

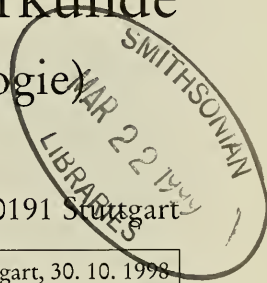
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Radiolaria from the Nusplingen Lithographic Limestone (Late Kimmeridgian, SW Germany)

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With 5 Plates and 9 Textfigures

Zusammenfassung

Aus dem Nusplinger Plattenkalk (Ober-Kimmeridium, südwestliche Schwäbische Alb) werden erstmals verschiedene, mäßig erhaltene Radiolarienfaunen vorgestellt. Dieses Vorkommen erweitert die allgemein geringe Dokumentation von Radiolarien aus jurassischen Schelfbereichen und bestätigt die Dominanz der Williriedellidae (cryptothoracale Nassellarien) in diesen Bereichen. Insgesamt werden 43 verschiedene Taxa beschrieben. Bei einigen Nassellarien sind durch die Steinkernerhaltung die inneren Strukturen des ersten Segmentes (Cephalis) abgeformt, die auf wichtige supragenerische Zusammenhänge hinweisen.

Abstract

Various moderately preserved radiolarian faunas are presented for the first time from the Nusplingen Lithographic Limestone (Upper Kimmeridgian) in the southwestern part of the Swabian Alb (SW Germany). This occurrence extends the generally poor documentation of radiolarians from Jurassic neritic seas, corroborating the predominance of the Williriedellidae (cryptothoracic nassellarians) in this realm. 43 different taxa are described. Due to internal cast preservation internal structures of the first segment (cephalis) are moulded in some nassellarians, pointing to important suprageneric relations.

1. Introduction

Late Jurassic radiolarian associations of Southern Germany were mainly reported from the Northern Calcareous Alps (STEIGER & STEIGER 1993, 1994). Until recently, only single specimens were described by GEYER (1961), STÜRMER (1963), and SCHAIRER (1971) from the Late Jurassic of the Swabian/Franconian Alb. KIESSLING (1997) described the first radiolarian fauna from the Oxfordian of the Franconian

Alb, followed by the discovery of highly diverse and well preserved radiolarian assemblages from the Lower Tithonian of the Solnhofen area (ZÜGEL 1997).

Radiolarians from the Nusplingen area were first figured by SCHAIRER (1971, figs. 23–24) comprising only two moderately preserved specimens. Only one of these specimens was clearly determined by KIESSLING (1997) as *Archaeodictyomitra apiarium* (RÜST).

The Nusplingen Lithographic Limestone is so far the only fossil-bearing lithographic limestone occurrence known from the Late Jurassic of the Swabian Alb. Recent excavations by the Stuttgart Museum of Natural History started in the early summer of 1993. Reports on the excavations and the fossil findings are continuously published by DIETL et al. (1995, 1996, 1997). SCHWEIGERT (1997) compiled the bibliography of the Nusplingen Lithographic Limestone with special regard to the fossil content.

Meanwhile, the stratigraphic position of the Nusplingen Lithographic Limestone is precisely determined (SCHWEIGERT et al. 1996; SCHWEIGERT & ZEISS 1998, in press). Unlike the more famous Lower Tithonian Solnhofen lithographic limestones of the southern Franconian Alb, the Nusplingen Lithographic Limestone completely belongs to the Late Kimmeridgian (Beckeri Zone, Ulmense Subzone, *zio-wepferi* horizon β + *hoelderi* horizons).

Sampling by W. RIEGRAF (1995) in the excavated section in the “Geologischer Steinbruch” of the Stuttgart Natural History Museum yielded the first radiolarian assemblages from two turbiditic marly layers and some polished limestone slabs. As a consequence of the radiolarian discovery from chert bearing sections in the Lower Tithonian Moersheim Formation of the Solnhofen area (ZÜGEL 1997), further sampling was concentrated on thin chert layers in the lower part of the Nusplingen Lithographic Limestone. They yielded a rich radiolarian fauna of mainly siliceous internal casts. Apart from this chert layers, rather rare radiolarian in siliceous shell preservation were found in fine-grained limestone samples from mainly the lower part of the sections.

Acknowledgements

Special acknowledgements go to Dr. Paulian Dumitrica (Bern) for fruitful discussions and numerous hints concerning the systematic part. The great hospitality of Dr. Ruth Dumitrica-Jud and Dr. Paulian Dumitrica allowed a very comfortable review of the first manuscript. Dr. Rainer Petschick (Frankfurt am Main) is acknowledged for his patience in repeatedly scanning and arranging some figures. J. Tochtenhagen (Frankfurt am Main) gave technical support at the SEM.

2. Geological setting

Late Jurassic series crop out as a wide arch on the northern rim of the Swabian and Franconian Alb, dipping gently to the southeast (Swabian Alb, Southern Franconian Alb) and to the east/northeast (Northern Franconian Alb). They are covered by the Tertiary Molasse deposits to the southeast and bordered by the Bohemian Massif in the northeast. Kimmeridgian series exhibit the overall Upper Jurassic pattern of massive sponge-algal mounds interfingering with bedded limestones on the Swabian/Franconian Alb (MEYER & SCHMIDT-KALER 1989). The Nusplingen area is situated in a neritic realm, separated by sponge-algal buildups and oolitic shoals from the Helvetian Basin in the south.



Fig. 1. Location of the Nusplingen Lithographic Limestone fossil sites in the western part of the Swabian Alb (Upper Danube area). 1–2 = Lithographic limestones of the Westerberg Basin, 3 = lithographic limestones of the “Grosser Kirchbühl Basin”. E = Egesheim quarry, N = Nusplingen quarry.

The Nusplingen Lithographic Limestone is found in two longitudinal basins (Fig. 1) surrounded atoll-like by older sponge-algal limestones (“Oberer Massenkalk”). The northern “Westerberg Basin” is actually about 1 km long and up to 0.6 km wide, with a slightly internal division caused by erosion and tectonic shifting. The southern “Grosser Kirchbühl Basin” is preserved only at its northern margin, the rest being eroded by the Untere Bära River. It reveals but a reduced section of only a few meters thickness as a thin cover on the southern slope of the “Grosser Kirchbühl” hill. Sedimentation set on at about the same time in both basins, as indicated by the ammonite faunas, and sedimentation conditions are basically the same.

The submarine relief at the onset of lithographic limestone sedimentation can be estimated in the “Grosser Kirchbühl Basin”. A minimum of 80 m of relief differences results from the differences of the lithographic limestone base on the underlying older massive limestones.

Actual occurrences of the lithographic limestones at Nusplingen are preserved only due to the relatively deep tectonic position. Therefore, reconstructions of the lithofacies distribution in this stratigraphic interval are rather difficult. Time equivalent sediments occur only about 5 km further south around the villages of Kolbingen and Renquishausen. The mainly re-crystallized Kolbingen Lithographic Limestone exhibits facies characteristics pointing to tidal influences, totally different from that of the Nusplingen Lithographic Limestone.

Further south, in the area of the Upper Danube valley and the northern Hegau, calcareous oolites and biotrital sponge-bearing limestones developed (e.g. Buchheim near Beuron). Deeper basinal realms on the shelf contain limestone marlstone alternations (upper part of the “Liegende Bankkalk Formation”, and “Zementmergel” Formation). High energetic facies types in submarine canyon systems cut the sponge algal facies from north to south (“Hattingen debris limestone”, lithofacies of the “Rauhe Kalke”).

The sponge algal facies of the Upper Jurassic shelf (“Swabian Facies”) continues to the south partly below the Molasse Basin, and grades into to the so-called “Helvetian Facies” at the northern margin of the Tethys (see reconstruction by MEYER & SCHMIDT-KALER 1989).

3. Sections

The section of the Nusplingen Lithographic Limestone at the excavation site “Geologischer Steinbruch” (Nusplingen district) consists of a 10.5 m thick series of calcareous laminites, subdivided by intercalation of some turbidite layers and some bioturbated beds (Fig. 2). Lithostratigraphic designations in this outcrop follow the terminology introduced by ALDINGER (1930).

Turbidite layers correspond to the model of the so-called “allodapic limestones” (MEISCHNER 1964) and can be traced throughout the Nusplingen Lithographic Limestone basins (“Westerberg Basin”, “Grosser Kirchbühl Basin”). Towards the margins of the basins they increase in thickness and contain coarse-grained debris.

The basal part of the lithographic limestone section at the basin margin is exposed in the excavation site “Egesheimer Steinbruch”. In contrast to the “Geologischer Steinbruch” the lithographic limestones and the intercalated turbidite layers are given a new lithostratigraphic terminology, due to problems of correlation when starting the excavations. Apart from turbidite layers, continuous chert layers occur in the “Egesheimer Steinbruch”, suitable for lithostratigraphic correlations. A single chert layer is intercalated in the section of the “Grosser Kirchbühl Basin”.

Chert layers can attain several millimetres, but are, however, generally only 1–2 mm thick. Furthermore, chert laminae of less than 1 mm thickness have been found in thin-sections (cf. SCHNEIDER 1969). Further chertification occurs as small chert lenses in turbidite layers and around some fossil remains. In the upper part of the sections cherts are virtually absent, apart from the topmost layer in the “Geologischer Steinbruch” (Layer K6 in ALDINGER 1930). However, this layer is built up by older reefal limestones, sloping on the younger lithographic limestones.

As a general trend of the Nusplingen Lithographic Limestone section in the “Westerberg Basin”, grain sizes decrease towards the top. On the other hand, the content of organic matter increases, mainly consisting of terrestrial plant remains and kerogen. These trends are interpreted as results of a beginning isolation of the “Westerberg Basin” during a sea level fall. Consequently, the surrounding sponge-algal limestones are partly dedolomized as a result of a phreatic diagenesis during emergence. None of these trends are traceable in the “Grosser Kirchbühl Basin”, as only the lower part of the lithographic limestone section is exposed.

More details on the different outcrops and some core sections of the Nusplingen Lithographic Limestone are given by DIETL et al. (1998).

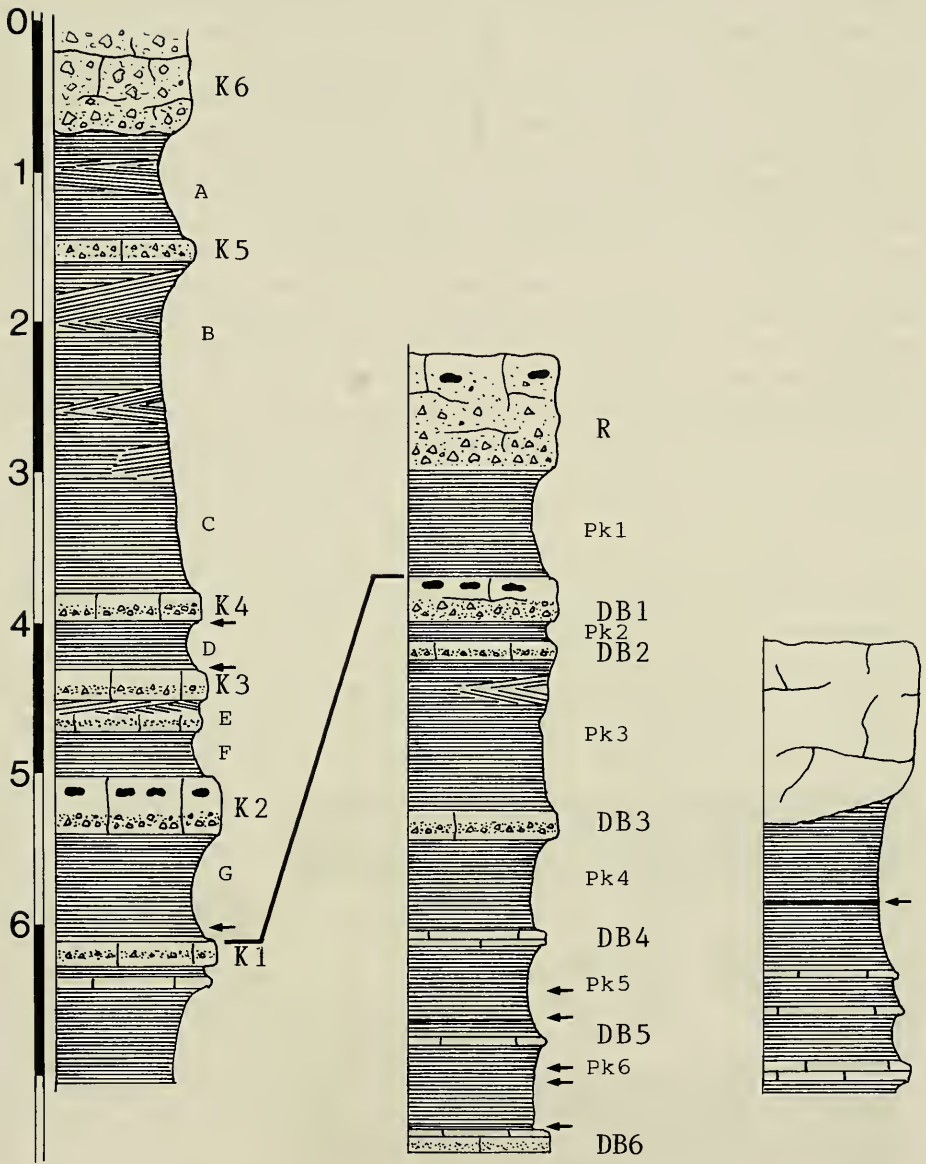


Fig. 2. Sampled sections of the Nusplingen Lithographic Limestone. Left: Nusplingen quarry with samples indicated by black arrows (from above: samples Nu 250, Nu 251, Nq-MG). Middle: Egeseim quarry (from above: samples Pk5-uc1, Pk5-lcl, Pk6-15-25, Pk6-25-30, Eg-bl1). Right: Grosser Kirchbühl Basin with sample GK-cl.

4. Material and Methods

Samples from three sections of the Nusplingen Lithographic Limestone were collected from various types of lithologies for a preliminary research on Radiolaria. The first sampling (W. RIEGRAF, 1995) in the Westerberg section was concentrated on two turbiditic marly layers in order to isolate foraminifera. The softly weathered, whitish-grey marlstones were washed with a 63µm sieve after watering. Vertically cut slabs from limestones are examined for re-crystallized calcitic radiolaria.

Limestone samples and limestones with chert layers and chert nodules were treated with diluted hydrochloric acid (5%) or diluted formic acid (5%) and washed with a 63µm sieve. Poor samples were completely picked out, whereas 130–200 specimens were randomly selected from samples with high radiolarian frequencies. Apart from quantitative picking, some samples with either complete preservation of internal casts or only moderately corroded tests were checked for rare species. SEM investigations were restricted to selected specimens, which have been distinguished by using binocular observations.

The figured specimens from the Nusplingen Lithographic Limestone are housed in the collection of the SMNS (Staatliches Museum für Naturkunde Stuttgart).

5. Preservation

Three main types of preservation can be identified in the Nusplingen radiolarian faunas, depending on the lithology of the sampled beds (Fig. 3).

1. Most of the pure limestone beds contain completely calcified radiolarians, that can only be partly identified by sections. Apart from the pure limestone beds, calci-

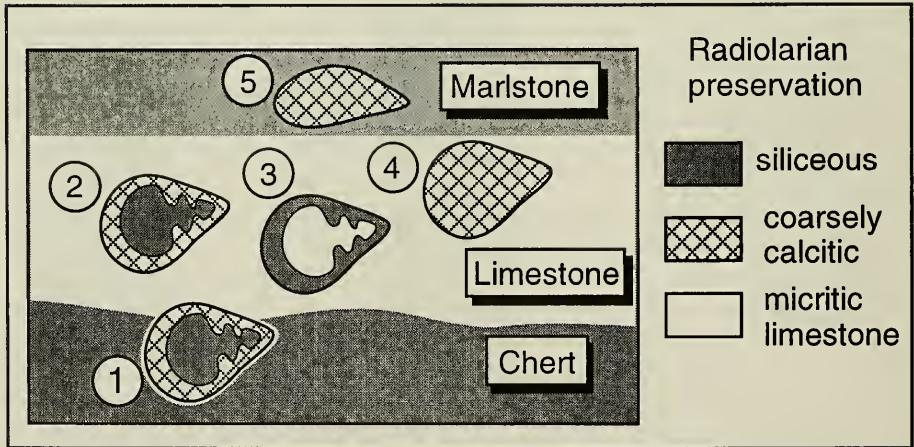


Fig. 3. Simplified sketch of radiolarian preservation in different lithologies of the Nusplingen Plattenkalk. 1: Coarsely calcitic test with siliceous internal cast in chert layers; frequent. – 2: Coarsely calcitic test with siliceous internal cast in micritic limestones; common immediately above and below chert layers. – 3: Siliceous tests in limestones, rare. – 4: Massive calcitic preservation in micritic limestones; common. – 5: Massive calcitic preservation, more or less compressed, in marlstones; common.

fied radiolarians are found compressed in some marly layers (Pl. 4, fig. 2). Due to re-crystallization and compaction, only very few radiolarians could be identified on the generic level.

2. Siliceous internal casts with coarsely re-crystallized calcitic tests are enclosed in thin chert layers from the lower part of the Nusplingen Lithographic Limestone. The same preservation is found in thin contact zone above and below the chert layers in the surrounding limestones.

3. Siliceous tests of radiolarians occur in slightly argillaceous fine-grained limestone beds in the lower part of the Nusplingen Lithographic Limestone. The same preservation is found in the fine-grained layers at the top of turbidites. Most specimens of the generally small-sized faunas are corroded. A very small portion of radiolarians with siliceous test preservation is found among the siliceous internal casts in the contact zones of limestones and chert layers.

Selective preservation of radiolarians must be considered in both chert layers and fine-grained limestones. In the chert layers, the dense construction of spongy spumellarians or hagiastriids without sufficient hollow internal space does not allow the formation of internal casts. Therefore, spongy spumellarians are limited to rare specimens in the fine-grained limestones.

Preservation of fragile tests in the fine-grained limestones point to a rather non-selective preservation. Nevertheless, radiolarians in these layers are corroded to a certain degree, often leaving only the apical part of the tests. Corrosion may contribute to the predominance of the compact Williriedellidae (KIESSLING 1997).

6. Radiolarian distribution

Radiolarian frequencies in some samples from the Nusplingen Lithographic Limestone are very different between chert layers and fine-grained limestones. Chert layers contain several hundred to a few thousand specimens/100g rock, whereas in fine-grained limestones frequencies do not exceed 100 specimens/100g rock.

Quantitative investigations of radiolarian faunal composition in the Nusplingen Lithographic Limestone are generally based on the level of families due to uncertainties in the determination of internal casts on generic level (Fig. 4).

Spumellarians comprise some Astrosphaeridae HAECKEL and Spongodiscacea HAECKEL (*Alievium* PESSAGNO, *Pyramispongia* PESSAGNO). They only contribute 0–5 % to the radiolarian fauna and are not divided further. Whereas coarse-grained chert layers contain internal casts of Astrosphaeridae, the spumellarian fauna in fine-grained limestone samples is restricted to Spongodiscacea.

Among the predominant nassellarians, the Williriedellidae DUMITRICA are the most frequent forms in most of the samples. Internal casts of this group are identified by three-segmented tests, with a distinct encasement of the thorax into the abdominal cavity. Although the cephalis is corroded in most of the specimens, the thorax can easily be identified by the imprints of a part of the cephalic skeleton on its proximal part. Williriedellidae are absolutely dominating in fine-grained limestones, making up 70–80 % of the radiolarian fauna. The strongly dominant species in samples with test preservation is *Zhamoidellum* sp. aff. *Z. ovum* DUMITRICA, followed by *Complexapora tirolica* KIESSLING, and rare *Williriedellum* sp.

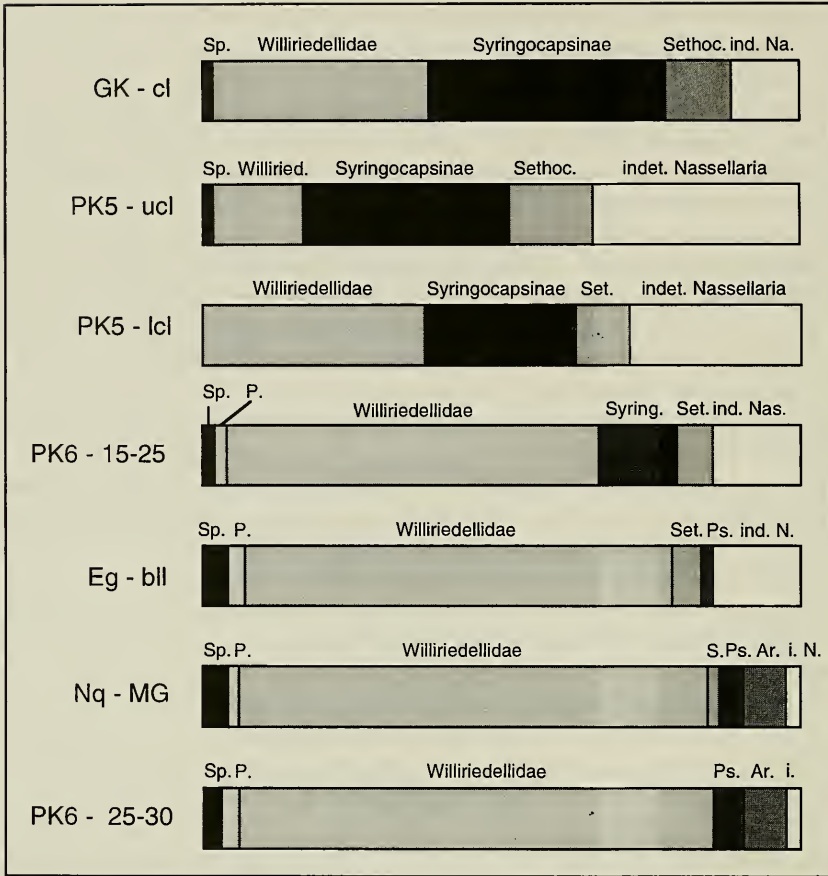


Fig. 4. Quantitative distribution of radiolarians in the Nusplingen samples. General dominance of Williriedellidae, apart from high portions of Syringocapsinae in chert layers. Abbreviations: Sp. = Spumellaria; P. = Poulpidae; Sethoc., Set., S. = Sethocapsidae; Ps. = Pseudodictyomitridae; Ar. = Archaeodictyomitridae.

Whereas fine-grained limestones are absolutely dominated by Williriedellidae, radiolarian faunas in chert layers contain a high portion of Syringocapsinae FOREMAN. Internal casts of this subfamily were identified by the combination of a conical apical part with an inflated last chamber, bearing one or four extensions. Whereas *Podocapsa* RÜST is easily determinable by four extensions of the last segment, *Podobursa* WISNIEWSKI and *Syringocapsa* NEVIANI cannot be clearly distinguished as internal casts. Frequencies of Syringocapsinae in chert layers can exceed those of Williriedellidae, whereas fine-grained limestone samples are virtually free from Syringocapsinae.

Sethocapsidae HAECKEL are present in all but one sample. It is the third group that can be determined by internal casts. They are composed of four segments, three segments slowly increasing and the last segment inflated. Although the cephalis is corroded in most of the specimens, the thorax can be easily identified by the imprint of

a part of the cephalic skeleton on its proximal part. Sethocapsidae occur more frequently in the coarse grained chert layers, with a maximum of about 14 %. Compared with the distribution of Syringocapsinae, they are not strictly limited to the chert layers.

Other forms are only identified in samples with at least partly preserved tests. As in three samples from the chert layers only internal casts of nassellarians are preserved, multicyrtyd forms with more than 5 segments are grouped together as undetermined Nassellaria. In the fine-grained limestone samples the portions of these groups never exceed 8 % of the radiolarian fauna. Another minor radiolarian faunal element in the fine-grained limestones are the Poulpidae (*Saitoum*), with a maximum portion of 3 %.

7. Palaeoecology

Radiolaria in the Late Jurassic are mainly reported from deep marine sediments of the Tethyan realm (e.g. BAUMGARTNER 1984; BAUMGARTNER et al. 1995b). Shallow marine occurrences are so far only known from the Russian platform (e.g. BRAGIN 1997; KOZLOVA 1972), and from some localities on the Franconian Alb (KIESSLING 1997; ZÜGEL 1997). Especially the latter occurrences can be compared with the Nusplingen radiolarians, showing some common characters as well as distinct differences.

A main common feature is the high frequency of Williriedellidae DUMITRICA in both the Oxfordian of the Franconian Alb (KIESSLING 1997) and the latest Kimmeridgian of the Swabian Alb, even taking into account their high resistance against corrosion (KIESSLING 1997). Moreover, the radiolarian fauna of the Moernsheim Formation in the Lower Tithonian of the Franconian Alb is largely dominated by Williriedellidae (ZÜGEL 1997; ZÜGEL, in prep.). Therefore, this group can be interpreted as autochthonous faunal element, living in the upper part of the water column in the neritic realm.

In contrast to the Williriedellidae, the Syringocapsinae are restricted to coarse-grained turbidite layers in the Nusplingen Lithographic Limestone. High diversity and abundance of Syringocapsinae at least point to a parautochthonous origin. Comparable occurrences of this group are reported from the Northern Limestone Alps (STEIGER 1992).

The faunal composition is generally Tethyan, with only very rare *Praeparavicungula*, a genus regarded as a characteristic faunal element of the Boreal realm (PESAGNO et al. 1993, HULL 1995). On the other hand, Pantanellidae as characteristic elements of the Central Tethyan Province (PESAGNO et al. 1993) were not found in the Nusplingen samples. Compared to the radiolarian fauna from the Lower Tithonian Moernsheim Formation of the Franconian Alb (ZÜGEL 1997, ZÜGEL, in prep.), the faunal composition in Nusplingen is less diverse.

Radiolarian faunas in the Upper Kimmeridgian from the Nusplingen area as well as in the Lower Tithonian from the Solnhofen area may indicate transgressive trends with immigration of Tethyan faunal elements, as stated by RIEGRAF (1986, 1987) for Callovian radiolarian occurrences from the Swabian Alb. Rich radiolarian assemblages in the Moernsheim Formation are correlated with a transgressive trend above the Solnhofen Formation (ZÜGEL 1997), as indicated by ammonites and nanno-

plankton distribution (KEUPP 1977). Radiolarian occurrences in the Nusplingen Lithographic Limestone can be correlated with an immigration of some Tethyan faunal elements, especially ammonites (*Hybonoticerias*, *Streblites*) and cuttlefishes, in the Late Kimmeridgian of the Swabian Alb. Chert layers with abundant radiolarians are restricted to the lower part of the Nusplingen Lithographic Limestone, whereas the regressive upper part is virtually free of cherts.

On the other hand, radiolarian distribution reflects preservational patterns, as discussed by KIESSLING (1997). On the Swabian and Franconian Alb highly diverse radiolarian occurrences with siliceous preservation are bound to strata with exceptional preservation of vertebrate fossils, as the Nusplingen Lithographic Limestone (see DIETL et al. 1995, 1996, 1997) and the Moernsheim Formation (BARTHEL et al. 1990). Apart from these occurrences, preservation of radiolarians is achieved by pyritization, as described by KIESSLING (1997) from the Oxfordian of the Franconian Alb.

8. Stratigraphy

Ammonite faunas indicate a Late Kimmeridgian age for the Nusplingen Lithographic Limestone (SCHWEIGERT et al. 1996; SCHWEIGERT & ZEISS 1998, in press). SCHWEIGERT et al. (1996) presented a high resolution biostratigraphy of the Beckeri Zone, with a correlation across the Tethyan Sea. The Nusplingen Lithographic Limestone is placed in the Ulmense Subzone (index: *Lithacoceras ulmense*), and comprise the *zio-wepferi* horizon β and the *hoelderi* ammonite horizons.

According to the concept of radiolarian biostratigraphy with Unitary Association Zones (UAZones 95 by BAUMGARTNER et al. 1995b), the biostratigraphic range of the Nusplingen Lithographic Limestone falls within UAZone 11 – Late Kimmeridgian to Early Tithonian.

As the Nusplingen material only contains a small selection of clearly determinable radiolarian species from the catalogue of BAUMGARTNER et al. (1995a), the above mentioned correlation cannot be surely verified. Moreover, the co-occurrence of *Loopus primitivus* (MATSUOKA & YAO), *Archaeodictyomitra minoensis* (MIZUTANI), *Protunuma japonicus* MATSUOKA & YAO, *Cinguloturris cylindra* KEMKIN & RUDENKO, and *Eucyrtidiellum pyramis* (AITA) rather points to UAZone 12 – Early to early Late Tithonian (cf. BAUMGARTNER et al. 1995a, 1995b). Therefore, it is suggested that the biostratigraphic ranges of *Cinguloturris cylindra* KEMKIN & RUDENKO, and *Eucyrtidiellum pyramis* (AITA) have to be slightly expanded downwards to UAZone 11 – Late Kimmeridgian to Early Tithonian. Typical forms of *Pyramispongia barmsteinensis* (STEIGER) appear in UAZone 13 (BAUMGARTNER et al. 1995a), the specimens from the Late Kimmeridgian Nusplingen Lithographic Limestone may represent a very early form with still a rather spherical than a clearly tetrahedral central test.

9. Systematic Palaeontology

Remarks. – The systematic framework is adopted from DUMITRICA (1995), slightly modified after DUMITRICA (in: DUMITRICA et al. 1997). Full synonymy until 1992 of most species listed below is to be found in the catalogue of BAUMGARTNER et al. (1995a). Due to partly poor preservation of the material only a small part of the

taxa is determined on species level. Some internal casts are only described on the level of families or subfamilies.

Class Radiolaria MÜLLER 1858
 Order Polycystina EHRENBERG 1838
 Suborder Spumellaria EHRENBERG 1875
 Superfamily Actinommacea HAECKEL 1862
 Family Astrosphaeridae HAECKEL 1887

Astrosphaeridae gen. et sp. indet.
 Pl. 1, figs. 1–5

Description. – Internal casts of double-shelled tests. Inner shell (macrosphere) often filled by the siliceous cast. Pores of the inner shell preserved as short pore casts. Outer part of the cast with triradiate pores corresponding to triradiate beams. Surface of well preserved casts (Pl. 1, fig. 1) with nop-like extensions representing pores of the outer (cortical) shell.

Remarks. – As a comparison to the cast preservation of the Nusplingen specimens, a related test from the Lower Tithonian of the Solnhofen area is shown on Pl. 1, fig. 5.

Material: 30 specimens from samples GK-cl (typical there), Pk5-ucl, Pk6–15–25.

Superfamily Spongodiscacea HAECKEL 1862
 Family Cavaspongiidae PESSAGNO 1973
 Genus *Pyramispongia* PESSAGNO 1973

Type species: *Pyramispongia magnifica* PESSAGNO 1973.

Pyramispongia barmsteinensis (STEIGER 1992)
 Pl. 1, fig. 6

- * 1992 *Nodotetraedra barmsteinensis* n. sp. – STEIGER, p. 33, pl. 4, figs. 9–14.
 1995a *Pyramispongia barmsteinensis* (STEIGER). – BAUMGARTNER et al., p. 464, pl. 6109, figs. 1–4.
 1997 *Pyramispongia barmsteinensis* (STEIGER). – ZÜGEL, p. 202, fig. 4.13.

Remarks. – Only three of the large spines at the rounded corners of the tetrahedral spongy shell are partly preserved. The figured Nusplingen specimen possesses additional smaller spines as described by STEIGER (1992) and ZÜGEL (1997).

Material: 2 specimens from sample GK-cl, Eg-bll.

Family Pseudoaulophacidae RIEDEL 1967 emend. DUMITRICA 1997
 Genus *Alievium* PESSAGNO 1972

Type species: *Theodiscus superbus* SQUINABOL 1914.

Alievium (?) sp.
 Pl. 1, fig. 7

- 1991 *Alievium* (?) sp. A. – CONTI & MARCUCCI, p. 793, pl. 1, fig. 6.

Description. – Lense-shaped spherical to rounded triangular shell composed of an irregular spongy meshwork. Three solid spines in a regularly triangular arrangement, composed of narrowly rounded blades and broad longitudinal grooves. Additional small spines (thorns) with triradiate bases, needle-shaped and sharply pointed at the end, arise from the equatorial plane of the shell.

Remarks. – The Nusplingen specimens are comparable to *Alievium* (?) sp. A of CONTI & MARCUCCI (1991). As the characteristic initial skeleton of the genus *Alievium* (DUMITRICA 1997) has not been investigated in this species, the generic assignment remains provisional.

Material: 2 specimens from sample GK-cl.

Suborder Nassellaria EHRENBERG 1875
Family Poulpidae DE WEVER 1981

Genus *Saitoum* PESSAGNO 1977

Type species: *Saitoum pagei* PESSAGNO 1977a.

Saitoum sp. aff. *S. pagei* PESSAGNO 1977
Pl. 1, figs. 8–9

aff. 1977a *Saitoum pagei* n. sp. – PESSAGNO, p. 98, pl. 12, figs. 11–14.

aff. 1995a *Saitoum pagei* PESSAGNO. – BAUMGARTNER et al., p. 486, pl. 3020, figs. 1–4. – [Full synonymy]

Remarks. – Only weak triradiation of the feet in the Nusplingen specimens compared the holotype of PESSAGNO (1977a).

Material: 3 specimens from samples GK-cl, Eg-bll, Nq-MG.

Saitoum sp. aff. *S. dercourti* WIDZ & DE WEVER
Pl. 1, fig. 10

aff. 1993 *Saitoum dercourti* n. sp. – WIDZ & DE WEVER, p. 85, pl. 1, fig. 17.

Remarks. – This species differs from *Saitoum dercourti* WIDZ & DE WEVER in lacking the characteristic protrusions and incisions of the collar. Pore frames in the Nusplingen specimens form tubercles, not developed in the type material.

Material: 7 specimens from samples GK-cl, Eg-bll, Nq-MG.

Family Williriedellidae DUMITRICA 1970

Genus *Complexapora* KIESSLING 1992

Type species: *Complexapora tirolica* KIESSLING 1992.

Complexapora tirolica KIESSLING 1992
Pl. 2, fig. 1

* 1992 *Complexapora tirolica* n. sp. – KIESSLING in: KIESSLING & ZEISS, p. 191, pl. 1, figs. 1–9; pl. 2, figs. 1–2.

1997 *Complexapora tirolica* KIESSLING. – KIESSLING, p. 39, pl. 6, fig. 10.

Remarks. – Apart from the increasing pore sizes and the diagonal arrangement of the pores in the abdominal segment, the Nusplingen specimens accord well to the material of KIESSLING (*in*: KIESSLING & ZEISS 1992; KIESSLING 1997).

Material: About 30 specimens from samples Pk6–25-30, Eg-bl1, Nq-MG.

Complexapora sp.

Pl. 2, fig. 2

1997 *Cryptamphorella macropora* DUMITRICA. – ZÜGEL, p. 202, fig. 5.2.

Remarks. – *Complexapora* sp. differs from *Complexapora tirolica* KIESSLING in having a larger cephalis in relation to the postcephalic test, and a transversal pore row between cephalis and thorax. As a result of the rapidly increasing diameter in the proximal part of the abdomen, the sutural pore is directed to the apical part of the test.

Material: About 10 specimens from samples Pk6–25-30, Nq-MG.

Genus *Zhamoidellum* DUMITRICA 1970

Type species: *Zhamoidellum ventricosum* DUMITRICA 1970.

Zhamoidellum sp. aff. *Z. ovum* DUMITRICA 1970

Pl. 2, fig. 3

aff. *1970 *Zhamoidellum ovum* n. sp. – DUMITRICA, p. 79, pl. 9, figs. 52a-b, 53–54.

aff. 1995a *Zhamoidellum ovum* DUMITRICA. – BAUMGARTNER et al., p. 656, pl. 4079, figs. 1–2, 4–6, non fig. 3. – [Full synonymy]

aff. 1997 *Zhamoidellum ovum* DUMITRICA. – KIESSLING, p. 40, pl. 6, fig. 13.

Remarks. – Irregular thoracal ridges in the Nusplingen specimens differ from the rather regular pore frames of the specimens figured and described by DUMITRICA (1970) and BAUMGARTNER et al. (1995a).

Material: Several hundred specimens from samples Pk6–25-30, Eg-bl1, Nq-MG. Only few specimens from samples GK-cl, Pk5-lcl, Pk5-ucl, PK6–15-25 due to predominant internal cast preservation.

Genus *Williriedellum* DUMITRICA 1970

Type species: *Williriedellum crystallinum* DUMITRICA 1970.

Williriedellum sp. 1

Pl. 2, figs. 4–5

Description. – Tricyrtid shell with poreless cephalis and porous thorax and abdomen. Cephalis without apical horn, collar stricture indefinite, but marked by a transverse row of small pores. Abdomen cherry-shaped, with a flattened proximal part and a slightly pointed terminal part. Central terminal part with a slightly protruding aperture.

Remarks. – The gross morphology of the Nusplingen specimens is comparable to *Williriedellum carpathicum* DUMITRICA, but lacks a distinct aperture tube. Moreover, a sutural pore is not found in the Nusplingen specimens, probably for reasons of preservation.

Material: 2 specimens from samples GK-cl, Pk6–25-30.

Williriedellum sp. 2

Pl. 2, fig. 6

Description. – Internal cast composed of three segments. Cephalic cast with oblique longitudinal groove as imprint of the apical spine. Thorax of about double the size of the cephalis, distinctly separated by a collar ring. Surface of the thoracal cast with imprints of dolomite crystals. Proximal part of the abdominal cast depressed due to a slight depression of the thorax into the abdominal cavity. Large inflated abdominal segment with regularly arranged pore casts and a cast of the terminal aperture.

Remarks. – *Williriedellum* is the only genus among the tricyrtid Williriedellidae in the Jurassic described with a terminal aperture (DUMITRICA 1970), allowing the determination of even internal casts.

Material: 3 specimens from samples GK-cl, Pk6–25–30.

Williriedellidae gen. et sp. indet.

Pl. 2, fig. 7–8

Description. – Internal cast composed of three segments. Cephalic cast with a smaller hemispherical part on the top, separated from the lower part by two horizontal arches, originating in the apical spine. A distinct longitudinal groove on one side of the cephalic cast represents the apical spine. Collar ring represented by a deep incision between cephalis and thorax. Thoracal cast inverted conical, with few small pore casts. Proximal part of the abdominal cavity depressed, as a result of a thoracal encasement. Large inflated abdominal cast covered with large pore casts, without cast of a terminal aperture.

Remarks. – These internal casts are the most frequent forms in samples with internal cast preservation. The thoracal depression into the abdominal cavity characterizes Williriedellidae DUMITRICA. The absence of an aperture cast suggests an assignment to either *Complexapora* KIESSLING or *Zhamoidellum* DUMITRICA. However, horizontal branches of the apical spine have so far not been mentioned in this family.

Material: Several hundred specimens from samples GK-cl, Pk5-ucl, Pk5-lcl, Pk6–25–30.

Family Sethocapsidae HAECKEL 1881

Genus *Sethocapsa* HAECKEL 1881

Type species: *Sethocapsa cometa* (PANTANELLI) in: RÜST 1885.

Remarks. – Four-segmented closed cyrtids with a large last segment are assigned to *Sethocapsa* HAECKEL, according to the proposal by DUMITRICA (1995) and the catalogue by BAUMGARTNER et al. (1995a).

Sethocapsa sp. aff. *S.* (?) *zweilii* JUD 1994

Pl. 2, fig. 9

aff. 1986 *Sethocapsa lagenaria* WU & LI. – AITA & OKADA, p. 116, pl. 3, fig. 11.

aff. *1994 *Sethocapsa* (?) *zweilii* n. sp. – JUD, p. 106, pl. 20, figs. 12–14.

aff. 1995a *Sethocapsa* (?) *zweilii* JUD. – BAUMGARTNER et al., p. 504, pl. 5464, figs. 1–4.

aff. 1997 *Minocapsa horokanaiensis* (KAWABATA). – HULL, p. 148, pl. 38, figs. 2–3, 7.

Remarks. – Due to poor preservation of the Nusplingen specimens, the existence of pores in the thorax cannot be verified clearly. *Sethocapsa* (?) *zweilii* is described without thoracic pores (JUD 1994). The postabdominal segment in the type material is more inflated.

Material: 7 specimens from samples GK-cl, Eg-bll.

Sethocapsa sp. 1

Pl. 2, fig. 10

Description. – Test of four segments, the first three segments forming a widely conical portion without distinctly incised strictures. Proximally flattened part of the postabdominal segment distinctly separated from the first three segments by a deeply incised stricture. The pattern of pores in the first three segments is completely overprinted by re-crystallization. Postabdominal segment with large hexagonal pore frames, surrounding large rounded pores.

Remarks. – The general morphology with a wide conical part of three segments and a distinctly separated large postabdominal segment is comparable to several species of *Sethocapsa*, e.g. *Sethocapsa uterculus* (PARONA) or *Sethocapsa simplex* TAKE-TANI.

Material: 2 specimens from samples GK-cl, PK6–25–30.

Sethocapsa sp. 2

Fig. 5; Pl. 2, figs. 11–12

Description. – Internal cast composed of four segments, with the first three segments (cephalis, thorax, abdomen) forming an apical cone. Postabdominal segment large, spherical, covered with diagonally arranged pore casts. Cephalis double-chambered, with a transverse partial septum (VB in FOREMAN 1966, OS in the pre-

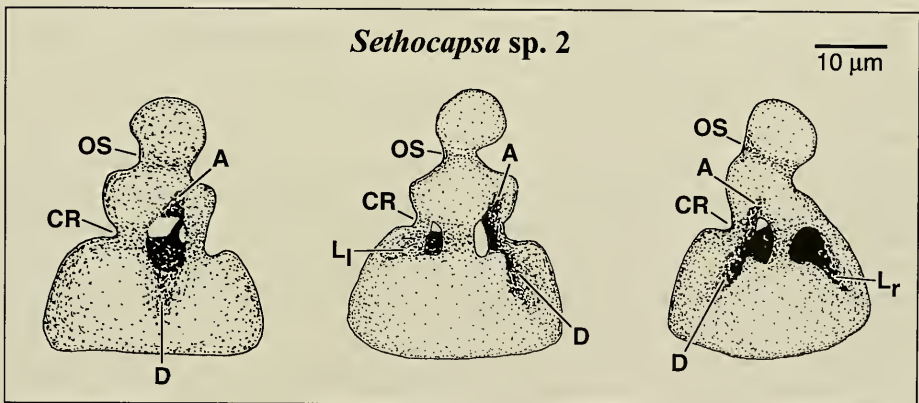


Fig. 5. *Sethocapsa* sp. 2, internal cast of the cephalothorax with double-chambered cephalis. Different views, with interpretation of the skeletal elements preserved as negative forms. – Abbreviations: A = apical spine; D = dorsal spine; L_r = right primary lateral spine; L_l = left primary lateral spine; OS = oblique septum dividing cephalic cavity into two superposed chambers; CR = collar ring as division between cephalis and thorax.

sent work) between the small upper chamber and the larger lower chamber. Lower chamber of the cephalis with four gates representing a cross-like arrangement of the median bar (MB) with the ventral spine (V) and the dorsal spine (D) on opposite sides, and two primary lateral spines (L_r , L_l). Separation of the cephalis from the thorax by a collar ring. A short groove directed to the apex and ending just below the septum of the chambers represents the apical spine (A). The distal parts of the primary lateral spines (L_r , L_l) and the dorsal spine (D) are visible as incisions in the proximal part of the thoracal cast. Internal casts of the thorax and the abdomen disch-shaped, with distinct separations.

Remarks. – The double-chambered cephalis of *Sethocapsa* sp. 2 is comparable to the *Yamatoum*-type structure (TAKEMURA 1986), normally realised in the Amphipyndacidae RIEDEL (1967). Compared to *Amphipyndax* FOREMAN the first cephalic chamber of *Sethocapsa* sp. 2 is distinctly smaller, as discussed for Jurassic double-chambered cephalic structures by TAKEMURA (1986). The same structures were found in the Parvicingulidae (DUMITRICA in DUMITRICA et al. 1997, and this work) and Syringocapsinae (DUMITRICA 1995, and this work). Among Cretaceous forms with double-chambered cephalis, *Siphonocampium* ? *davidi* SCHAAF (cf. SCHAAF 1984: 102–103) seems to be very closely related to *Sethocapsa* sp. 2. Both forms have four segments, the last segment being largely inflated.

Material: 1 complete internal cast from sample GK-cl. About 50 specimens of internal casts without preserved cephalis from samples GK-cl, Pk6–15–25, Pk5-lcl, Pk5-ucl.

Family Xitidae PESSAGNO 1977

Genus *Xitus* PESSAGNO 1977

Type species: *Xitus plenus* PESSAGNO 1977b.

Xitus sp.

Pl. 3, fig. 1

Description. – Test of four to five segments, with cephalis and thorax distinctly separated by broad intersegmental strictures. Cephalis with a short apical horn and a short ventral spine. Tubercles on the segments and in the intersegmental zones connected by a system of complex ridges, starting from the abdominal segment. Finely porous inner wall layer visible between the ridges. Distal part of the fourth segment tapering, with constricted round aperture. Insertion of a thin-walled fifth segment, represented by a finely porous terminal tube on the edge of the fourth segment.

Remarks. – Tubercles on both segments and intersegmental spaces are characteristic for *Xitus* PESSAGNO and *Pseudoxitus* WU & PESSAGNO (cf. DUMITRICA in: DUMITRICA et al. 1997). The prolongation of the ventral spine is comparable to the genus *Hsuum* PESSAGNO as described for *Hsuum feliformis* (JUD 1994). Widely spaced ridges with only few tubercles as well as the distinctly incised intersegmental zones in the Nusplingen specimen are comparable to *Xitus singularis* HULL 1997.

Material: 1 specimen from sample GK-cl.

Family Pseudodictyomitridae PESSAGNO 1977

Genus *Loopus* YANG 1993Type species: *Pseudodictyomitra primitiva* MATSUOKA & YAO 1985.*Loopus primitivus* (MATSUOKA & YAO 1985)

Pl. 3, figs. 2–3

- * 1985 *Pseudodictyomitra primitiva* n. sp. – 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.
 1995a *Pseudodictyomitra primitiva* MATSUOKA & YAO. – BAUMGARTNER et al., p. 454, pl. 3189, figs. 1–5.
 1997 *Loopus primitivus* (MATSUOKA & YAO). – HULL, p. 91, pl. 36, figs. 13, 16.

Remarks. – Morphologic varieties of the Nusplingen specimens according to MATSUOKA & YAO (1985) with rounded conical forms (MATSUOKA & YAO 1985, pl. 1, figs. 1–4; HULL 1997, pl. 36, fig. 13) and conical forms (MATSUOKA & YAO 1985, pl. 1, fig. 5–6; HULL 1997, pl. 36, fig. 16).

Material: 3 specimens from samples GK-cl, Pk6–15–25.

Loopus doliolum DUMITRICA 1997

Pl. 3, fig. 4

- * 1997 *Loopus doliolum* n. sp. – DUMITRICA *in*: DUMITRICA et al., p. 30, pl. 5, figs. 3, 5, 14.

Remarks. – Apart from the lack of the last segments with decreasing diameters, the Nusplingen specimen accords well with the material of DUMITRICA (*in*: DUMITRICA et al. 1997).

Material: 1 specimen from sample GK-cl.

Genus *Pseudodictyomitra* PESSAGNO 1977Type species: *Pseudodictyomitra pentacolaensis* PESSAGNO 1977b.*Pseudodictyomitra* sp. 1

Pl. 3, fig. 5

Description. – Test conical, composed of ten segments. First three segments constantly increase in diameter, forming an apical cone. Following segments distinctly separated by intersegmental grooves. Distinct costae closely spaced on the segments, interrupted by two transversal rows of pores in the intersegmental zones. Distal pore row mostly with mostly pores (pseudo-pores). Last segment constricted, without costae.

Material: 1 specimen from sample GK-cl.

Pseudodictyomitra sp. 2

Pl. 3, fig. 6–7

- 1997 *Pseudodictyomitra carpatica* (LOZYNIAK). – ZÜGEL, p. 204, fig. 5.5.

Description. – This species differs from *Pseudodictyomitra* sp. 1 in the slightly reduced number of massive costae.

Remarks. – According to the more narrow definition by DUMITRICA (*in*: DUMITRICA et al. 1997), the Nusplingen species as well as the specimen described from the Lower Tithonian Moernsheim Formation (ZÜGEL 1997) cannot be assigned to *Pseudodictyomitra carpatica* (LOZYNIAK).

Material: 2 specimens from samples GK-cl, Pk6–15–25.

Family Archaeodictyomitridae PESSAGNO 1976

Genus *Archaeodictyomitra* PESSAGNO 1976

Type species: *Archaeodictyomitra squinaboli* PESSAGNO 1976.

Archaeodictyomitra apiarium (RÜST 1885)

Pl. 3, fig. 8

- * 1885 *Lithocampe apiarium* n.sp. – RÜST, p. 314, pl. 39(14), fig. 8.
- 1971 cf. *Dictyomitra* sp. – SCHAIRER, p. 50, fig. 23.
- 1995a *Archaeodictyomitra apiarium* (RÜST). – BAUMGARTNER et al., p. 98, pl. 3263, figs. 1–7. – [Full synonymy]
- 1997 *Archaeodictyomitra apiarium* (RÜST). – DUMITRICA *in*: DUMITRICA et al., p. 38, pl. 7, fig. 7.

Material: 5 specimens from samples Pk6–15–25, Pk5-ucl, Nq-MG.

Archaeodictyomitra minoensis (MIZUTANI 1981)

Pl. 3, fig. 9

- * 1981 *Pseudodictyomitra minoensis* n. sp. – MIZUTANI, p. 178, pl. 58, fig. 4; pl. 63, figs. 9–10.
- 1985 *Archaeodictyomitra minoensis* (MIZUTANI). – MATSUOKA & YAO, pl. 2, fig. 5.
- 1995a *Archaeodictyomitra minoensis* (MIZUTANI). – BAUMGARTNER et al., p. 104, pl. 3305, figs. 1–5. – [Full synonymy]
- 1997 *Archaeodictyomitra minoensis* (MIZUTANI). – DUMITRICA *in*: DUMITRICA et al., p. 40, pl. 9, figs. 2–3.
- 1997 *Archaeodictyomitra minoensis* (MIZUTANI). – ZÜGEL, p. 204, fig. 5.6–5.7.

Material: 6 specimens from samples Pk6–25–30, Pk6–15–25, Eg-lll, Nq-MG.

Archaeodictyomitra shengi YANG 1993

Pl. 3, fig. 10

- * 1993 *Archaeodictyomitra shengi* n. sp. – YANG, p. 111, pl. 19, figs. 2, 11; pl. 20, fig. 1.

Remarks. – The Nusplingen specimen shows 11 costae visible on one side on the distal part of the test, comparable to one of the paratypes of YANG (1993, pl. 19, fig. 11), although YANG described 13–16 costae (YANG 1993: 111). However, the outline of the Nusplingen specimen accords well to the type material.

Material: 1 specimen from sample GK-cl.

Archaeodictyomitra sixi YANG 1993

Pl. 3, figs 11–12

- * 1993 *Archaeodictyomitra sixi* n. sp. – YANG, p. 112, pl. 19, figs. 3, 19; pl. 20, figs. 9–10, 19.
- 1997 *Archaeodictyomitra sixi* YANG. – HULL, p. 79, pl. 32, fig. 5.

Remarks. – The Nusplingen specimens show variations from slender to inflated tests as described and figured by YANG (1993).

Material: 10 specimens from samples GK-cl, Nq-MG.

Family Theoperidae HÆCKEL 1881 emend. RIEDEL 1967 emend. TAKEMURA 1986

Genus *Phalangites* O'DOHERTY 1994

Type species: *Phalangites calamus* O'DOHERTY 1994.

Phalangites sp.

Pl. 3, figs. 13–14

Description. – Long spindle-shaped internal cast composed of a short proximal portion with 3 segments and a very long distal segment. All segments separated by deep constrictions. Cephalic cast globular, with four holes visible on the dorsal part, representing the apical spine (A), dorsal spine (D) and two secondary lateral spines (l_r, l_l). Thoracic and abdominal casts trapezoidal, slowly increasing in diameter. Long distal segment cylindrical in the proximal part, slowly tapering distally. Surface of the thoracic and abdominal casts with small pore casts, postabdominal segment with large pore casts arranged in longitudinal rows.

Remarks. – Segmentation of the short apical part contrasting with the very long last segment accords well to either *Phalangites sceptrum* (JUD) or *Phalangites acus* (JUD). However, an internal cast of *Phalangites sceptrum* (JUD) figured by DUMITRICA (*in*: DUMITRICA et al. 1997, pl. 13, fig. 8) is clearly different from the Nusplingen casts in exhibiting an indistinctly separated cephalothorax. The same structure can be inferred from the conical shape of the apical test in *Phalangites acus* (JUD).

Material: 2 specimens from sample GK-cl.

Genus *Protunuma* ICHIKAWA & YAO 1976

Type species: *Protunuma fusiformis* ICHIKAWA & YAO 1976.

Protunuma japonicus MATSUOKA & YAO 1985

Pl. 3, fig. 15

* 1985 *Protunuma japonicus* n.sp. – MATSUOKA & YAO, p. 130, pl. 1, figs. 11–15; pl. 3, figs. 6–9.

1995a *Protunuma japonicus* MATSUOKA & YAO. – BAUMGARTNER et al., p. 434, pl. 3292, figs. 1–8. – [Full synonymy]

1997 *Protunuma japonicus* MATSUOKA & YAO. – CHIARI et al., pl. 3, fig. 17.

1997 *Protunuma japonicus* MATSUOKA & YAO. – ZÜGEL, p. 204, fig. 5.8.

1997 *Protunuma japonicus* MATSUOKA & YAO. – HULL, p. 156, pl. 43, figs. 8, 14–15.

Remarks. – Slender spindle-shaped variation with longitudinal pore rows recrystallized.

Material: 3 specimens from samples GK-cl, Pk5-lcl, Nq-MG.

Genus *Stichomitra* CAYEUX 1897

Type species: *Stichomitra bertrandi* CAYEUX 1897.

Stichomitra sp.

Pl. 3, fig. 16

Description. – Test conical, composed of 4 well distinct segments. Cephalis globular, imperforate, without or with only a very small apical horn. Collar stricture with few small pores. Following segments with a regular increase both in height and in width. Maximum diameter in the proximal central part of the segments, slowly tapering to the deep intersegmental constrictions. Each post-cephalic segment with small pores surrounded by pore rims. Apart from one transversal row of pores in the constricted intersegmental zones, pores are rather irregularly distributed on the surface of the test. Distal part of the last preserved segment with rests of a fifth (terminal) segment.

Remarks. – The number of segments with distinct constrictions in the Nusplingen specimens accord with *Stichomitra doliolum* AITA. It differs from this species in the fourth segment being distinctly smaller in respect to the first three segments.

Material: 6 specimens from samples GK-cl, Eg-bll, Nq-MG.

Family Eucyrtidiellidae TAKEMURA 1986

Genus *Eucyrtidiellum* BAUMGARTNER 1984

Type species: *Eucyrtidium* (?) *unumaensis* YAO 1979.

Eucyrtidiellum pyramis (AITA 1986)

Pl. 3, figs. 17–18

- * 1986 *Eucyrtidiellum* (?) *pyramis* n. sp. – AITA in: AITA & OKADA, p. 109, pl. 6, figs. 8–13; pl. 7, fig. 1a-b.
- 1987 *Eucyrtidiellum pyramis* (AITA). – AITA, p. 65, pl. 14, fig. 2.
- 1995a *Eucyrtidiellum pyramis* (AITA). – BAUMGARTNER et al., p. 216, pl. 3019, figs. 1–2. – [Full synonymy]
- 1997 *Eucyrtidiellum* sp. cf. *E. pyramis* (AITA). – CHIARI et al., pl. 2, fig. 15.
- 1997 *Eucyrtidiellum pyramis* (AITA in AITA & OKADA). – ZÜGEL, p. 204, figs. 5.9–5.10.

Remarks. – Complete specimens with a porous terminal tube (cf. ZÜGEL 1997, figs. 5.9–5.10.). Some specimens are more inflated compared to the holotype (AITA in: AITA & OKADA 1986). The occurrence of this species in the Late Kimmeridgian Nusplingen Lithographic Limestone is below the first appearance in the Early Tithonian reported by BAUMGARTNER et al. (1995a, 1995b).

Material: 8 specimens from samples GK-cl, Pk6–15-25, Nq-MG.

Family Canoptidae PESSAGNO in: PESSAGNO & POISSON 1979

Genus *Cinguloturris* DUMITRICA 1982

Type species: *Cinguloturris carpathica* DUMITRICA in: DUMITRICA & MELLO 1982.

Cinguloturris cylindra KEMKIN & RUDENKO 1993

Pl. 4, fig. 1

- * 1993 *Cinguloturris cylindra* n. sp. – KEMKIN & RUDENKO, p. 116, text-fig. 1b; pl. 2, figs. 3, 9–15.

- 1995a *Cinguloturris cylindra* KEMKIN & RUDENKO. – BAUMGARTNER et al., p. 144, pl. 6101, figs. 1–4. – [Full synonymy]
 1997 *Cinguloturris cylindra* KEMKIN & RUDENKO. – ZÜGEL, p. 206, figs. 5.11–5.12.

Remarks. – Incomplete specimens with 6–7 segments, costae mostly corroded. The occurrence of this species in the Late Kimmeridgian Nusplingen Lithographic Limestone is below the first appearance in the Early Tithonian reported by BAUMGARTNER et al. (1995a, 1995b).

Material: 6 specimens from samples GK-cl, Pk6–25–30, Nq-MG.

Family Parvicingulidae PESSAGNO 1977 emend. DUMITRICA 1995
 Subfamily Parvicingulinae PESSAGNO 1977

Genus *Mirifusus* PESSAGNO 1977 emend. BAUMGARTNER 1984

Type species: *Mirifusus guadalupensis* PESSAGNO 1977a.

*Mirifusus diana*e (KARRER 1867)

Pl. 4, figs. 2–3

- * 1867 *Lagena diana*e n. sp. – KARRER, p. 365, pl. 3, figs. 8a–b.
 1991 *Mirifusus diana*e (KARRER). – DUMITRICA & DE WEVER, p. 553–557, figs. 1, 2a–b.
 1995a *Mirifusus diana*e minor BAUMGARTNER. – BAUMGARTNER et al., p. 314, pl. 3286, figs. 1–5.
 1997 *Mirifusus diana*e (KARRER). – DUMITRICA in: DUMITRICA et al. 1997, p. 52, pl. 11, fig. 8.

Remarks. – The relatively short apical cone and the strongly inflated central part of both the internal casts and the calcified specimens point to *Mirifusus diana*e (KARRER). Internal casts from Nusplingen show two rows of tubercles as representatives of pore rows comparable to an internal cast of a specimen figured by DUMITRICA (in: DUMITRICA et al. 1997, pl. 11, fig. 8). *Mirifusus diana*e (KARRER) is distinguished from other species of *Mirifusus* PESSAGNO by having only two transversal rows of pores on each segment.

Material: 4 specimens from samples Nu 250, GK-cl.

Genus *Praecaneta* PESSAGNO, BLOME & HULL 1993

Type species: *Ristola decora* PESSAGNO & WHALEN 1982.

Praecaneta (?) sp.

Pl. 4, fig. 4

Description. – Conical test, composed of 8 segments. Globular cephalis, thorax, and abdomen form an apical cone. Separation of segments in the apical cone by transversal pore rows. Postabdominal segments slowly increase in diameter. Segments are separated by “H-link” circumferential ridges. Pores of the median pore row in each segment small, mostly closed by re-crystallization.

Remarks. – The apical portion of the test and the robust “H-link” circumferential ridges accord with the definition of the genera *Praecaneta* PESSAGNO, BLOME & HULL and *Caneta* PESSAGNO, BLOME & HULL. As the most distal part is

not preserved in the Nusplingen specimen, the assignment to *Praecaneta* is provisional.

Material: 1 specimen from sample GK-cl.

Genus *Praeparvicingula* PESSAGNO, BLOME & HULL 1993

Type species: *Parvicingula profunda* PESSAGNO & WHALEN 1982.

Praeparvicingula holdsworthi (YANG 1993)

Pl. 4, fig. 5

* 1993 *Parvicingula holdsworthi* n. sp. – YANG, p. 119, pl. 22, figs. 5–6, 16, 20.

1995 *Praeparvicingula holdsworthi* (YANG). – HULL, p. 38, pl. 5, figs. 3, 11.

Remarks. – Apical cone and strong circumferential ridges of the Nusplingen specimen accord well to the type material of the species (YANG 1993).

Material: 1 specimen from sample Nq-MG.

Genus *Ristola* PESSAGNO & WHALEN 1982

Type species: *Parvicingula* (?) *procera* PESSAGNO 1977a.

Ristola sp.

Pl. 4, fig. 6

Description. – Long slender internal cast with about 35 segments preserved. At least cephalothorax missing in the proximal part. Distal part with an indistinctly separated cast, that may represent a terminal tube. Proximal third of the test with slowly increasing diameters of segments, central and distal part rather cylindrical. Segmental casts disc-shaped, clearly separated by deep constrictions.

Remarks. – The Nusplingen internal cast is comparable to an internal cast figured by DUMITRICA (*in*: DUMITRICA et al. 1997, pl. 11, fig. 7), questionably assigned to *Ristola altissima* (RÜST). Without preservation of at least the apical part of the shell, a specific determination is not possible.

Material: 1 specimen from sample GK-cl.

Genus *Tethysetta* DUMITRICA 1997

Type species: *Tethysetta pygmaea* DUMITRICA 1997.

Tethysetta sp. aff. *T. mashitaensis* (MIZUTANI 1981)

Pl. 4, fig. 7

aff. 1981 *Parvicingula mashitaensis* n. sp. – MIZUTANI, p. 176, pl. 57, fig. 7; pl. 58, figs. 1–2.

aff. 1995a *Parvicingula mashitaensis* MIZUTANI. – BAUMGARTNER et al., p. 410, pl. 3245, figs. 1–7. – [Full synonymy]

Description. – Spindle-shaped internal cast, composed of 13 preserved segments, the cephalis missing and the most distal part presumably representing the cast of a terminal tube or of an inverted conical terminal segment. Portion from the thorax down to segment 9 conical, with slightly concave outlines on both sides. De-

crease of diameter from segment 10 to 13 continued by the terminal tube or terminal segment, resulting in an inverted rounded cone. Almost complete terminal closure by the end of the terminal tube. Starting from the fourth segment, each cast of the segments with three circumferential rows of small tubercles, corresponding to three pore rows in the shell. Especially in the proximal part of the test, only the median row is clearly visible.

Remarks. – The slender conical form of the proximal test portion accords well with the shell of *Tethysetta mashitaensis* (MIZUTANI). As no related shell specimens have been found in the Nusplingen material, the internal casts are only provisionally assigned to this species.

Material: 7 specimens from samples GK-cl, Pk5-u-cl.

Tethysetta (?) sp.

Fig. 6; Pl. 4, figs. 8–9

Description. – Slender spindle-shaped internal cast, composed of 13 segments. Cephalothorax indistinctly separated from the thorax. Cephalis with the imprint of an oblique septum (OS) dividing the cephalic cavity into two superposed chambers. Larger lower chamber of the cephalic cast with four gates, representing ventral spine (V), two primary lateral spines (L_r , L_l) and dorsal spine (D). A vertical groove opposite to the dorsal spine is interpreted as cast of the apical spine (A). Two secondary lateral spines (l_r , l_l) are represented by small horizontal grooves.

Cast slowly increasing in width down to the seventh segment, then slowly decreasing to the last segment. Last segment shows a long and narrow terminal tube. Starting from the fourth or fifth segment, each cast of the segments with three circumferential rows of small tubercles, corresponding to three pore rows in the shell.

Remarks. – The spindle shaped test with a long and narrow terminal tube is characteristic for the genus *Tethysetta* (DUMITRICA in: DUMITRICA et al. 1997). The double-chambered cephalis with an oblique septum is comparable to the herein described cephalic types of different Syringocapsinae (cf. DUMITRICA 1995). An inter-

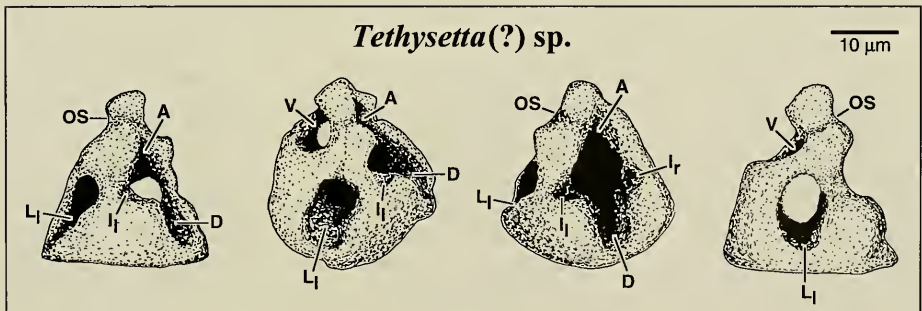


Fig. 6. *Tethysetta* (?) sp., internal cast of the cephalothorax with a double-chambered cephalis. Different views, with interpretations of the skeletal elements preserved as negative forms. – Abbreviations: A = apical spine; V = ventral spine; D = dorsal spine; L_l = left primary lateral spine; l_r = right secondary lateral spine; l_l = left secondary lateral spine; OS = oblique septum dividing cephalic cavity into two superposed chambers.

nal cast of another parvicingulid with the same feature is figured by DUMITRICA (*in*: DUMITRICA et al. 1997, pl. 9, fig. 15, 20) and compared to that of the family Amphipyndacidae.

Material: 6 specimens from samples GK-cl, Pk5-ucl.

Family Amphipyndacidae RIEDEL 1967
Subfamily Syringocapsinae FOREMAN 1973

Genus *Podobursa* WIŚNIEWSKI 1889 emend. FOREMAN 1973

Type species: *Podobursa dunikowskii* WIŚNIEWSKI 1889.

Podobursa sp. aff. *P. triacantha* (FISCHLI 1916)
Pl. 4, fig. 10

aff. 1916 *Theosyringium acanthophorum* RÜST var. *triacanthus*. – FISCHLI, p. 47, fig. 38.

aff. 1973 *Podobursa triacantha* (FISCHLI). – FOREMAN, p. 266, pl. 13, fig. 1.

aff. 1992 *Podobursa triacantha triacantha* (FISCHLI). – STEIGER, p. 72, pl. 19, figs. 12–13.

aff. 1993 *Podobursa triacantha* (FISCHLI). – STEIGER & STEIGER, p. 136, pl. 2, figs. 19–22.

aff. 1997 *Podobursa triacantha triacantha* (FISCHLI). – ZÜGEL, p. 206, fig. 5.15.

Remarks. – The internal casts of the Nusplingen specimens were, composed of four segments, but the cast of the cephalis in the cephalothorax are almost completely corroded. Descriptions of *Podobursa* WIŚNIEWSKI are largely based on three segments, because the separation of the cephalis and the thorax is not visible from outside. Some variations of *Podobursa triacantha* (FISCHLI) possess a modified triangular last segment (cf. STEIGER & STEIGER 1993, pl. 2, figs. 17, 18) comparable to the shape of the internal casts of the Nusplingen specimens.

Material: 2 specimens from sample GK-cl.

Podobursa (?) sp.
Pl. 4, fig. 11

Description. – Internal casts with four segments. Cephalothorax with double-chambered cephalis, without distinct separation of the cephalis from the thorax. Abdomen short, distinctly separated from the cephalothorax and the postabdomen. Postabdomen large and inflated, with a long internal cast of a terminal tube. Surface of the cephalothoracic cast smooth. Abdominal cast with small pore casts. Cast of the postabdominal segment including the terminal tube with large tubercles corresponding to pores in the shell.

Remarks. – Without preservation of lateral spines on the last segment, *Podobursa* WIŚNIEWSKI cannot be distinguished from some species of *Syringocapsa* NEVIANI. However, the long terminal tube points to *Podobursa*. Most descriptions of species from both genera mention only three segments because a separation of the cephalis and the thorax is not visible from outside.

The cephalic structure visible in the internal cast preservation is of amphipyndacid type, supporting the inclusion of the Syringocapsinae FOREMAN under the Amphipyndacidae RIEDEL. This structure is so far known in *Syringocapsa* NEVIANI, as remarked by DUMITRICA (1995).

Material: 10 specimens from sample GK-cl.

Genus *Podocapsa* RÜST 1885 emend. FOREMAN 1973

Type species: *Podocapsa guembeli* RÜST 1885, subsequent designation by CAMPBELL 1954.

Podocapsa amphitreptera FOREMAN 1973

Fig. 7; pl. 4, figs. 12–14

- * 1973 *Podocapsa amphitreptera* n. sp. – FOREMAN, p. 267, pl. 13, fig. 11.
 1992 *Podocapsa amphitreptera* FOREMAN. – STEIGER, p. 61, pl. 17, fig. 1.
 1993 *Podocapsa amphitreptera* FOREMAN. – STEIGER & STEIGER, p. 135, pl. 1, figs. 1–12, pl. 2, figs. 13–15.
 1994 *Podocapsa amphitreptera* FOREMAN. – JUD, p. 94, pl. 17, figs. 2–3.
 1995a *Podocapsa amphitreptera* FOREMAN. – BAUMGARTNER et al., p. 428, pl. 3171, figs. 1–5. – [Full synonymy]
 1997 *Podocapsa amphitreptera* FOREMAN. – ZÜGEL, p. 206, fig. 5.17.
 1997 *Podocapsa amphitreptera* FOREMAN. – HULL, p. 110, pl. 43, figs. 1–2, 16–17.

Remarks. – In contrast to the description of three segments by most authors, the internal casts reveal four segments, with a non-separated cephalothorax, followed by a small conical abdomen and a large postabdominal segment.

Description. – Cephalic cast with four gates, representing ventral spine (V), two primary lateral spines (L_r , L_l) and dorsal spine (D). A longitudinal groove directed to the apex represents the apical spine (A). Two shallow grooves on both sides of the dorsal spine cast may be interpreted as casts of the secondary lateral spines (l_r , l_l). The cephalis is divided into two superposed chambers by an oblique septum (OS) comparable to *Syringocapsa* NEVIANI. This character supports the inclusion of the Syringocapsinae FOREMAN under the Amphipyndacidae RIEDEL (cf. DUMITRICA 1995).

The Nusplingen internal casts belong to forms with long slender porous extensions and conical apical tests as figured by STEIGER (1992, pl. 17, fig. 1), STEIGER &

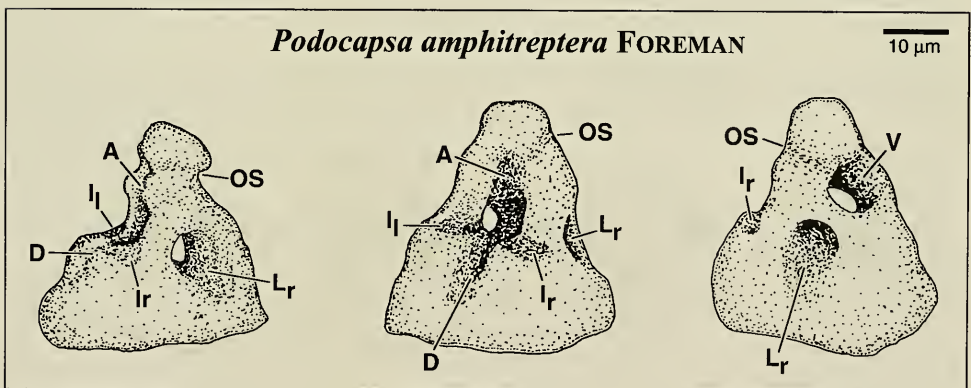


Fig. 7. *Podocapsa amphitreptera* FOREMAN, internal cast of the cephalothorax with a double-chambered cephalis. Different views, with interpretations of the skeletal elements preserved as negative forms. – Abbreviations: A = apical spine; V = ventral spine; D = dorsal spine; L_r = right primary lateral spine; l_r = right secondary lateral spine; l_l = left secondary lateral spine; OS = oblique septum dividing cephalic cavity into two superposed chambers.

STEIGER (1993, pl. 1, figs. 5–8), JUD (1994: pl. 17, fig. 3), BAUMGARTNER et al. (1995a, pl. 3171, fig. 3), and HULL (1997, pl. 43, figs. 1–2, 16–17).

Material: 20 specimens from samples GK-cl, Pk5-ucl, Pk5-lcl, Eg-bll.

Genus *Syringocapsa* NEVIANI 1900

Type species: *Theosyringium robustum* VINASSA 1901.

Syringocapsa sp. aff. *S. lata* YANG 1993

Fig. 8–9; pl. 5, figs. 1–3

aff. *1993 *Syringocapsa lata* n. sp. – YANG, p. 132, pl. 24, figs. 1–2, 16, 20–21; pl. 26, figs. 7, 11, 15.

aff. 1997 *Podobursa lata* (YANG). – HULL, p. 102, pl. 42, fig. 6.

Remarks. – The Nusplingen internal casts accord in proportions of apical part, central inflated part, and terminal tube to *Syringocapsa lata* YANG. Especially the long apical part of the test with four segments and the only moderate inflation of the fifth segment characterise this species.

Description. – Cephalic cast with four gates, representing ventral spine (V), two primary lateral spines (L_r , L_l) and dorsal spine (D). A short groove represents the apical spine (A), and a pair of horizontal grooves indicate the position of the secondary lateral spines (l_r , l_l). The proximal part of the cephalis is constricted from the main part by an oblique septum (OS), thus forming a separate small chamber. This feature justifies the assignment of the Syringocapsinae to the Amphipyndacidae (DUMITRICA 1995).

Material: About 50 specimens from samples GK-cl, Pk6–15–25, Pk5-ucl, Pk5-lcl.

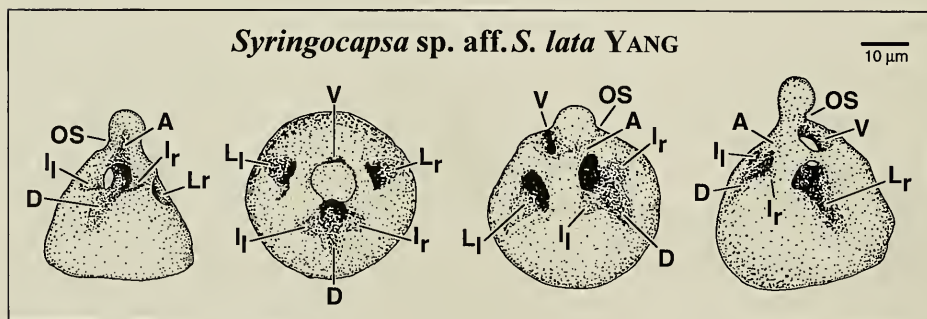


Fig. 8. *Syringocapsa* sp. aff. *S. lata* YANG, internal cast of the cephalothorax with a double-chambered cephalis. Different views, with interpretations of the skeletal elements preserved as negative forms. – Abbreviations: A = apical spine; V = ventral spine; D = dorsal spine; L_r = right primary lateral spine; L_l = left primary lateral spine; l_r = right secondary lateral spine; l_l = left secondary lateral spine; OS = oblique septum dividing cephalic cavity into two superposed chambers.

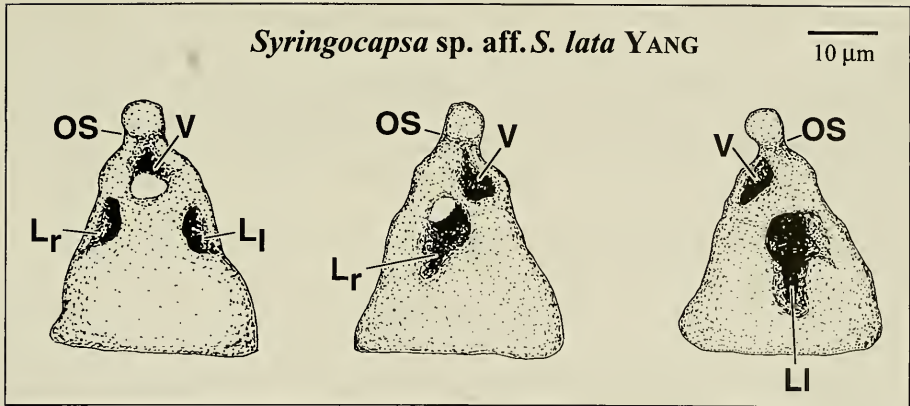


Fig. 9. *Syringocapsa* sp. aff. *S. lata* YANG, internal cast of the cephalothorax with a double-chambered cephalis. Different ventro-lateral views side with interpretations of the skeletal elements preserved as negative forms. – Abbreviations: V = ventral spine; D = dorsal spine; L_r = right primary lateral spine; L_l = left primary lateral spine; OS = oblique septum dividing cephalic cavity into two superposed chambers.

Syringocapsinae gen. et sp. indet.

Pl. 5, fig. 4

Description. – Internal cast with three segments preserved, lacking the cephalis. Gradually increasing diameters from the thorax to the proximal part of the postabdominal segment. Unlike its most proximal part, the main part of the postabdominal segment is large and globular. Three casts of porous extensions are directed obliquely downwards from the base of the abdominal segment. They diverge to form a regular tripod. The surfaces of the thoracic and abdominal casts are covered by small pore casts. Large pore casts cover the postabdominal segment and its extensions.

Remarks. – A tripod pattern of extensions on the last globular segment has not been described among *Syringocapsinae*.

Material: 1 specimen from sample GK-cl.

Family *Spongocapsulidae* PESSAGNO 1977

Genus *Spongocapsula* PESSAGNO 1977

Type species: *Spongocapsula palmerae* PESSAGNO 1977a.

Spongocapsula sp.

Pl. 5, fig. 6

Description. – Internal cast of a test with 7 segments, gradually increasing in width and height. Last segment globular, its height measuring more than a third of the complete test. Proximal part of the segments flattened to slightly depressed. Distal part rounded, partly depressed into the following segment. Surface of the seg-

ments covered by irregularly arranged pore casts, partly fused to irregular small ridges.

Remarks. – Irregular ridges and tubercles on the cast point to an assignment to the family Spongocapsulidae PESSAGNO. The Nusplingen specimens with a rather gradual increase of segments and the last segment only about 2 times higher than the previous one are more closely related to *Spongocapsula* PESSAGNO than to *Obesacapsula* PESSAGNO.

Material: 1 specimen from sample GK-cl.

Spongocapsula (?) sp.

Pl. 5, fig. 5

Description. – Incomplete internal cast composed of five segments, which represent presumably the abdomen and four postabdominal segments. Segments gradually increasing in width from the abdomen to the third postabdominal segment, last one postabdominal segment tapering. Proximal part of the segments flattened to slightly depressed, distal part rounded and somehow depressed into the next segment. Surfaces of the segmental casts with small ridges and tubercles in irregular arrangement, increasing in size from the abdomen to the third postabdominal segment.

Remarks. – Irregular ridges and tubercles instead of pore casts point to an assignment to the family Spongocapsulidae. A gradual increase of segment diameters and the decrease in the last segments indicates a close morphologic relation to *Spongocapsula* PESSAGNO (see PESSAGNO 1977a).

Material: 1 specimen from sample GK-cl.

Genus *Obesacapsula* PESSAGNO 1977

Type species: *Obesacapsula morroensis* PESSAGNO 1977a.

Obesacapsula sp. aff. *O. rusconensis* BAUMGARTNER 1984

Pl. 5, fig. 8

aff. *1984 *Obesacapsula rusconensis* n. sp. – BAUMGARTNER, p. 776, pl. 6, figs. 7–9.

aff. 1995a *Obesacapsula rusconensis rusconensis* BAUMGARTNER. – BAUMGARTNER et al., p. 348, pl. 3282, figs. 1–3. – [Full synonymy]

Remarks. – The incomplete specimens are closely related to *Obesacapsula rusconensis* BAUMGARTNER, lacking the voluminous last postabdominal segment.

Material: 2 specimens from sample GK-cl.

Obesacapsula sp.

Pl. 5, fig. 7

Description. – Internal cast with four segments preserved, lacking the cephalis and the thorax. Abdomen and two following postabdominal segments gradually increasing in size. Last postabdominal segment large, more than double as wide and 5 times higher as the previous one. The internal cast of the terminal aperture suggests a thick test wall. Surface of all segments re-crystallized, without casting the inner test surface.

Remarks. – The large size of the last segment with respect to the previous segments is a characteristic feature of *Obesacapsula* PESSAGNO (1977a).

Material: 3 specimens from samples GK-cl, Pk5-lcl.

10. Conclusions

The discovery of radiolarians from the Upper Kimmeridgian of the Nusplingen area corroborates the occurrence of this group in the neritic realm at the northernmost margin of the Tethys (see discussion in KIESSLING 1997). Distributional patterns confirm the Williriedellidae as the most frequent radiolarians in Upper Jurassic neritic seas (KIESSLING 1997). Despite the preservational factors in the distribution patterns of radiolarians, their occurrences in the Nusplingen Lithographic Limestone are interpreted as a result of a transgressive interval (RIEGRAF 1986, 1987). Further investigations on the faunal and sedimentary inventory of the Nusplingen Lithographic Limestone by the Stuttgart Natural History Museum will result in a more detailed palaeoecological interpretation.

Although the preservation of most radiolarians as internal casts rarely allows a specific determination, the study of these casts is very important for the knowledge of the inner cephalic structures and, therefore, for the systematic position of the genera and families.

Our study reveals the following types of cephalic structures:

1. Cephalis simple, separated from the thorax by a deep internal constriction, corresponding to the so-called collar septum. This cephalis shows a globular cavity with a vertical dorsal groove, representing the imprint of the apical spine. This groove suggests that the apical spine is fused to the cephalic wall by forming an inner longitudinal rib. Some forms also show a weak horizontal concavity at the upper part of the cephalic cast, suggesting the presence of a pair of arches originated in the apical spine. This type of cephalis, described already by DUMITRICA (1970), is characteristic among the Williriedellidae.

2. Cephalis simple, globular, with four dorsal circular holes as casts of the spines A, D, l_r , and l_l . The ventral part with the casts of the spines V, L_r , and L_l is not visible in the mounted specimens. The cephalic cavity is separated by the thoracal cavity by a deep constriction. This type of cephalis occurs in the genus *Phalangites*.

3. Cephalis of amphipyndacid structure. This type of cephalis is characterized by having the cephalic cavity clearly divided into two superposed chambers (a smaller upper chamber and a larger lower one) by a transverse oblique septum (OS in the present paper, VB in FOREMAN 1966). The internal casts of this type show the presence of the spines A, V, D, L_r , L_l , l_r , and l_l . The spines L always correspond to circular holes in the casts, whereas the spines l and D form grooves of variable depths, suggesting their close position to the test wall. Moreover, in these casts the cephalic cavity is not necessarily separated from the thoracal cavity by a collar septum. This type of structure was found in casts which can be assigned to *Sethocapsa*, Parvicin-*gulidae* and *Syringocapsinae*, all of them showing a close relationship to the Amphipyndacidae (DUMITRICA 1995).

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Plate 1

Spumellaria and Poulpidae (Nassellaria).

- Fig. 1. *Astrosphaeridae* gen. et sp. indet. Specimen with complete pore casts; GK-cl, SMNS 63573/4. – Maximum diameter: 175 μm .
- Fig. 2. *Astrosphaeridae* gen. et sp. indet. Specimen with regular arrangement of three-bladed beam casts; GK-cl, SMNS 63574/2. – Diameter: 180 μm .
- Fig. 3. *Astrosphaeridae* gen. et sp. indet. Half broken cast of mainly the space between inner and outer spheres; GK-cl, SMNS 63574/1. – Diameter: 155 μm .
- Fig. 4. *Astrosphaeridae* gen. et sp. indet. Complete cast with filled space of the inner sphere; GK-cl, SMNS 63573/3. – Maximum diameter: 185 μm .
- Fig. 5. *Astrosphaeridae*, gen. et sp. indet. Specimen with test preservation. Lower Tithonian Moernsheim Formation, Mühlheim, Schaudiberg (locality and section see ZÜGEL 1997). – Diameter: 165 μm .
- Fig. 6. *Pyramispongia barmsteinensis* (STEIGER), corroded specimen with only 3 broad spines partly preserved on the edges of the rounded tetrahedral central shell; GK-cl, SMNS 63573/2. – Maximum diameter: 295 μm .
- Fig. 7. *Alievium* (?) sp., specimen with one complete and two broken triradiate spines; additional small spines arise from the equatorial plane; GK-cl, SMNS 63573/1. – Vertical diameter: 210 μm .
- Fig. 8. *Saitoum* sp. aff. *S. pagei* PESSAGNO. Specimen with smaller second apical horn and feet curved outward, lateral view; GK-cl, SMNS 63574/3. – Vertical diameter: 180 μm .
- Fig. 9. *Saitoum* sp. aff. *S. pagei* PESSAGNO. Antapical view of specimen on fig. 6, showing the cephalic skeleton; GK-cl, SMNS 63574/3. – Maximum horizontal diameter: 140 μm .
- Fig. 10. *Saitoum* sp. aff. *S. dercourti* WIDZ & DE WEVER, lateral view showing the massive collar without incisions or protusions; GK-cl, SMNS 63573/11. – Length: 205 μm .

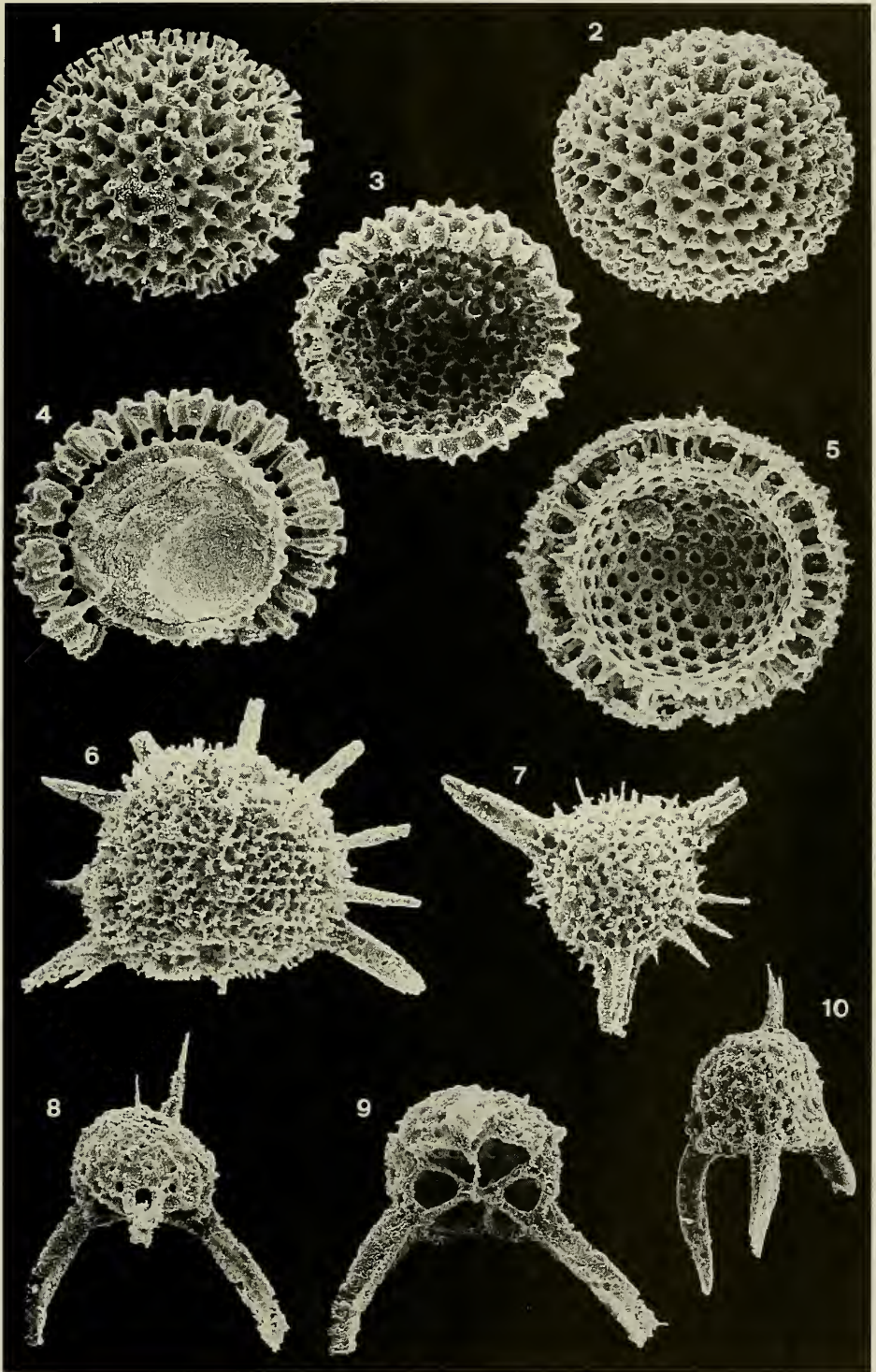


Plate 2

Nasselaria: Williriedellidae and Sethocapsidae.

- Fig. 1. *Complexapora tirolica* KIESSLING, Pk6–15-25, SMNS 63574/16. – Length: 185 μm .
- Fig. 2. *Complexapora* sp., sutural pore opens to the apical part of the test; Pk6–15-25, SMNS 63573/25. – Length: 115 μm .
- Fig. 3. *Zhamoidellum* sp. aff. *Z. ovum* DUMITRICA. Pk6–15-25, SMNS 63573/26. – Length: 110 μm .
- Fig. 4. *Williriedellum* sp. 1. Lateral view; GK-cl, SMNS 63573/10. – Length: 110 μm .
- Fig. 5. *Williriedellum* sp. 1. Oblique view on the terminal aperture; GK-cl, SMNS 63573/10. – Maximum width: 110 μm .
- Fig. 6. *Williriedellum* sp. 2, internal cast with a cast of the terminal aperture; Pk6–15-25, SMNS 63574/17. – Length: 85 μm .
- Fig. 7. Williriedellidae gen. et sp. indet. Lateral view, cephalis with cast of the apical spine; PK6–15-25, SMNS 63574/18. – Length: 95 μm .
- Fig. 8. Williriedellidae gen. et sp. indet. Oblique apical view, showing the concave shape of the proximal part of the abdomen.; Pk6–15-25, SMNS 63574/18. – Maximum width: 80 μm .
- Fig. 9. *Sethocapsa* sp. aff. *S. (?) zweilii* JUD; GK-cl, SMNS 63574/23. – Length 155 μm .
- Fig. 10. *Sethocapsa* sp. 1. GK-cl, SMNS 63573/21. – Length: 190 μm .
- Fig. 11. *Sethocapsa* sp. 2. Lateral view of the internal cast; GK-cl, SMNS 63574/4. – Length 140 μm .
- Fig. 12. Detail from fig. 11, cephalothorax with double chambered cephalis and casts of cephalic spines; arrow indicates oblique septum dividing the cephalic cavity. – Maximum width: 32 μm .

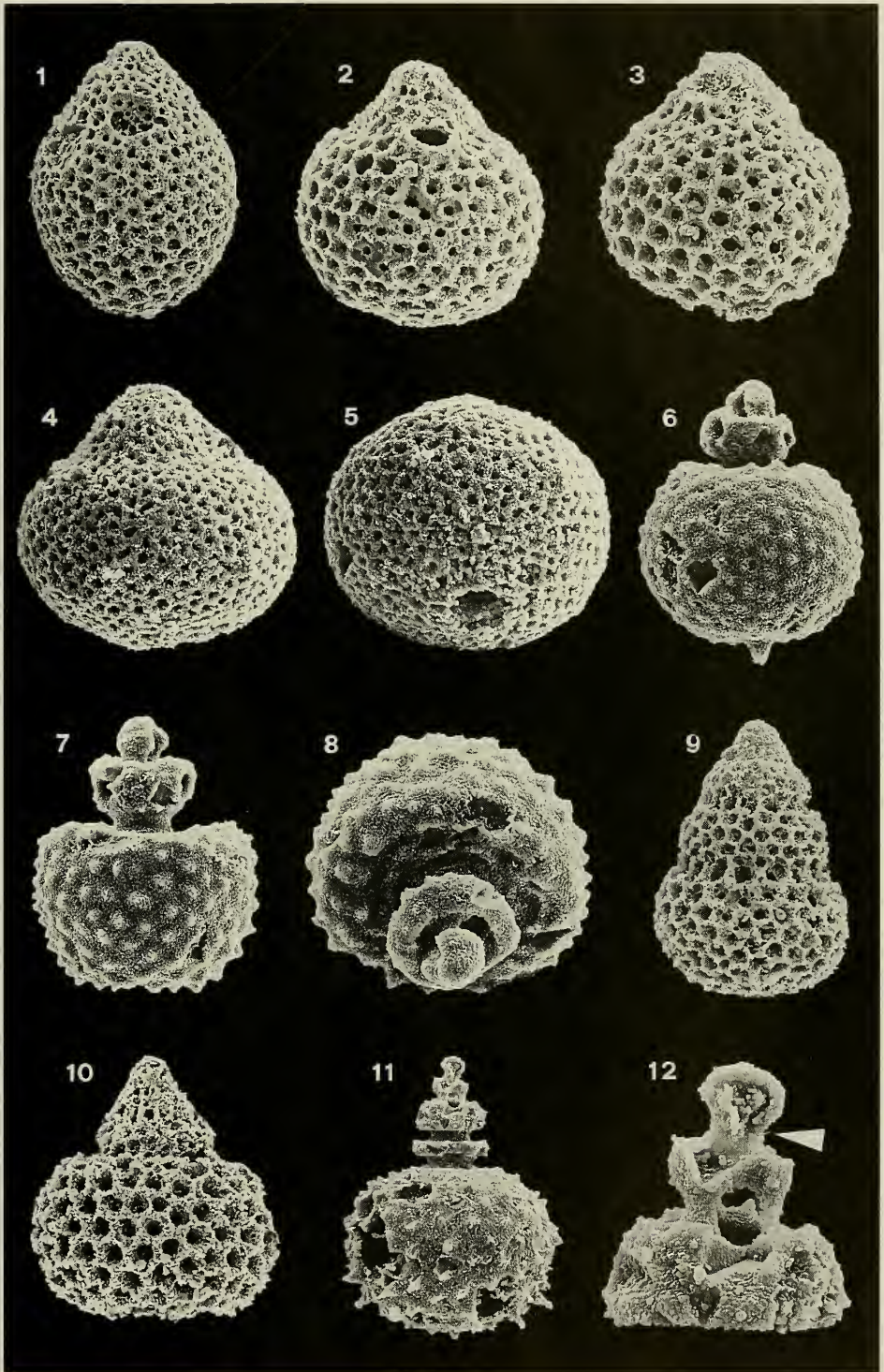


Plate 3

Nassellaria: Xitidae, Pseudodictyomitridae, Archaeodictyomitridae, Theoperidae, and Eucyrtidiellidae.

- Fig. 1. *Xitus* sp. Prolongation of ventral spine (left) beside the apical horn; insertion of a terminal tube; GK-cl, SMNS 63573/12. – Length: 185 μ m.
- Fig. 2. *Loopus primitivus* (MATSUOKA & YAO). Rounded conical form; Pk6–15–25, SMNS 63573/24. – Length: 220 μ m.
- Fig. 3. *Loopus primitivus* (MATSUOKA & YAO). Conical form; Nq-MG, SMNS 63573/22. – Length: 170 μ m.
- Fig. 4. *Loopus doliolum* DUMITRICA. GK-cl, SMNS 63573/15. – Length 130 μ m.
- Fig. 5. *Pseudodictyomitra* sp. 1. GK-cl, SMNS 63573/14. – Length: 200 μ m.
- Fig. 6. *Pseudodictyomitra* sp. 2. Rounded conical specimen with reduced costae on the last segments; GK-cl, SMNS 63573/16. – Length: 180 μ m.
- Fig. 7. *Pseudodictyomitra* sp. 2. Conical specimen, last segment corroded; Pk6–15–25, SMNS 63573/23. – Length: 200 μ m.
- Fig. 8. *Archaeodictyomitra apiarium* (RÜST). Pk6–15–25, SMNS 63573/27. – Length: 260 μ m.
- Fig. 9. *Archaeodictyomitra minoensis* (MIZUTANI). Pk6–15–25, SMNS 63574/19. – Length: 195 μ m.
- Fig. 10. *Archaeodictyomitra shengi* YANG. GK-cl, SMNS 63573/17. – Length: 220 μ m.
- Fig. 11. *Archaeodictyomitra sixi* YANG, slender form. GK-cl, SMNS 63574/9. – Length: 115 μ m.
- Fig. 12. *Archaeodictyomitra sixi* YANG, inflated form. GK-cl, SMNS 63574/10. Length: 140 μ m.
- Fig. 13. *Phalangites* sp. Lateral view of the complete specimen. GK-cl, SMNS 63574/11. – Length: 440 μ m.
- Fig. 14. Detail of fig. 13 with the cephalis, showing casts of cephalic spines (A – apical spine; D – dorsal spine; l_r – right secondary lateral spine, l_l – left secondary lateral spine). – Maximum width: 31 μ m.
- Fig. 15. *Protunuma japonicus* MATSUOKA & YAO. GK-cl, SMNS 63573/18. – Length: 190 μ m.
- Fig. 16. *Stichomitra* sp. GK-cl, SMNS 63574/8. – Length: 110 μ m.
- Fig. 17. *Eucyrtidiellum pyramis* (AITA), inflated form. Pk6–15–25, SMNS 63573/28. – Length: 130 μ m.
- Fig. 18. *Eucyrtidiellum pyramis* (AITA), slender form with porous terminal tube. Pk6–15–25, SMNS 63574/21. – Length: 160 μ m.

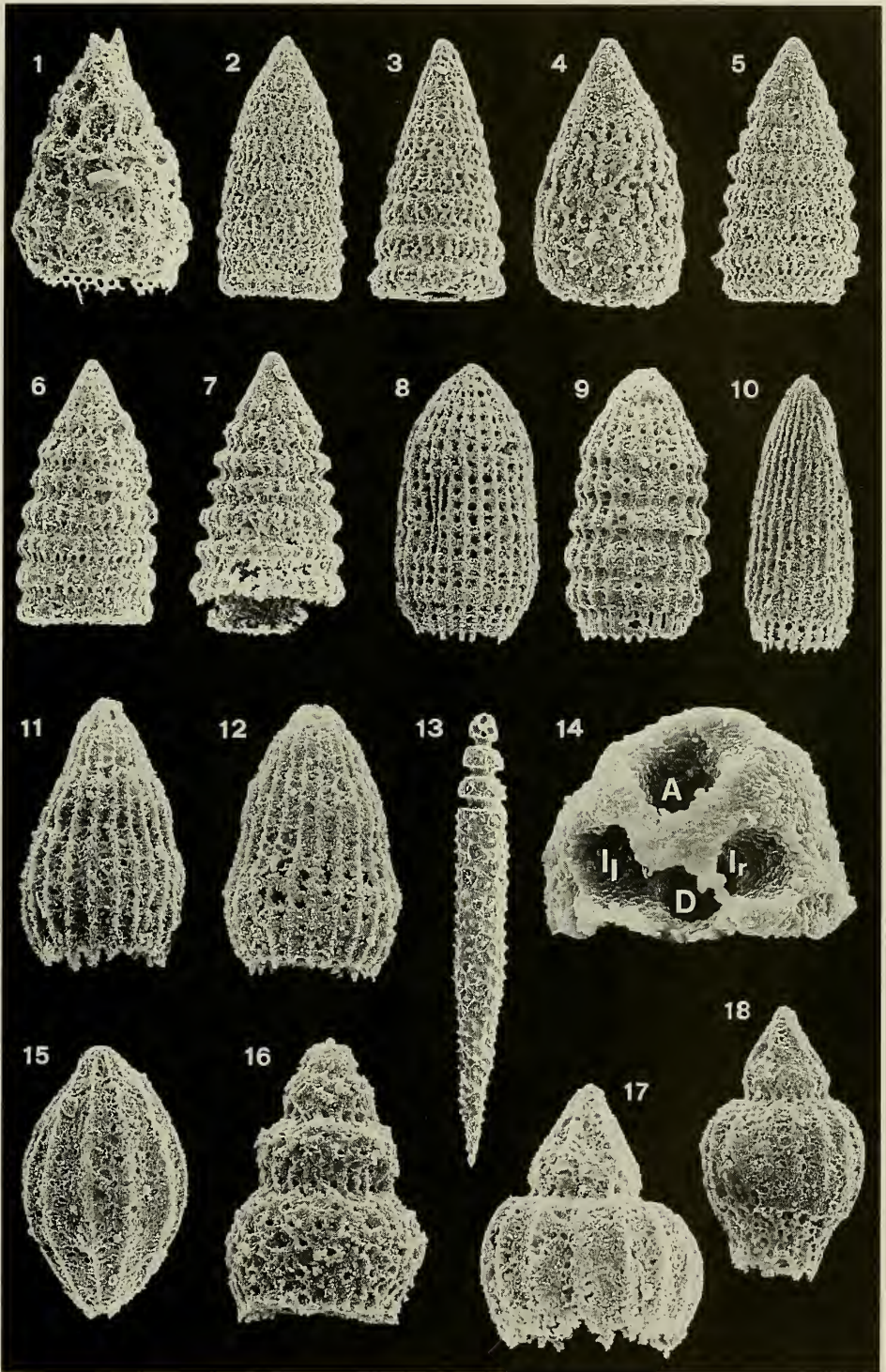


Plate 4

Nassellaria: Parvicingulidae and Syringocapsinae.

- Fig. 1. *Cinguloturris cylindra* KEMKIN & RUDENKO. PK6–15–25, SMNS 63574/20. – Length: 230 μm .
- Fig. 2. *Mirifusus diana*e (KARRER). Re-crystallized calcitic specimen; Nu 250, SMNS 63573/29. – Length: 630 μm .
- Fig. 3. *Mirifusus diana*e (KARRER). Siliceous internal cast; GK-cl, SMNS 63574/7. – Length: 520 μm .
- Fig. 4. *Praecaneta* (?) sp. GK-cl, SMNS 63573/13. – Length: 170 μm .
- Fig. 5. *Praeparvicingula holdsworthi* (YANG). Corroded specimen; Nq-MG, SMNS 63574/22. – Length: 200 μm .
- Fig. 6. *Ristola* sp., internal cast. GK-cl, SMNS 63573/8. – Length: 1050 μm .
- Fig. 7. *Tethysetta* sp. aff. *T. mashitaensis* (MIZUTANI). Internal cast; GK-cl, SMNS 63574/6. – Length: 365 μm .
- Fig. 8. *Tethysetta* (?) sp.; internal cast. Lateral view of the complete specimen; GK-cl, SMNS 63574/5- Length: 395 μm .
- Fig. 9. Detail of fig. 8 with the double-chambered cephalothorax, showing casts of cephalic spines; arrow indicates oblique septum dividing the cephalic cavity. – Maximum diameter 27 μm .
- Fig. 10. *Podobursa* sp. aff. *P. triacantha* (FISCHLI). Internal cast with triangular last segment, cephalis corroded; GK-cl, SMNS 63574/14. – Length: 260 μm .
- Fig. 11. *Podobursa* (?) sp. Internal cast composed of 4 segments (cephalothorax, abdomen, large postabdominal segment); GK-cl, SMNS 63573/5. – Length: 320 μm .
- Fig. 12. *Podocapsa amphitreptera* FOREMAN. Internal cast composed of four segments (cephalothorax, abdomen and large postabdominal segment); oblique apical view. GK-cl, SMNS 63574/12. – Maximum diameter 375 μm .
- Fig. 13. Lateral view of the specimen from fig. 12. – Length: 320 μm .
- Fig. 14. Detail of the specimen from fig. 12–13 with the cephalothorax, showing casts of cephalic spines; arrow indicates oblique septum dividing the cephalic cavity. – Maximum width: 37 μm .

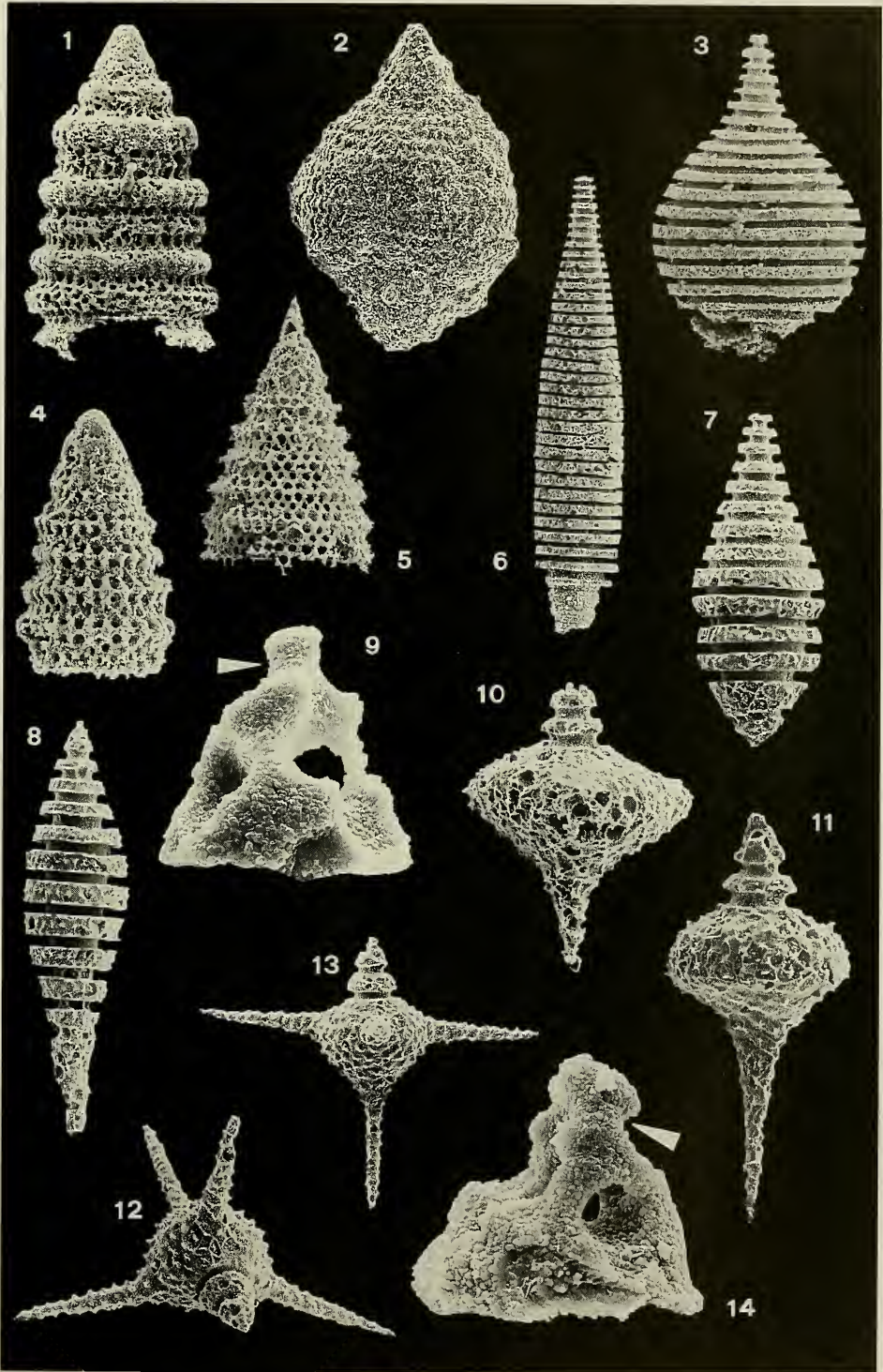
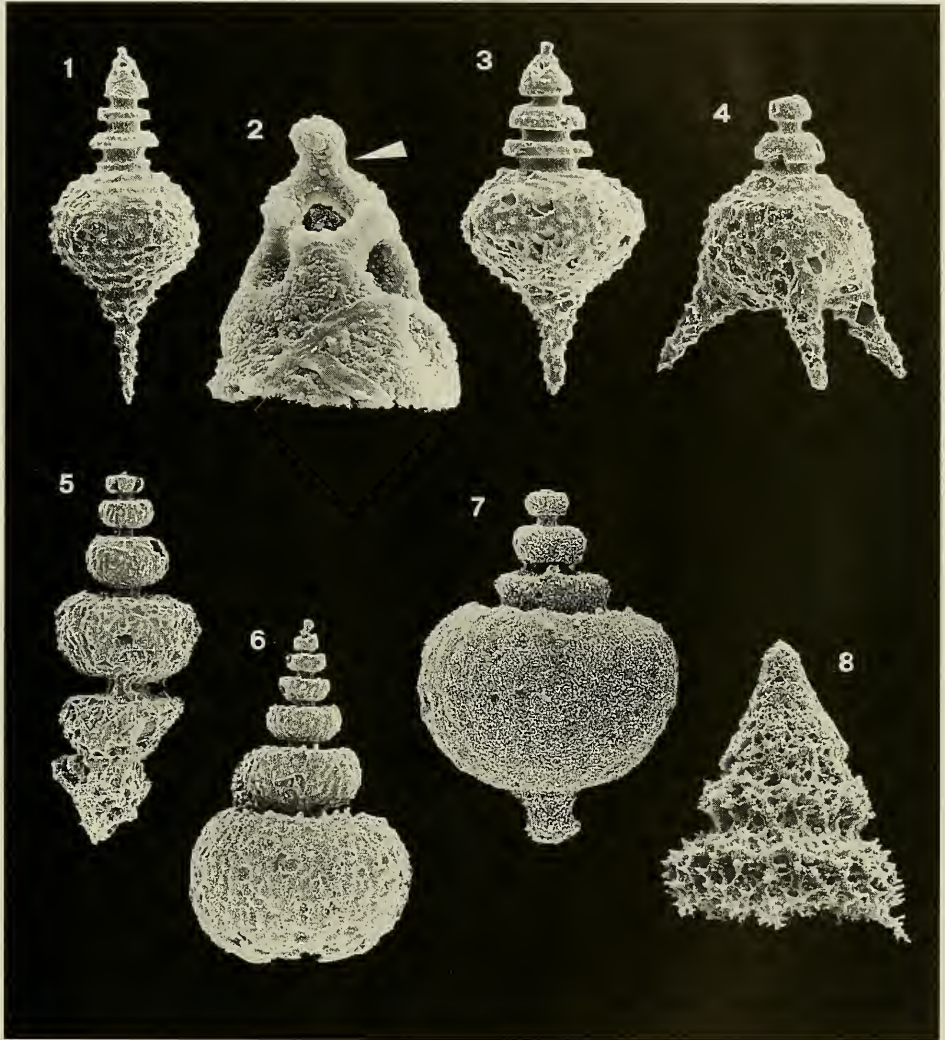


Plate 5

Nassellaria: Syringocapsinae and Spongocapsulidae from sample GK-cl.

- Fig. 1. *Syringocapsa* sp. aff. *S. lata* YANG; internal cast; internal cast. Complete lateral view of a slender specimen. SMNS 63574/13. – Length: 265 μ m.
- Fig. 2. *Syringocapsa* sp. aff. *S. lata* YANG; internal cast. Detail from fig. 1, showing the cephalothorax with casts of the cephalic spines. Arrow indicates position of the oblique septum (OS). – Maximum width: 32 μ m.
- Fig. 3. *Syringocapsa* sp. aff. *S. lata* YANG; internal cast. Lateral view of an inflated form. SMNS 63573/6. – Length: 275 μ m.
- Fig. 4. Syringocapsinae, gen. et sp. indet.; internal cast with tripod-like extensions on the last segment. SMNS 63573/7. – Length: 235 μ m.
- Fig. 5. *Spongocapsula* (?) sp.; internal cast with irregular ridges and tubercles. SMNS 63573/19. – Length: 525 μ m.
- Fig. 6. *Spongocapsula* sp.; internal cast with irregular ridges and tubercles. SMNS 63573/20. – Length: 370 μ m.
- Fig. 7. *Obesacapsula* sp.; internal cast with a very large last segment and a cast of the terminal aperture. SMNS 63574/15. – Length: 425 μ m.
- Fig. 8. *Obesacapsula* sp. aff. *O. rusconensis* BAUMGARTNER; apical cone without large last segment. SMNS 63573/9. – Length: 120 μ m.



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