with small circular pores and bearing 3-4 tubercles visible at its lower part on half the perimeter. Abdomen and the following two postabdominal segments much larger and forming a robust truncate conical body. Each segment has one circumferential row of big tubercles. Similar rows, but with smaller tubercles, are also developed on the intersegmental suture zone. Tubercles are usually interconnected with the neighbouring ones by ribs giving the surface a stellate ornamentation. Fifth segment wide open. The sixth segment is very rarely preserved (Fig. 16h); it is thinner walled, inverted truncate cone-shaped and has a circumferential row of five tubercles on its middle part.

Remarks. The specimens illustrated by Steiger (1992) as *Xitus spicularius* from the Tithonian-lower Valanginian differ from the specimens from S'Ozzastru section by being less wide conical. Similar specimens, but somehow wider conical, have been illustrated by O'Dogherty (1994) as *Xitus clava* (Parona) from the lower Aptian, but do not belong to this species, as demonstrated later by Dumitrică (in Dumitrică et al., 1997, p. 58, pl. 14, figs. 4, 5), when he erected the genus *Clavaxitus* for Parona's species.

Studied material. Many specimens.

Range and occurrence. Valanginian to Aptian so far as known in Tethys.

Genus *Xitus* Pessagno, 1977

Type species. *Xitus plenus* Pessagno, 1977.

Remarks. The type species seems to be a junior synonym of *Eucyrtidium vermiculatum* Renz, 1974. There is doubt due to the fact that Renz illustrated this species in transmitted light and the images are too small and not of high quality as those produced by electroscanning microscopy. Among all the species herein described and illustrated in the family Xitidae, only *Xitus vermiculatus* (Renz) is

close to the type species of the genus and agrees with the genus *Xitus* as originally described by Pessagno (1977b).

Xitus vermiculatus (Renz, 1974)

Fig. 16e

1974 *Eucyrtidium vermiculatum* Renz, p. 792, pl. 8, figs. 17-19; pl. 11, fig. 22.

?1977b *Xitus spineus* Pessagno, p. 56, pl. 10, figs. 3, 12, 16, 20.

1977b *Xitus plenus* Pessagno, p. 55, pl. 12, fig. 15.

1981 *Xitus vermiculatus* (Renz) – Schaaf, p. 441, pl. 19, figs. 6a, 6b.

1981 *Xitus* sp. – Schaaf, p. 441, pl. 4, fig. 12.

1981 *Xitus* sp. indet. – Schaaf, pl. 21, figs. 10a, b.

1982 *Novixitus tuberculatus* Wu & Li, p. 69, pl. 2, fig. 6.

1988 *Parvicingula?* sp. – Thurow, p. 403, pl. 6, fig. 10.

1993 *Xitus vermiculatus* (Renz) – Ellis, p. 978, pl. 4, figs. 12, 13.

1994 *Novixitus (?) tuberculatus* (Wu) – Jud, p. 86, pl. 13, figs. 7-9.

1994 *Xitus elegans* (Squinabol) – O'Dogherty, p. 126, pl. 11, figs. 9-14.

?1994 *Novixitus (?) danieliani* Jud, p. 85, pl. 13, fig. 6.

?1995 *Novixitus tuberculatus* Wu & Li – Baumgartner et al., p. 338, pl. 5693, figs. 1-5.

?1995 *Novixitus (?) danieliani* Jud – Baumgartner et al., p. 336, pl. 5524, fig. 2.

1995 *Xitus plenus* Pessagno – Takahashi & Ishii, pl. 3, fig. 12.

1997 *Xitus vermiculatus* (Renz) – Dumitrică et al., p. 57, pl. 12, figs. 5, 10.

1998 *Xitus asymbatos* (Foreman) – Vishnevskaya & De Wever, p. 257, pl. 1, figs. 11, 12.

2003 *Xitus elegans* (Squinabol) – Zyabrev et al., fig. 3.55.

2009 *Novixitus (?) tuberculatus* Wu – Ishii et al., p. 347, pl. 19, fig. 2.

Studied material. The illustrated specimen from sample OZ838 (coll. MGP, stub PD120-OZ838-R05-07) and another specimen from sample OZ833.

Dimensions. Length of shell 220 µm, maximum diameter 124 µm.

Remarks. The species is rather long-ranged in the lower Cretaceous (see below) and very characteristic by its conical shell and by having two circumferential rows of tubercles: a bigger one in the middle of segments and a smaller one along the segment partition.

Novixitus (?) danieliani Jud seems to be synonymous of *Xitus vermiculatus* with an additional distal segment provided with three spines. The whole test, except this last segment, is perfectly similar to Renz's species. In this situation one could consider that *X. vermiculatus* is an incompletely developed specimen of *N. danieliani*, or a *N. danieliani* specimen that during the fossilisation or laboratory treatments lost the last segments. This possibility is suggested by the specimen illustrated in Baumgarten et al. (1995) from the lower Hauterivian of the Murguceva section, Svinița (Romania), in which one can see that the connection of the last segment bearing the three spines with the main part of test is weak.

Range and occurrence. The species seems to be cosmopolitan in the Lower Cretaceous of Tethys from Valanginian to late Aptian according to O'Dogherty (1994).

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