

MIDDLE MIOCENE RADIOLARIANS FROM THE DUHO FORMATION IN THE POHANG BASIN, KOREA

Youngsuk BAK*, Jong Deock LEE* and Hyesu YUN**

* Department of Earth & Environmental Sciences, Chonbuk National University, Jeonju

** Department of Geology, Chungnam National University, Daejeon 305-764

ABSTRACT

Radiolarian faunas are found and described for the first time from sediments of the Pohang Tertiary basin. Eleven samples collected from the Duho Formation in Sodongri area yielded a total of 103 species belonging to 62 genera. They are well preserved, and occur with diatoms, silicoflagellates, ebridian and spongy spicules, which are not further investigated in this study.

The faunas are dominated by cold-water taxa such as *Botryopyle dictyocephalus*, *Lithelius minor*, *Spongopyle osculosa*, *Stylodictya validispina*, *Antarctissa strelkovi*, *Saccospyris antarctica*, *Peripyramis circumtexta*, and *Triceraspyris antarctica* indicating strong influence of cold-water current during deposition of the Duho formation of the Sodongri area.

Based on the last occurrence of *Cyrtocapsella tetrapera* the studied sequence is not younger than late Middle Miocene (11.95 Ma ; Theyer et al. 1978). This age is in well agreement with the hitherto known age of 12 Ma obtained from the equivalent sequence, and locality by other fossil groups.

INTRODUCTION

Radiolaria are holoplanktonic protozoa widely distributed in the oceans and occur throughout the water column from the near-surface to hundreds of meters depth. As with many planktonic organisms, their abundance in geographical region is related to the quality of the water mass, including such variables as temperature, salinity, productivity, and available nutrients. In geologic history few fossil groups reveal as complete record as the radiolarians. These protozoans were so diverse and widespread throughout Phanerozoic time and have left behind a detailed evolutionary record.

The fundamental relationship between major distribution patterns of radiolarians and the water masses, and complete record with rapid evolution make them potentially one of the most important marine microfossil groups in interpreting paleoenvironment and fine stratigraphy. For the reason radiolarians seem to be very useful also for the Pohang basin.

In fact, Kim (1965) tried to apply radiolarians in his biozonation. However, he only mentioned about the Tertiary radiolarian occurrence from the Chunbuk Conglomerate formation without any taxonomic description or photographs, although he established a bio-zonule by basis of these radiolarians. The continuing effort of later researchers documenting the radiolarians has failed in spite of abundant sampling and processing sediments from the Chunbuk Conglomerate formation.

The discovery was unexpectedly achieved during the diatom processing from the Duho formation developed near Sodongri area north of Heunghae and the first purpose of this paper is to report the discovery of radiolarians in the Pohang basin. Secondly, our study is to prove the applicability of radiolarians in interpretation of regional conditions in paleo-oceanography and detailed biostratigraphic analysis. Especially, it is hoped that the radiolarians will fill the information gaps which previously-described microfossil groups could not replenish.

MATERIAL AND METHODS

Eleven samples are collected from the Duho formation in the sodongri area. They are lithologically composed of gray to dark-gray mudstones with thin-bedded fine sandstones. All samples yield abundant radiolarians (Fig.1.).

In sampling sediments and sedimentary rocks for radiolarian investigations, procedures

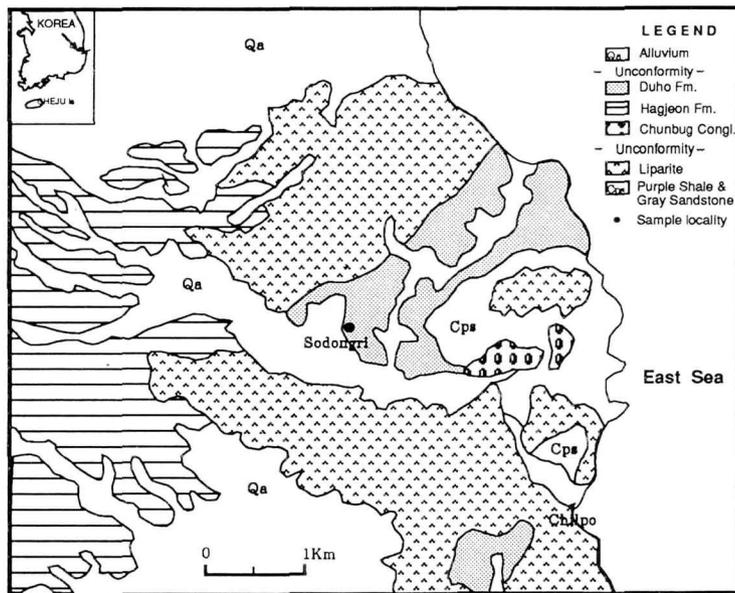


Fig.1. Geologic map of the Sodongri area with sample locality.

do not differ substantially from those employed in collecting other types of microfossils. The sample preparation procedure is slightly modified from process of Sanfilippo *et al.* (1985) and Boltovskoy *et al.* (1983) as following.

Preparation

1. Ten grams of material are crushed and placed in a clean beaker of 500 ml capacity, containing 50 ml of hydrogen peroxide (H₂O₂) and 25 ml of a 10% solution of hydrochloric acid.
2. This mixture is then heated at about 100°C for one hour on the hot plate.
3. Once more, 15 ml of hydrogen peroxide and hydrochloric acid are added to the beaker.
4. The beaker are boiled on hot plate (70°C–100°C) for three hours and left the beaker at the normal temperature (24 hours).
5. After complete reaction, the residues are divided in to clean water and fine material.
6. The residues are decanted three times with the distilled water and sieved with 250 µm and 63 µm.
7. The separated residues are placed in clean labeled bottles with distilled water.

Preparation for transmitted-light microscopic observation

8. The residues are pipetted evenly onto labelled glass slides and the accompanying water is evaporated at 50°C.
9. When completely dry, air is expelled from the skeletons by the addition of a few drops of xylene (refractive index ; 1.5055) and Canada balsam (ref. index ; 1.519) is dropped onto them , a cover glass (22X40 mm) completes the preparation.
10. The slides are placed for two weeks at 70°C in a precision mechanical convection oven.

Preparation for SEM observation

11. After chemical processing, the residues are filtered through filter paper and dried by oven.
12. The radiolarians are selected under a binocular microscope from the residues.
13. Specimens previously SEM observed and photographed must be carefully mounted on the SEM sample stub (diameter ; 15 mm) and coated with a 500 Å thick layer of gold.

Preparation for SEM and transmitted-light microscopic observation

14. When photographing the same radiolarian skeleton both by light microscopy and by SEM, the specimens are selected one by one under a binocular microscope, under low magnification.
15. For the inner structure observation, xylene drops in the radiolaria on the slide and photographing with transmitted-light microscope at a magnification of X 150.
16. Xylene is removed with a picking brush and rinsed in a drop of acetone on a radiolaria, before transferring them to SEM stub.
17. The specimens for SEM observation is coated with gold and photographs.

Occurrence

The radiolarian abundance in examined all specimen a slide from each site is indicated

as : A, abundant (over 26 specimens) ; C, common (11–25 specimens) ; F, few (6–10 specimens) ; R, rare (2–5 specimens) and T, trace (single specimen).

The state of preservation of these microfossils is classified into ; G, good (signifying that more than half of the specimens are unbroken with minimal dissolution) ; M, moderate (denoting breakage in more than half specimens and/or some degree of dissolution) ; P, poor (meaning that most specimens are fragmented and/or exhibited a high degree of dissolution).

Classificatory scheme

Although various classifications of radiolarian had been proposed since Ehrenberg (1847), modern classifications have only recently developed, chiefly by paleontologists. These classifications are based primarily on the skeletal morphology of Recent and Cenozoic forms. Today most radiolarian workers use a combination of Riedels (1970, 1971, 1977, 1978, 1981, 1986, 1990) and Petrushevskayas (1972, 1975, 1986, 1990) classifications. Recently most use the combined scheme of Nigrini and Moores (1979) and Nigrini and Lombaris (1984) works, which are also used in this study and catalogs of modern and Miocene radiolarians.

RESULTS

A total of 103 species belonging to 62 genera are identified from the Duho formation for the first time in the Pohang basin (Table 1–1, 1–2).

The major species are *Actinomma* sp., *Arachnocorallium* sp., *Botryopyle dictyocephalus*, *Caposphaera* sp., *Lithomitra lineata* group, *Lithelius minar*, *Spongurus* sp. A, *Spongurus* sp. B, *Stylochlamydidium asteriscus*, and *Theocorys redondoensis*. The accessory species are *Eucyrtidium calvertense*, *E. cienkowskii*, *Lithelius nautiloides*, *Actinomma antarcticum*, *Larcopyle buetschlii*, *Cyrtocapsella cornuta*, *C. japonica*, and *C. tetrapera* (Table 2–1, 2–2).

Among them the cold-water species are dominant as being represented by *Botryopyle dictyocephalus*, *Lithelius minor*, *Spongopyle osculosa*, *Stylodictya validispina*, *Antarctissa strelkovi*, *Saccospyris antarctica*, *Peripyramis circumtexta*, and *Triceraspyris antarctica*. The warm-water species, in contrast, are rare and their abundance is also low ; *Lamprocyclus maritimalis*, *Collosphaera huxleyi*, *Lophophaena simplex*, and *L. obtusa*. Conclusively, the studied section is influenced by cold-water current as being documented by other microfossils such as nannoplankton, foraminifers and dinoflagellates (Yi and Yun 1995, Jung 1993, Byun 1995).

Riedel and Sanfilippo (1971) defined the last occurrence of *Cyrtocapsella tetrapera* to be near the top of the *Dorcadospyris alata* Zone (early Middle Miocene). However, Nigrini (1985) suggested that this datum should be at 12.4–12.7 Ma. Theyer et al.(1978) are in the opinion it should be at 11.95 Ma.

Therefore, based on the last occurrence of *Cyrtocapsella tetrapera* the studied sequence is not younger than late Middle Miocene (11.95 Ma ; Theyer et al. 1978) . This age is in well agreement with the hitherto known age of 12 Ma obtained from the equivalent sequence, and locality by other fossil groups (Yi and Yun 1995, Jung 1993, Byun 1995).

Table 1-1. Occurrence chart of the radiolarians from Sodongri.

Formation		Duho Fm.										
species	samples	SD1	SD2	SD3	SD4	SD5	SD6	SD7	SD8	SD9	SD10	SD11
	preservation	G	G	G	G	P	G	G	G	M	G	G
<i>Acanthodesmidae</i> gen. et. spp. indet					T							
<i>Actinomma antarcticum</i>				C	F	R		R	T	T		
<i>Actinomma haysi</i>				A	T			R		T		R
<i>Actinomma medusa</i>			T	A	C			R		T		R
<i>Actinomma</i> spp.	T	R	R	A	A	R	A	A	R		R	R
<i>Amphitholus</i> spp.			R		R				T	T		
<i>Antarctissa longa</i>				R								
<i>Antarctissa robusta</i>	R	T										
<i>Antarctissa strelkovi</i>				R								
<i>Antarctissa</i> sp.	T											
<i>Arachnocorallium</i> spp.	A	C	A	C	T	A	A	A	A	F	A	C
<i>Axoprunum angelinum</i>			R	R	R							T
<i>Botryopera capitata</i>	R	R	R	R			T					
<i>Botryopyle dictyocephalus</i>	T	T	C	C			T	R	T	R	R	T
<i>Botryopyle</i> sp.	T								T		T	
<i>Callimitra atavia</i>				T								
<i>Calocyclus semipolita</i>								T				
<i>Cannartus</i> sp.				T								
<i>Carpocanarium</i> spp.			R	R	T			T	T	R	T	T
<i>Carposphaera</i> spp.	T	R	R	F	A		A	A	A	A	A	A
<i>Ceratocyrtis cucularis</i>		R	R		T				T			
<i>Ceratocyrtis histicosus</i>	R	T		F	R						T	
<i>Ceratocyrtis robustus</i>				T			T					
<i>Ceratocyrtis</i> sp. "r" group of Petrushevskaya 1975				T	T						T	
<i>Ceratocyrtis</i> sp.	T											
<i>Circodiscus microporus</i>	T				T					T		T
<i>Clathrospyrus sandellae</i>									R		T	
<i>Collosphaera huxley</i>					T							
<i>Collosphaera</i> spp.					T			R	R		R	
<i>Cornutella profunda</i>	T								T			
<i>Cyrtocapsella cornuta</i>	R			T							T	
<i>Cyrtocapsella japonica</i>	T								T			
<i>Cyrtocapsella tetrapera</i>							T			T	T	
<i>Cyrtocapsella</i> sp.												T
<i>Desmospyris rhodospyroides</i>					T							R
<i>Desmospyris spongiosa</i>		R	F	C			R					T
<i>Dictyophimus</i> sp.		T	T									R
<i>Discopyle ellipsis</i>	T											
<i>Drupptractus irregularis</i>		R			F					T		R
<i>Drupptractus nanus</i>		R			F							F
<i>Eucyrtidium calvertense</i>	T		R	F	F		T		T			R
<i>Eucyrtidium cienkowskii</i>	R	T	C	F			R	T	R	T		F
<i>Eucyrtidium</i> sp.	T		T								T	
<i>Gondwanaria japonica</i>			F	R				R				
<i>Gondwanaria</i> sp.									T			
<i>Hexacanthium</i> spp.	T	F	A	A			A					R
<i>Hexapyle</i> spp.				R			T					
<i>Hexastylus</i> sp.				R								
<i>Lamprocyclus maritilis</i>				T	T							
<i>Larcopyle buetschlii</i>				T	C		F		R	T		F
<i>Larcospira minor</i>	R		F	C			T				T	R
<i>Larcospira moschkovskii</i>			R	R						T		

Table 1-2. Occurrence chart of the radiolarians from Sodongri.

Formation		Duho Fm.										
species	samples preservation	SD1	SD2	SD3	SD4	SD5	SD6	SD7	SD8	SD9	SD10	SD11
		G	G	G	G	P	G	G	G	M	G	G
<i>Larcospira quadrangula</i>				T								T
<i>Liriospyris mutuarua</i>				T								
<i>Liriospyris</i> sp.			T	R	T							
<i>Lithelius foremanae</i>				T	R		T	T		T		
<i>Lithelius minar</i>					C		C	T		R	R	C
<i>Lithelius nautiloides</i>		R		R	F	R	T	T	T	T	T	R
<i>Lithelius</i> sp.	T			R								
<i>Lithomelissa</i> sp.aff. <i>L. haeckeli</i>				R	T			R	T		R	F
<i>Lithomelissa cheni</i>				R					T		T	F
<i>Lithomelissa ehrenbergi</i>				F	T			T		T		R
<i>Lithomelissa heros</i>		T	R	C	T		R		T			
<i>Lithomelissa</i> spp.	T			R	R	T		T	T		R	T
<i>Lithomelissa stigi</i>	T	T		F	R				T		T	T
<i>Lithomitra lineata</i> group		R		C	T			R	F	R	R	T
<i>Lonchosphaera</i> sp.				C	T						T	
<i>Lophophaena simplex</i>					T							
<i>Lophophaena?</i> <i>obtusa</i>			T									
<i>Lophophaena</i> spp.				R	T				T		T	
<i>Lychnocanoma grande</i>					T		T					
<i>Periphaena decora</i>		R		F	F		T					
<i>Peripyramis circumtexta</i>								T			T	R
<i>Phormacantha hystrix</i>		R	R		T		T					
<i>Phormospyris stabilis antarctica</i>												T
<i>Phormospyris stabilis stabilis</i>			T	T	R						T	T
<i>Phorticium polykladum</i>					T							R
<i>Prunopyle titan</i>					F		T	T				T
<i>Pylospira</i> sp.	T							T				T
<i>Saccospyris antarctica</i>				T	T							
<i>Siphocampe</i> sp.				R			T		R		R	
<i>Spirocyrtis</i> sp.				T								
<i>Spongaster</i> spp.				R	R	T	R					T
<i>Spongocore cylindrica</i>							T					T
<i>Spongodiscus biconcavus</i>		T					T					
<i>Spongodiscus maculatus</i>		T		R	R	T	F	R	T			F
<i>spongodiscus pulcher</i>				T	T	T		T				
<i>Spongopyle osculosa</i>				R	R		T	T				R
<i>Spongurus</i> sp.A of Nigrini & Lombardi 1984		R	T	C	A	R	F	R	R	R	R	C
<i>Spongurus</i> sp.B of Nigrini & Lombardi 1984		R	T	C	A		F	R	R	R		F
<i>Stichopodium biconicum</i>				T								
<i>Stylochlamydidium asteriscus</i>		R	R	F	A	F	A	C	C	F	C	C
<i>Stylodictya aculeata</i>		F	T		R							T
<i>Stylodictya validispina</i>		R		R	R	T			T			R
<i>Stylodictya</i> sp.		T	R	T	T	T						
<i>Stylosphaera minor</i>			T		T							
<i>Styptosphaera spumacea</i>												T
<i>Theocorys redondoensis</i>				R	R	T	R		R	T		T
<i>Tholospyris cortinisca</i>					T							
<i>Tholospyris</i> sp. aff. <i>T. infericosta</i>				T								
<i>Tholospyris</i> sp.					R				T			
<i>Triceraspyris antarctica</i>								T	T			T
<i>Trissocyclid</i> sp.								R				R

Table 2-1. Stratigraphic range chart of the radiolarians from Sodongri.

Epoch		Middle Miocene										
species	samples	SD1	SD2	SD3	SD4	SD5	SD6	SD7	SD8	SD9	SD10	SD11
<i>Actinomma</i> spp.												
<i>Botryopera capitata</i>												
<i>Antarctissa robusta</i>												
<i>Antarctissa</i> sp.												
<i>Botryopyle dictyocephalus</i>												
<i>Botryopyle</i> sp.												
<i>Carposphaera</i> spp.												
<i>Ceratocyrtis histicosus</i>												
<i>Ceratocyrtis</i> sp.												
<i>Circodiscus microporus</i>												
<i>Cornutella profunda</i>												
<i>Cyrtocapsella cornuta</i>												
<i>Cyrtocapsella japonica</i>												
<i>Discopyle ellipsopsis</i>												
<i>Eucyrtidium calvertense</i>												
<i>Eucyrtidium cienkowskii</i>												
<i>Eucyrtidium</i> sp.												
<i>Hexacanthium</i> spp.												
<i>Larcospira minor</i>												
<i>Lithelius nautiloides</i>												
<i>Lithelius</i> sp.												
<i>Lithomelissa heros</i>												
<i>Lithomelissa</i> spp.												
<i>Lithomelissa stigi</i>												
<i>Lithomitra lineata</i> group												
<i>Arachnocorallium</i> spp.												
<i>Periphaena decora</i>												
<i>Phormacantha hystrix</i>												
<i>Prunopyle titan</i>												
<i>Pylospira</i> sp.												
<i>Spongodiscus biconcavus</i>												
<i>Spongodiscus maculatus</i>												
<i>Spongurus</i> sp.A of Nigrini & Lombardi 1984												
<i>Spongurus</i> sp.B of Nigrini & Lombardi 1984												
<i>Stylochlamydidium asteriscus</i>												
<i>Stylodictya aculeata</i>												
<i>Stylodictya</i> sp.												
<i>Stylodictya validispina</i>												
<i>Actinomma medusa</i>												
<i>Amphitholus</i> spp.												
<i>Axoprunum angelinum</i>												
<i>Ceratocyrtis cucularis</i>												
<i>Desmospyris spongiosa</i>												
<i>Dictyophimus</i> sp.												
<i>Drupptractus irregularis</i>												
<i>Drupptractus nanus</i>												
<i>Liriospyris</i> sp.												
<i>Lophophaena?</i> obtusa												
<i>Phormospyris stabilis stabilis</i>												
<i>Stylosphaera minor</i>												
<i>Actinomma antarcticum</i>												
<i>Antarctissa longa</i>												
<i>Antarctissa strelkovi</i>												

Table 2-2. Stratigraphic range chart of the radiolarians from Sodongri.

Epoch		Middle Miocene										
species	samples	SD1	SD2	SD3	SD4	SD5	SD6	SD7	SD8	SD9	SD10	SD11
<i>Callimitra atavia</i>				—								
<i>Cannartus</i> sp.				—								
<i>Carpocanarium</i> spp.				—								
<i>Ceratocyrtis robustus</i>				—								
<i>Ceratocyrtis</i> sp. "r" group of Petrushevskaya 1975				—								
<i>Gondwanaria japonica</i>				—								
<i>Hexastylus</i> sp.				—								
<i>Lamprocyclus maritatus</i>				—								
<i>Larcopyle buetschlii</i>				—								
<i>Larcospira moschkovskii</i>				—								
<i>Larcospira quadrangula</i>				—								
<i>Liriospyris mutuaria</i>				—								
<i>Lithelius foremanae</i>				—								
<i>Lithomelissa</i> sp. aff. <i>L. haeckeli</i>				—								
<i>Lithomelissa cheni</i>				—								
<i>Lithomelissa ehrenbergi</i>				—								
<i>Lonchosphaera</i> sp.				—								
<i>Lophophaena</i> spp.				—								
<i>Saccospyris antarctica</i>				—								
<i>Siphocampe</i> sp.				—								
<i>Spirocyrtis</i> sp.				—								
<i>Spongaster</i> spp.				—								
<i>spongodiscus pulcher</i>				—								
<i>Spongopyle osculosa</i>				—								
<i>Stichopodium biconicum</i>				—								
<i>Theocorys redondoensis</i>				—								
<i>Tholospyris</i> sp. aff. <i>T. infericosta</i>				—								
<i>Acanthodesmidae</i> gen. et. spp. indet				—								
<i>Actinomma haysi</i>				—								
<i>Collosphaera huxley</i>				—								
<i>Collosphaera</i> spp.				—								
<i>Desmospyris rhodospyroides</i>				—								
<i>Hexapyle</i> spp.				—								
<i>Lithelius minar</i>				—								
<i>Lophophaena simplex</i>				—								
<i>Lychnocanoma grande</i>				—								
<i>Phorticium polycladum</i>				—								
<i>Tholospyris cortinisca</i>				—								
<i>Tholospyris</i> sp.				—								
<i>Spongocore cylindrica</i>				—								
<i>Calocyclus semipolita</i>				—								
<i>Cyrtocapsella tetrapera</i>				—								
<i>Peripyramis circumtexta</i>				—								
<i>Triceraspyris antarctica</i>				—								
<i>Clathrospyris sandellae</i>				—								
<i>Gondwanaria</i> sp.				—								
<i>Trissocyclid</i> sp.				—								
<i>Cyrtocapsella</i> sp.				—								
<i>Phormospyris stabilis antarctica</i>				—								
<i>Styptosphaera spumacea</i>				—								

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SYSTEMATIC DESCRIPTION

Phylum PROTOZOA

Class ACTINOPODA

Subclass RADIOLARIA Müller, 1858

Order POLYCYSTINA Ehrenberg, 1838, emend. Riedel, 1967b

Suborder SPUMELLARIA Ehrenberg, 1875

Family ACTINOMMIDAE Haeckel, 1862, emend. Riedel, 1967b

Genus *AXOPRUNUM* Haeckel, 1887, emend. Petrushevskaya & Koslova, 1972**Type species** : *Axoprunum stauraxonium* Haeckel, 1887, pl. 48, fig. 4.*Axoprunum angelinum* (Campbell & Clark, 1944) Kling, 1973

Pl. 3, fig. 8

1944 *Stylosphaera angelina* n.sp. - Campbell and Clark, p. 12, figs. 14–20.1973 *Axoprunum angelinum* (Campbell and Clark) comb. nov. - Kling, p. 634, pl. 1, fig. 13–16, pl. 6, fig. 14–18.1973 *A. angelinum* - Ling, p. 777, pl. 1, fig. 1–4.1975 *A. angelinum* - Foreman, p. 618, pl. 9, figs. 28,29.1978 *A. angelinum* - Piasias & Moore, p. 846, pl. 1, fig. 4.1981 *A. angelinum* - Weaver et al., p. 83, pl. 3, figs. 3–4.1985 *A. angelinum* - Pérez-Guzmán, p. 328, pl. 1, fig. 1.1990 *A. angelinum* - Lazarus, p. 717.

Description : This species consists of one cortical and two medullary shells. Shell bears two large polar spines which are as long as major axis of the cortical shell. Medullary shells are connected to the cortical shell by numerous stout radial beams, two stout polar spines lying along the major axis penetrate through cortical shell. Pores are circular shaped and 12 pores are arranged across the equator.

Dimensions : Diameter of innermost shell 13 μm ; of second shell 45 μm ; of cortical shell 164 μm . Length of spines 86 μm .

Abundance : Trace to rare

Genus *DRUPPATRACTUS* Haeckel, 1887**Type species** : *Druppattratus hippocampus* Haeckel, 1887, p. 324, pl. 16, figs. 10,11.*Druppattractus irregularis* Popofsky, 1912

Pl. 2, fig. 12

1912 *Druppattractus irregularis* n.sp. - Popofsky, p. 114, text-figs. 24–26.1974 *D. irregularis* Popofsky - Riedel et al., p. 704, pl. 54, fig. 1 ; p. 101, pl. 1, figs. 14–16.1982 *D. irregularis* Popofsky - Blueford, p. 206, pl. 6, figs. 7a-b.

Description : Cortical shell is usually oval, and medullary shell is characterized by pyriform. Two three-bladed polar spines are unequal in their size. Pores are small, and circular in outline. Outer shell is connected to the inner shell by six to eight radial beams.

Dimensions : Diameter of cortical shell 81 μm ; of inner shell 36 μm , Length of larger spine 53 μm ; of shorter spine 24 μm .

Abundance : Trace to few

Drupatractus nanus Blueford, 1982

Pl. 2, figs. 10–11

1982 *Drupatractus nanus* n. sp. - Blueford, p. 204, pl. 7, figs. 3a-4.

Description : Cortical shell is thickened and ovoidal. In optic views, ovate medullary shell has pores which are smaller than those of cortical shell. Two polar spines are three-bladed and unequal in their size. Four or five radial beams are connecting inner shell to outer one.

Dimensions : Diameter of the cortical shell 86 μm ; of inner shell 32 μm . Length of the long spine 64 μm ; of the shorter spine 23 μm .

Abundance : Rare to few

Family LITHELIIDAE Haeckel, 1862

Genus *LARCOPYLE* Dreyer, 1889

Type species : *Larcopyle bütschlii* Dreyer, 1889, p. 48, fig. 70.

Larcopyle bütschlii Dreyer, 1889

Pl. 3, fig. 1

1889 *Larcopyle bütschlii* n.sp. - Dreyer, p. 124. pl. 10, fig. 70.

1966 *L. bütschlii* - Benson, p. 280, pl. 19, figs. 3–5.

1979 *L. bütschlii* - Nigrini & Moore, p. S131, pl. 17, figs. 1a,1b.

1984 *L. bütschlii* - Nigrini & Lombardi, p. S89, pl. 13, figs. 1a,1b.

1990 *L. bütschlii* - Abelmann, p. 694, pl. 4, fig. 4.

Description : Shell is ellipsoidal with bumpy surface. This shell is composed of loose meshwork, and shows an apparently spiral structure. Spines are very short and conical. Pores are large and irregular in their shape.

Dimensions : Major diameter of the shell 131 μm ; minor diameter 8 μm .

Abundance : Trace to Common

Genus *LARCOSPIRA* Haeckel, 1887

Larcospira moschkovskii Kruglikova, 1978

Pl. 3, fig. 15

1974 *Larcospira* sp. - Kruglikova, pl. 2, figs. 15–16.

1978 *Larcospira moschkovskii* n.sp. - Kruglikova, p. 88, pl. 27, figs. 3–6.

1984 *L. moschkovskii* Kruglikova - Nigrini & Lombardi p. S91, pl. 13, figs. 2a, b.

Description : Shell is elliptical lens-shaped, sponge and perforated. It consists of double spiral whose whorls are elongated. Pores are numerous, latticed and randomly arranged. Outer whorl is three times as wide and two times as long as inner part.

Dimensions : Length of major axis 136–177 μm ; of minor axis 91–127 μm . Length of major axis of inner whorls 76–96 μm ; of minor axis 50–71 μm .

Abundance : Trace to rare

Genus *LITHELIUS* Haeckel, 1860

Type species : (by monotype) *Lithelius spiralis* Haeckel, 1860b, p. 843 ; 1862, pl. 27, figs. 6–7.

Lithelius foremanae Sanfilippo & Riedel, 1973

Pl. 3, fig. 16

1973 *Lithelius foremanae* n.sp. - Sanfilippo & Riedel, p. 522, pl. 7, figs. 1–6 ; pl. 26, figs. 4,5.

Description : Cortical shell is spherical and robust with cylindrical spines scattered over the surface. Shell shows an inner structure which builds a spiral of 2-3 whorls. The whorls are increasing in width outward. Spiral lattice are connected with one another and with the cortical shell by numerous radial bars. Pores are subcircular, and shows very irregular size and distribution.

Dimensions : Diameter of the shell 105-130 μm .

Abundance : Trace to Rare

Lithelius minor Jørgensen, 1900

Pl. 3, fig. 14

1900 *Lithelius minor* n.sp. - Jørgensen, p. 65, pl. 5, fig. 24

1966 *L. minor* Jørgensen - Benson, p. 262, pl. 17, fig. 10

1979 *L. minor* Jørgensen - Nigrini & Moore, p. 135, pl. 17, figs. 3,4a,b

1984 *L. minor* Jørgensen - Nigrini & Lombardi, p. 95, pl. 14, figs. 1a,b

Description : Shell is spherical, with thorn or thin conical spines. inner structure is a double spiral and supported by thin radial beams which arise from central part. Pores are subcircular to circular and irregular size.

Dimensions : Diameter of the shell 69 μm .

Abundance : Trace to common

Lithelius nautiloides Popofsky, 1908

Pl. 1, fig. 3 ; Pl. 4, fig. 9

- 1908 *Lithelius nautiloides* n.sp. - Popofsky, p. 230, pl. 27, fig. 4.
 1958 *L. nautiloides* - Riedel, p. 228, pl. 2, fig. 3.
 1967 *L. nautiloides* - Petrushevskaya, p. 53, fig. 27, 28I, 29I.
 1973 *L. nautiloides* - Petrushevskaya, p. 572, pl. 3, fig. 1,3,5, pl. 33, fig. 3,4.
 1975 *L. nautiloides* - Chen, p. 513, pl. 24, fig. 7.
 1979 *L. nautiloides* - Nigrini & Moore, p. S137.
 1984 *L. nautiloides* - Nigrini & Lombardi, p. S97, pl. 14, figs. 2a,2b.
 1990 *L. nautiloides* - Abelmann, p. 694, pl. 4, fig. 5.

Description : Subspherical shell consists of a completely involute spiral of four or five whorls. The whorls of the spiral increased in width outward, and are connected with numerous radial bars. The bars extend radially from the shell center to the outer part building radial spines on the shell surface.

Dimensions : Diameter of shell of five whorls 75 μ m.

Abundance : Trace to few

Family PHACODISCIDAE Haeckel, 1881

Genus *PERIPHAENA* Ehrenberg, 1873, emend. Sanfilippo & Riedel, 1973

Type species : (by monotype) *Periphaena decora* Ehrenberg, 1873, p. 246 ; 1875, pl. 28, fig. 6

Periphaena decora Ehrenberg, 1873

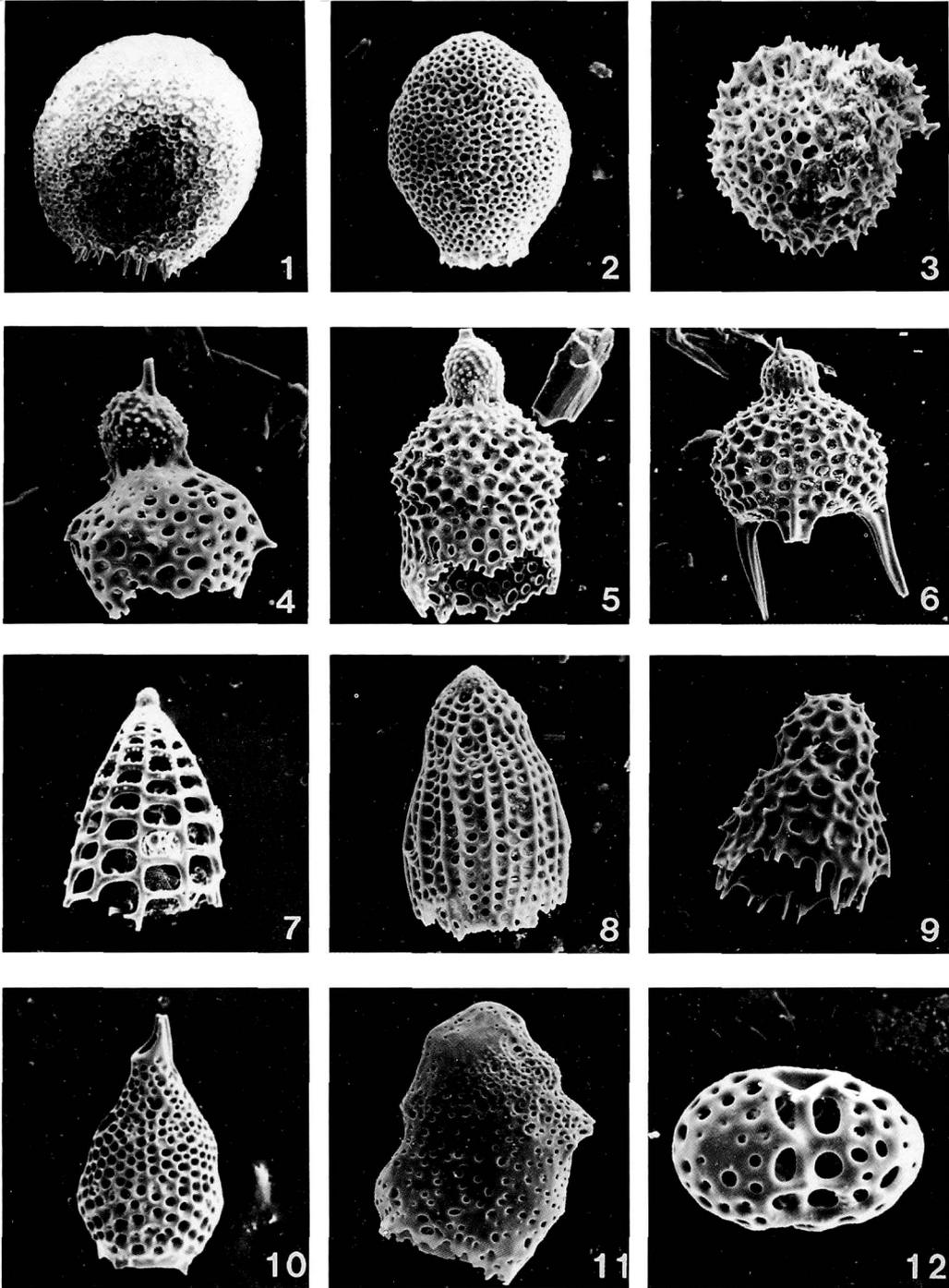
Pl. 2, fig. 2 ; Pl. 4, fig. 2

- 1847b *Haliomma humboldtii* - Ehrenberg, p. 55.
 1854b *H. humboldtii* - Ehrenberg, pl. 36, fig. 27.
 1873 *Periphaena decora* n.sp. - Ehrenberg, p. 246.
 1875 *P. decora* - Ehrenberg, pl. 28, fig. 6.
 1875 *Haliomma humboldtii* - Ehrenberg, pl. 27, fig. 3.
 1887 *Heliodiscus humboldti* (Ehrenberg) - Haeckel, p. 449.

PLATE 1

Fig. 1. *Spongopyle osculosa* X277 : SD3. **Fig. 2.** *Prunopyle titan* X240 : SD4. **Fig. 3.** *Lithelius nautiloides* X330 : SD3. **Fig. 4.** *Gondwanaria japonica* X390 : SD7. **Fig. 5.** *Theocorys redondoensis* X260 : SD6. **Fig. 6.** *Lychnocanoma grande* X230 : SD4. **Fig. 7.** *Peripyramis circumtexta* X350 : SD10. **Fig. 8.** *Eucyrtidium cienkowskii* X260 : SD8. **Fig. 9.** *Antarctissa strelkovi* X360 : SD3. **Fig. 10.** *Lamprocyclus maritalis* X230 : SD4. **Fig. 11.** *Botryopyle dictyocephalus* X320 : SD7. **Fig. 12.** *Liriospyris mutuarua* X300 : SD3.

PLATE 1



- 1887 *H. cingillum* - Haeckel, p. 448, pl. 33, fig. 7.
 1887 *Periphaena cincta* - Haeckel, p. 426, pl. 33, fig. 4.
 1887 *Perizona scutella* - Haeckel, p. 427, pl. 32, fig. 7.
 1957 *Heliodiscus humboldti*(Ehrenberg) - Riedel, p. 258, pl. 62, fig. 2.
 1957 *Periphaena decora* - Riedel, p. 258, pl. 62, fig. 1.
 1973 *P. decora* (Ehrenberg) - Sanfilippo & Riedel, p. 523, pl. 8, figs. 8–10, pl. 27, figs. 2–5.
 1992 *P. decora* (Ehrenberg) - Takemura, p. 743, pl. 6, fig. 8.
 1992 *P. decora* Ehrenberg - Blome, p. 645, pl. 4, fig. 14.

Description : Shell is lenticular, with a girdle of varying width. Cortical shell is thick-walled. Medullary shell is rounded and large. Pores on the cortical shell are numerous, rounded and cylindrical form.

Dimensions : Maximum diameter of cortical shell 207 μm ; minimum diameter 181 μm .

Abundance : Trace to few

Family PYLONIIDAE Haeckel, 1881

Genus *PRUNOPYLE* Dreyer, 1889

Type species : *Prunopyle pyriformis* Dreyer, 1889, p. 18, pl. 2, fig. 19

Prunopyle titan Campbell & Clark, 1944

Pl. 1, fig. 2 ; Pl. 3, fig. 2

- 1944 *Prunopyle titan n.sp.* - Campbell & Clark, p. 20, pl. 3, figs. 1–3.
 1965 *P. titan* - Hays, p. 173, pl. 2, fig. 4.
 1973 *P. titan* - Keany & Kennett, p. 539, fig. 4.
 1976 *P. titan* - Weaver, p. 578, fig. 6.
 1990 *P. titan* - Abelman, p. 693, pl. 3, fig. 16.

Description : Shell is ovate, smooth with distinct osculum. The species consists of numerous concentric shells, which are compact in the central part. Pylome is covered by small and circular pores which are densely developed.

Dimensions : Length of the shell 159 μm . Width of the shell 123 μm ; of the osculum 27–59 μm .

Abundance : Trace to few

Family SPONGODISCIDAE Haeckel, 1862, emend. Riedel, 1967

Genus *CIRCODISCUS* Petrushevskaya & Koslova, 1972

Type species : *Trematodiscus microporus* Stöhr, 1880, p. 108, pl. 4, fig. 17.

Circodiscus microporus (Stöhr) group, 1880

Pl. 4, fig. 1

- 1880 *Trematodiscus microporus* - Stöhr, p. 108, pl. 4, fig. 17.

- 1887 *Porodiscus microporus* - Haeckel, p. 493.
 1972 *Circodiscus microporus* (Stöhr) - Petrushevskaya & Koslova, p. 526, pl. 19, fig. 1-7.
 1975 *C. microporus* (Stöhr) - Petrushevskaya, p. 576.
 1984 *C. microporus* (Stöhr) group - Nigrini & Lombardi, s73, pl. 10, fig. 3
 1993 *C. microporus* (Stöhr) group - Hull, p. 11, pl. 3, fig. 12

Description : Flat shell consists of two elliptical rings of equal width around the central chamber. Outer shell is about 2 times wider than inner elliptical rings. Radial connector beams are present. Pores are small, numerous and rounded.

Dimensions : Diameter of central chamber 45 μm ; of first ring 89 μm ; of second ring 140 μm ; shell diameter 236 μm .

Abundance : Trace

Genus *SPONGODISUS* Ehrenberg, 1854a

Type species : (designated by Frizzell and Middour, 1951, p. 26) *Spongodiscus resurgens* Ehrenberg, 1854a, p. 246 ; 1854b, pl. 35b, fig. 16.

Spongodiscus maculatus Clark & Campbell, 1944, emend. Blueford, 1988.
 Pl. 4, fig. 4

- 1944 *Spongodiscus maculatus* n.sp. - Clark & Campbell, p. 25, pl. 4, figs. 2-3.
 1988 *S. maculatus* (Clark & Campbell) - Blueford, p. 254, pl. 7, figs. 6-7

Description : Spongy shell is circular in outline with abundant pores. Spongy texture which is characteristic of this species is dense in innerpart and becomes loose outward. Radial beams and annual rings are not present. Some specimens have pylomes.

Dimensions : Diameter of shell 190-280 μm .

Abundance : Trace to few

Genus *SPONGOPYLE* Dreyer, 1889

Spongopyle osculosa Dreyer, 1889
 Pl. 1, fig. 1 ; Pl. 4, fig. 3

- 1889 *Spongopyle osculosa* n.sp. - Dreyer, p. 42, pl. 11, figs. 99,100
 1958 *S. osculosa* Dreyer - Riedel, p. 226, pl. 1, fig. 12
 1967 *S. (?)osculus* (Dreyer) - Petrushevskaya, p. 42, figs. 20-22
 1984 *S. osculosa* Dreyer - Nigrini & Lombardi, s115, pl. 15, fig. 1

Description : This species shows large biconvex lens-shape. The central part is thickened and composed of a denser spongy mass. Pylome is thin. Pores are subrounded, numerous and irregularly distributed. One pole has an osculum with radial beams.

Dimensions : Width of shell 171 μm , Length of shell 187 μm .

Abundance : Trace to rare

Genus *STYLOCHLAMYDIUM* Haeckel, 1887*Stylochlamyidium asteriscus* Haeckel, 1887

Pl. 2, fig. 1

1887 *Stylochlamyidium asteriscus* n.sp. - Haeckel, p. 514, pl. 41, fig. 101979 *S. asteriscus* Haeckel - Nigrini & Moore, s113, pl. 14, fig. 51984 *S. asteriscus* Haeckel - Nigrini & Lombardi, s75, pl. 10, fig. 4

Description : Shell is biconcave-lens form with concentric rings. Concentric rings are composed of 7 bands which increase in width toward shell margin. Radial beams extend from the center to the shell surface. Subrounded pores are numerous and irregularly arranged.

Dimensions : Diameter of central shell 16 μm ; of shell 133 μm .

Abundance : Rare to abundant

Genus *STYLODICTYA* Ehrenberg, 1847, emend. Koslovain Petrushevskaya and Koslova, 1972**Type species** : *Stylodictya gracilis* Ehrenberg, 1854.*Stylodictya aculeata* Jørgensen, 1905

Pl. 4, fig. 5

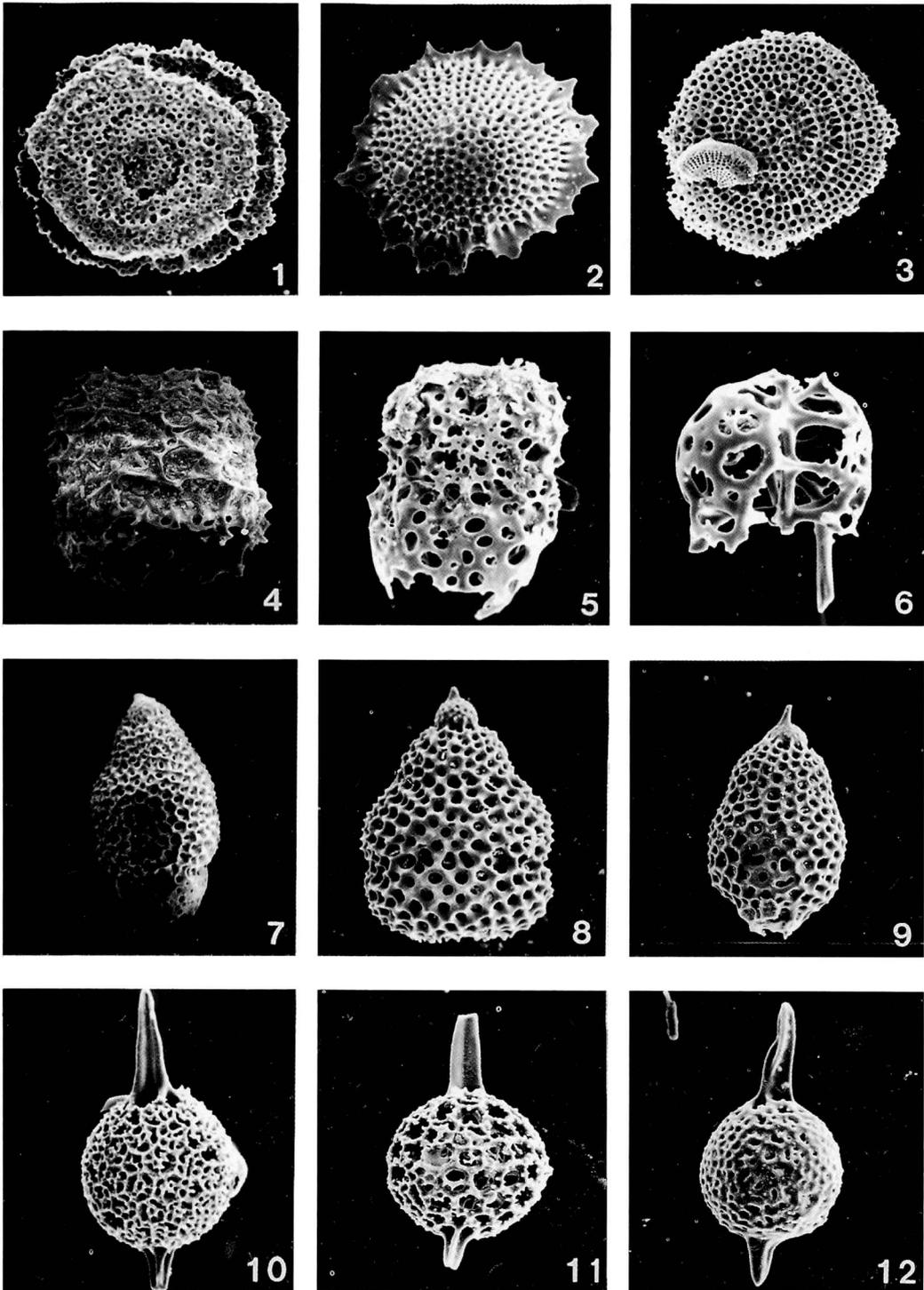
1905 *Stylodictya aculeata* n.sp. - Jørgensen, p. 119, pl. 10, fig. 41.1967 *S. aculeata* - Petrushevskaya, p. 35, pl. 17, figs. 1-3.1972 *S. aculeata* - Petrushevskaya & Koslova, pl. 18, fig. 6.1979 *S. aculeata* - Nigrini & Moore, p. S101, pl. 13, fig. 3.4.1984 *S. aculeata* - Nigrini & Lombardi, p. S69, pl. 10, figs. 1a, 1b.1990 *S. aculeata* - Abelman, p. 693, pl. 3, fig. 9.

Description : This species is discoidal shell, with approximately 4-5 bands which increase in width toward periphery of disc. Radial spines extend to outer shell surface. Central portion of disc looked like rosette.

PLATE 2

Fig.1 : *Stylochlamyidium asteriscus* X240 : SD6. **Fig.2** : *Periphaena decora* X200 : SD1. **Fig.3** : *Stylodictya validispina* X270 : SD11. **Fig.4** : *Desmospyris spongiosa* X260 : SD2. **Fig.5** : *Saccospyris antarctica* X270 : SD3. **Fig.6** : *Triceraspyris antarctica* X330 : SD7. **Fig.7-8** : *Cyrtocapsella cornuta* 7 : X160 : SD1 ; 8 : X220 : SD3. **Fig.9** : *C. tetrapera* X230 : SD7. **Fig.10-11** : *Drupatractus nanus* 10 : X270 : SD2 ; 11 : X290 : SD4. **Fig.12** : *D. irregularis* X290 : SD11.

PLATE 2



Dimensions : Diameter of first ring 30–35 μm ; of second ring 55–60 μm ; of third 80–85 μm ; of fourth 110–115 μm . Diameter of disk with five rings about 140 μm .

Abundance : Trace to few

Stylodictya validispina Jørgensen, 1905

Pl. 2, fig. 3 ; Pl. 4, fig. 6

1905 *Stylodictya validispina* n.sp. - Jørgensen, p. 119, pl. 10, fig. 40.

1967 *S. validispina* - Petrushevskaya, p. 33, fig. 17, IV–V.

1979 *S. validispina* - Nigrini & Moore, p. S103, pl. 13, fig. 5a,5b.

1985 *S. validispina* - Nigrini & Lombardi, p. S71, pl. 10, fig. 2.

1990 *S. validispina* - Abelmann, p. 693, pl. 3, fig. 10.

Description : Form of shell is flat-disc which is not thickened in middle part. This species is characterized by distinct concentric chamber. Width of the chambers increase slightly to the periphery of disc. Radial beams extend from the center to the margin. Circular pores shows some regular arrangement.

Dimensions : Diameter of central chamber 11 μm ; of first ring 29 μm ; of second ring 47 μm ; of third 65 μm ; of fourth 87 μm ; of five 114 μm . Diameter of disk with six rings about 136 μm .

Abundance : Trace to rare

Family SPONGURIDAE Haeckel, 1862, emend. Petrushevskaya, 1975

Genus *SPONGURUS* Haeckel, 1860

Type species : *Spongurus cylindricus* Haeckel, 1860.

Spongurus (?) sp. A Nigrini & Lombardi, 1984

Pl. 3, fig. 3

1967 *Spongurus*(?) sp. - Petrushevskaya, p. 33, fig. 16, III ; fig. 26.I

1979 *S.* (?) sp. - Nigrini & Moore, p. 67, pl. 8, fig. 4

1984 *S.* (?) sp. A - Nigrini & Lombardi, p. 33, pl. 5, figs. 1a,b

Description : Ellipsoidal shell consists of finely pored meshwork, which is loosely spongius. In optical section, spiral meshwork consists of 6 whorls.

Dimensions : Width of shell 96 μm , Length of shell 145 μm .

Abundance : Trace to abundant

Spongurus (?) sp. B Nigrini & Lombardi, 1984

Pl. 3, fig. 4

1984 *Spongurus*(?) sp. B - Nigrini & Lombardi, p. 35, pl. 5, figs. 2a-c.

Description : Shell is ellipsoidal, composed of spongy, concentric meshwork. Shell surface is thorny, with a group of long and conical thorns at each pole. Inner part shows concentric rings ; distance between ellipsoids increased toward periphery. Some specimens developed pylome.

Dimensions : Width of shell 77 μm , Length 130 μm .

Abundance : Trace to abundant

Family ACANTHODESMIIDAE Haeckel, 1862, emend. Riedel, 1967b

Genus *CERATOSPYRIS* Ehrenberg, 1847

Type species : *Cornutella cucularis* Ehrenberg, 1873, 1875, pl. 2, fig. 7

Ceratocyrtis histricosa (Jørgensen), 1905

Pl. 4, fig. 10

1905 *Helotholus histricosa* n.sp. - Jørgensen, p. 137, pl. 16, figs. 86-88.

1967 *H. histricosa* Jørgensen - Petrushevskaya, p. 91, fig. 2

1971b *Ceratocyrtis histricosa* (Jørgensen) - Petrushevskaya, p. 98, pl. 52, figs. 2-4

1976 *C. histricosa* (Jørgensen) - Bjorklund, pl. 8, figs. 19-24, pl. 11, figs. 4-5.

1979 *C. histricosa* (Jørgensen) - Petrushevskaya & Kozlova, p. 115

1984 *C. histricosa* (Jørgensen) - Nigrini & Lombardi, N11, pl. 15, fig. 6

1994 *C. histricosa* (Jørgensen) - Funakawa, p. 463, figs. 7, 1a-1b.

Description : Surface of the shell is smooth without spines. Cephalis is hemispherical. Thorax is broadly campanulate. The pores are irregular in size, most of them being roundish, smallest on the cephalis, largest on the thorax. On the cephalis and thorax, narrow needle shaped by-spines are scattered.

Dimensions : Length of the cephalis 20 μm ; width 31 μm , Length of the thorax 86 μm ; width 119 μm .

Abundance : Trace to few

Genus *LIRIOSPYRIS* Haeckel, 1881, emend. Goll, 1968

Type species : *Liriospyris hexapoda* Haeckel, 1887

Liriospyris mutuaria Goll, 1968

Pl. 1, fig. 12 ; pl. 4, fig. 7

1968 *Liriospyris mutuaria* n.sp. - Goll, p. 1428-1429, pl. 175, figs. 6,10,11,14, text-fig. 9.

1972 *L. mutuaria* - Goll, p. 967, pl. 71, fig. 2.

1977 *L. mutuaria* - Riedel & Sanfilippo, p. 868-869, pl. 16, fig. 15.

1992 *L. mutuaria* - Yu-jing Wang & Qun Yang, p. 101, pl. 1, fig. 18.

1994 *L. mutuaria* - Mahapatra & Sharma, p. 160, pl. 2, fig. 8.

Description : Shell has sagittal ring. Frontal or axial spines are absent. Lattice shell is smooth with three pairs of sagittal-lattice pores. Pores are subcircular varying between 3 μm and 16 μm in diameter.

Dimensions : width of sagittal ring 56 μm , Height of sagittal ring 66 μm .

Abundance : Trace

Family ARTOSTROBIIDAE Riedel, 1967a, emend. Foreman, 1973

Genus *PERIPYRAMIS* Haeckel, 1881, emend. Riedel, 1958

Type species : *Peripyramis circumtexta* Haeckel, 1887, pl. 54, fig. 5

Peripyramis circumtexta Haeckel, 1887

Pl. 1, fig. 7 ; Pl. 4, fig. 12

1887 *Peripyramis circumtexta* n.sp. - Haeckel, p. 1162, pl. 54, fig. 5

1958 *P. circumtexta* Haeckel - Riedel, p. 231, pl. 2, figs. 8,9

1967 *P. circumtexta* Haeckel - Petrushevskaya, p. 111, fig. 64, I-II, fig. 65, I-II

1972 *P. circumtexta* (Haeckel) - Petrushevskaya & Koslova, p. 551, pl. 31, fig. 4.

1979 *P. circumtexta* Haeckel - Nigrini & Moore, N29, pl. 21, figs. 4a,b

Description : Hyaline cephalis is small and ovate. Thorax is conical and occupied by quadrangular pores which increase in size distally. Numerous short, forked spines arise from the longitudinal and transverse skeletal bars of the thorax.

Dimensions : Total length 98 μm , Maximum breadth 67 μm .

Abundance : Trace to rare

Family CANNOBOTRYIDAE Haeckel, emend. Riedel, 1967b

Genus *BOTRYOPYLE* Haeckel, 1881

Type species : *Botryopyle dictyocephalus* Haeckel, 1887, pl. 96, fig. 6.

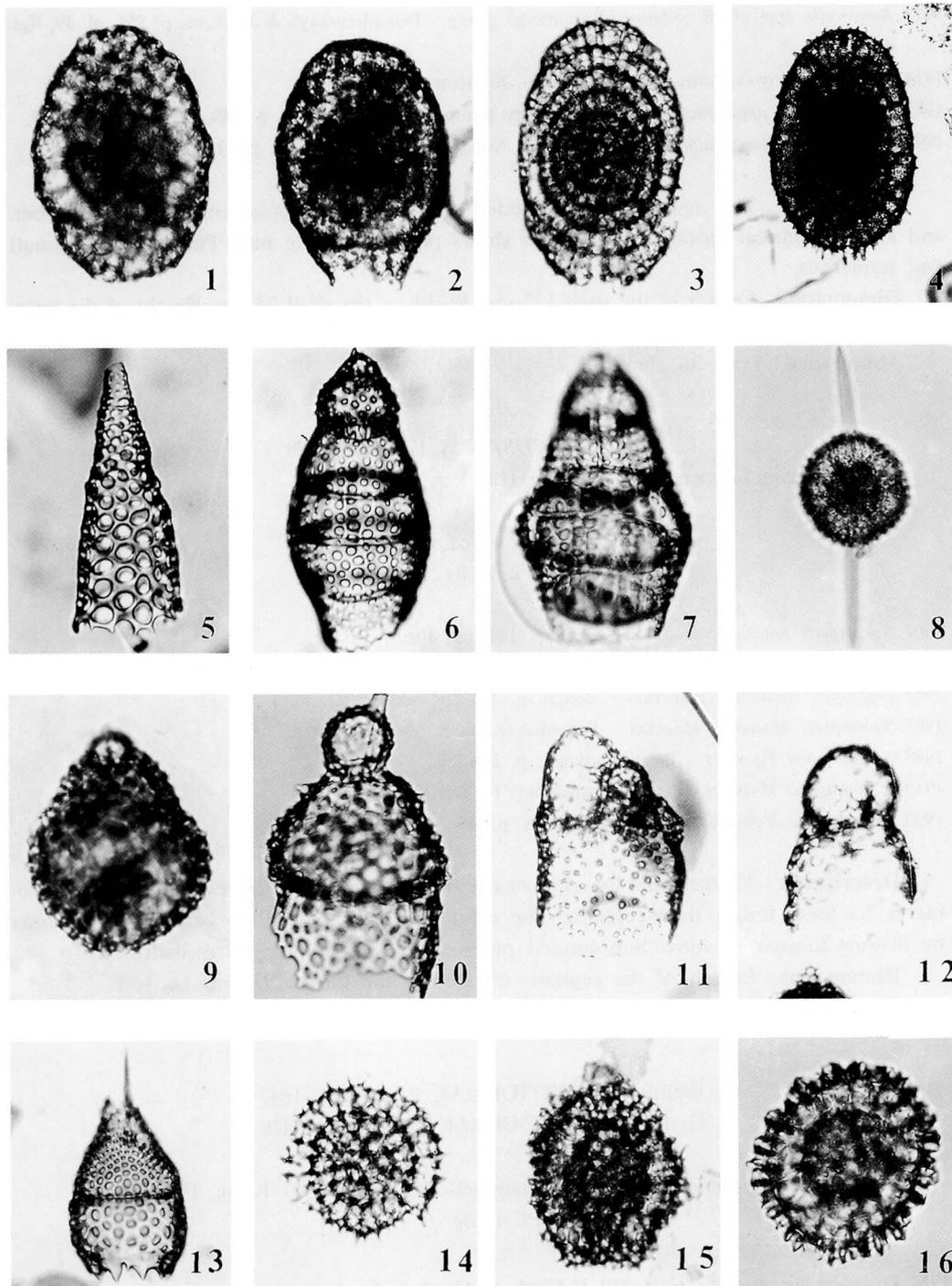
Botryopyle dictyocephalus Haeckel, 1887

Pl. 1, fig. 11 ; Pl. 3, fig. 11

PLATE 3

Fig.1 : *Larcopyle bütschlii* X260 : SD4. **Fig.2** : *Prunopyle titan* X210 : SD6. **Fig.3** : *Spongurus* sp.A X260 : SD1. **Fig.4** : *Spongurus* sp.B X270 : SD7 **Fig.5** : *Cornutella profunda* X260 : SD8. **Fig. 6** : *Eucyrtidium cienkowskii* X260 : SD3. **Fig.7** : *E. calvertence* X260 : SD4. **Fig.8** : *Axprunum angelinum* X170 : SD3. **Fig.9** : *Cyrtocapsella japonica* X260 : SD1. **Fig.10** : *Theocorys re-dondoensis* X270 : SD6. **Fig.11** : *Botryopyle dictyocephalus* X300 : SD7. **Fig.12** : *Antarctissa robusta* X300 : SD1. **Fig.13** : *Lamprocyclas maritalis* X200 : SD3. **Fig.14** : *Lithelius minor* X330 : SD11. **Fig.15** : *Larcopyle bütschlii* X260 : SD9. **Fig.16** : *Lithelius foremanae* X260 : SD4.

PLATE 3



- 1887 *Botryopyle dictyocephalus* - Haeckel, p. 1113, pl. 96, fig. 6.
 1971 *B. dictyocephalus* Haeckel group - Riedel & Sanfilippo, p. 1602, pl. 1J, figs. 21-26, pl. 2J, figs. 16-18, pl. 3f, figs. 9-12.
 1972 *Botryocella* spp. aff. *B. cribrosa* (Ehrenberg) group - Petrushevskaya & Koslova, p. 554, pl. 39, figs. 4-6.
 1974 *Botryopyle dictyocephalus* Haeckel group - Johnson, pl. 6, fig. 6.
 1975 *Botryocella(?) appeninica* vinassa de Regny group - Petrushevskaya, p. 589, pl. 13, figs. 16, 23.
 1992 *Botryopyle dictyocephalus* Haeckel group - Atsushi Takemura, p. 743, pl. 3, fig.7.

Description : This species group included all forms with a large antecephalic chamber, and a subcylindrical thorax. The skeleton shows perforated plate wall. Pores are very small and numerous.

Dimensions : Length of the shell 127 μm , Width of the shell 95 μm , Height of the antecephalic lobe 55 μm ; of the postcephalic lobe 36 μm .

Abundance : Trace to common

Genus *SACCOSPYRIS* Haecker, 1908

Type species : *Saccospyris antarctica* Haecker, 1907

Saccospyris antarctica Haecker, 1907

Pl. 2, fig. 5

- 1907 *Saccospyris antarctica* n.sp. - Haecker, p. 124, fig. 10a,b.
 1908 *S. antarctica* - Haecker, p. 447-448, pl. 84, figs. 584, 589, 590.
 1958 *Botryopyle antarctica*(Haecker) - Riedel, p. 224-226, text-fig. 13, pl. 4, fig. 12.
 1965 *Saccospyris antarctica* Haecker - Petrushevskaya, p. 96-98, fig. 10.
 1968 *S. antarctica* Haecker - Petrushevskaya, p. 149-150.
 1975 *S. antarctica* Haecker,- Petrushevskaya, pl. 13, figs. 21,28.
 1990 *S. antarctica* Petrushevskaya - Abelman, p. 697.

Description : Antecephalic lobe has nearly the same height as the encephalic lobe. Thorax is 1.5 times longer than cephalis. The whorl shell is divided into cephalis and thorax by distinct lumbar stricture. Subrounded pores are large and irregularly distributed.

Dimensions : Length of the cephalis 65 μm ; of the thorax 93 μm .

Abundance : Trace

Family EUCYRTIDIIDAE Ehrenberg, 1847

Genus *LYCHNOCANOMA* Ehrenberg, 1847b

Lychnocanoma grande (Campbell & Clark, 1944) Kling, 1973

Pl. 1, fig. 6

- 1944 *Lychnocanium grande* - Campbell & Clark, p. 42, pl. 6, fig. 3-6

1973 *Lychnocanoma grande* (Campbell & Clark) comb.nov. - Kling, p. 637, pl. 10, figs.10–14

1985 *Lychnocanoma grande* (Campbell & Clark) - Pérez-Guzmán, p. 332, pl. 2, fig. 5

Description : Cephalis is separated from thorax by clear constriction. Cephalis has an apical spine and small pores. Thorax possessed three, and eight or nine pores on the thorax between two feet. Feet are three-edged, nearly straight. Pedestal is not present.

Dimensions : Width of the thorax 119 μm , length of the shell (including with apical spine and basal feet) 192 μm .

Abundance : Trace

Family PLAGONIIDAE Haeckel,1881, emend. Riedel,1967b

Genus ANTARCTISSA Petrushevskaya,1967

Type species : *Lithobotrys denticulata* Ehrenberg, 1844

Antarctissa robusta Petrushevskaya, 1975

Pl. 3, fig. 12

1975 *Antarctissa robusta* n.sp. - Petrushevskaya, pl. 11, figs. 21–22.

1975 ? *A. equiceps* (Campbell & Clark) sensu- Petrushevskaya, pl. 11,figs. 23-25.

1975 *A. antedenticulata* - Chen, pl. 18, figs. 1–2.

1989 *A. robusta* - Lazarus & Pallant, pl. 1, figs. 20–22.

1990 *A. robusta* - Abelmann, p. 694, pl. 4, figs. 10a,b.

1990 *A. robusta* - Lazarus, p. 714, pl. 3, figs. 6,7.

Description : Cephalis and thorax are approximately equal-sized. Irregular hemispherical cephalis has scattered small pores with hyaline surface. External feet or spines are not present.

Abundance : Trace to rare

Antarctissa strelkovi Petrushevskaya,1967

Pl. 1, fig. 9 ; Pl. 4, fig. 13

1908 *Helotholus histricosa sensu* - Popofsky, p. 278, pl. 32, fig. 1–5, pl. 36, fig.2.

1958 *H. histricosa* - Riedel, p. 234, pl. 3, fig. 8.

1967 *Antarctissa strelkovi* n.sp. - Petrushevskaya, p. 89, pl. 51, fig. 3–6.

1975 *A. strelkovi* - Petrushevskaya, p. 591, pl. 18, fig. 5

1979 *A. strelkovi* - Petrushevskaya, Nigrini & Moore. N5, pl. 18, fig. 2b, pl. 18, fig. 2a

1990 *A. strelkovi* - Lazarus, p. 713, pl. 3, figs. 13–15.

Description : The first segment is separated from the second by a slight constriction. The ratio of cephalis width to thorax width is 1 : 1.73. Pores on both segments are rounded, and randomly distributed ; their sizes vary greatly. On the surface thorns are present.

Dimensions : Length of the cephalis 36 μm , it width 47 μm , Length of the thorax 63

µm, width 79 µm, overall length of the shell is up to 99 µm.

Abundance : Rare

Genus *LITHOMELISSA* Ehrenberg, 1847, emend. Petrushevskaya, 1971a

Type species : *Lithomelissa microptera* Ehrenberg, 1854a, pl. 36, fig. 2

Lithomelissa stigi Bjorklund, 1976

Pl. 4, fig. 11

1976 *Lithomelissa stigi* n.sp. - Bjorklund, p. 1125, pl. 15, figs. 12–17.

Description : Cephalis is small, approximately one-third of the thorax diameter. Thorax form is campanulate with large rounded pores. Cylindrical vertical and apical spines are well developed, and lateral spines do not pierce the thoracic wall.

Dimensions : Width of cephalis 44 µm ; of thorax 142 µm, Height of cephalis 33 µm ; of thorax 66 µm ; of test 113 µm, Length of apical spine 15 µm.

Abundance : Trace to few

Family PTEROCORYTHIDAE Haeckel 1881, emend. Riedel 1967b

Genus *GONDWANARIA* Petrushevskaya, 1975

Type species : *Sethoconus(?) dogeli* Petrushevskaya, 1967, pl. 53, fig. 1,2

Gondwanaria japonica (Nakaseko, 1963) group, Petrushevskaya, 1975

Pl. 1, fig. 4

1963 *Sethocyrtis japonica* - Nakaseko, p. 176, pl. 1, fig. 10, fig. 6.

1973 *S. japonica* - Nakaseko & Suchano, pl. 3, fig. 2.

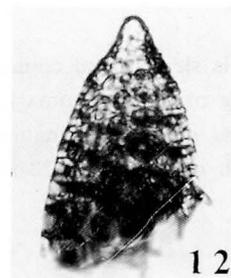
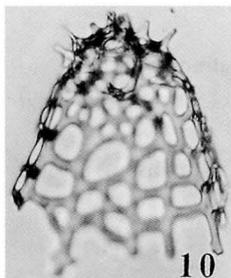
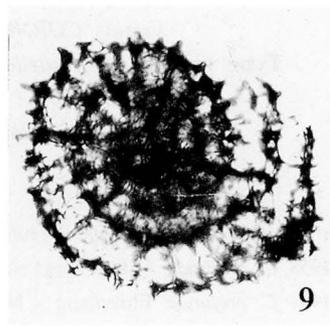
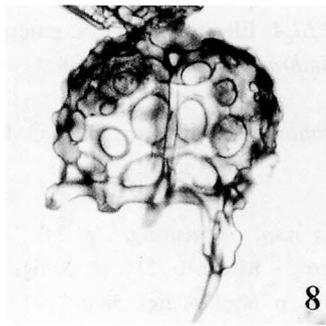
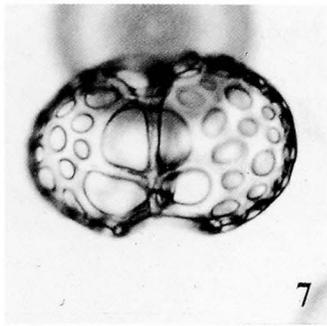
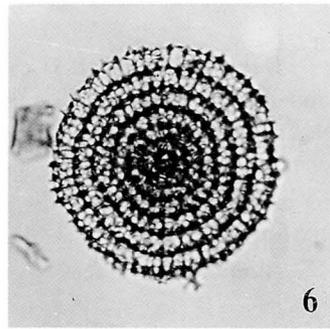
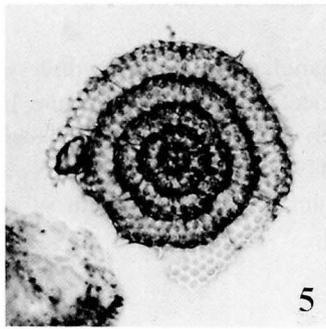
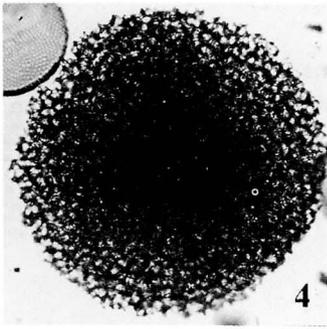
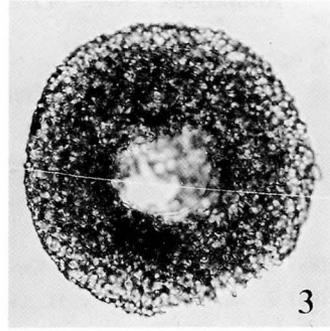
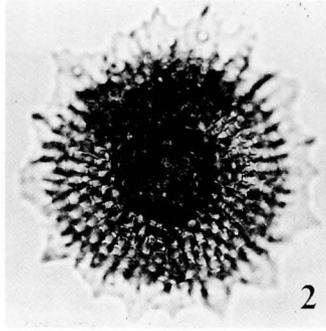
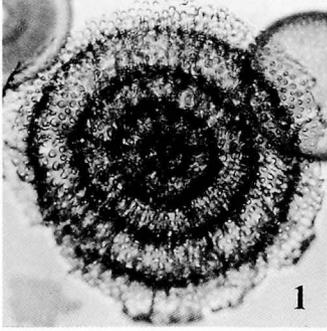
1975 *Gondwanaria japonica* (Nakaseko) comb.nov. - Petrushevskaya, p. 584, pl. 8, fig. 15, pl. 9, figs. 2–7, pl. 12, fig. 1.

1990 *G. japonica* (Nakaseko) group - Abelman, p. 697, pl. 7, fig. 3A,B

PLATE 4

Fig.1 : *Circodiscus microporus* X210 : SD9. **Fig.2** : *Periphaena decora* X200 : SD3. **Fig.3** : *Spongopyle osculosa* X200 : SD3. **Fig.4** : *Spongodiscus maculatus* X260 : SD6. **Fig.5** : *Stylodictya aculeata* X300 : SD1. **Fig.6** : *Stylodictya validispina* X270 : SD11. **Fig.7** : *Liriospyris mutuaria* X300 : SD11. **Fig.8** : *Triceraspyris antarctica* X360 : SD6. **Fig.9** : *Lithelius nautiloides* X370 : SD 5. **Fig.10** : *Ceratocyrtis histicosus* X260 : SD3. **Fig.11** : *Lithomelissa stigi* X300 : SD3 **Fig.12** : *Peripyramis circumtexta* X260 : SD11. **Fig.13** : *Antarctissa strelkovi* X310 : SD3.

PLATE 4



Description : Cephalis is global, with stout apical spines. Neck and secondary spines are well developed. Thorax is nearly conical, and pores are irregularly arranged.

Dimensions : Length of the shell 106 μm ; of the cephalis 30 μm ; of the thorax 57 μm .

Abundance : Rare to Few

Genus *LAMPROCYCLAS* Haeckel, 1881

Lamprocyclus maritalis Haeckel group, 1887

Pl. 1, fig. 10 ; Pl. 3, fig. 13

1887 *Lamprocyclus maritalis* n.sp. - Haeckel, p. 1390, pl. 74, figs. 13, 14

1967 *L. maritalis maritalis* Haeckel - Nigrini, p. 74, pl. 7, fig. 5

1979 *L. maritalis maritalis* Haeckel - Nigrini & Moore, N75, pl. 25, fig. 4

1984 *L. maritalis* Haeckel group - Nigrini & Lombardi, N163, pl. 30, figs. 1a, b

Description : Shell is campanulate, divided into three segments. Cephalis is cylindrical and quadrangular with stout apical spine. Collar stricture is distinct. Subterminal teeth on the abdomen just above the peristome are conical or thorn-like.

Dimensions : Total length 119–173 μm , Length of cephalis 27–36 μm ; of thorax 45–63 μm ; of a abdomen 45–72 μm , Maximum breadth of thorax 81–90 μm ; of abdomen 100–128 μm .

Abundance : Trace

Family THEOPERIDAE Haeckel, 1881, emend. Riedel, 1967b

Genus *CORNUTELLA* Ehrenberg, 1838, emend. Nigrini, 1967

Type species : *Cornutella clathrata* Ehrenberg, 1838

Cornutella profunda (Ehrenberg, 1854a) Riedel, 1958

Pl. 3, fig. 5

1854a *Cornutella clathrata* β *profunda* n.sp. - Ehrenberg, . p. 241

1958 *C. profunda* (Ehrenberg) stat.nov. - Riedel, p. 232, pl. 3, figs. 1, 2.

1967 *C. profunda* Ehrenberg - Nigrini, p. 60, pl. 6, figs. 5a-c

1972 *C. profunda* (Ehrenberg) - Petrushevskaya & Koslova, p. 551, pl. 30, figs. 18–19.

1984 *C. profunda* Ehrenberg - Nigrini & Lombardi, N93, pl. 22, fig. 1

Description : Shell is slender and conical with smooth surface. Hyaline cephalis is sometimes indistinguishable or small. Thorax is sharply conical with variable number of regularly arranged subcircular pores. Termination is ragged.

Dimensions : Length of cephalis 7–20 μm ; of thorax 110–200 μm , Maximum breadth 45–65 μm .

Abundance : Trace

Genus *CYRTOCAPSELLA* Haeckel, 1887, emend. Sanfilippo & Riedel, 1970

Type species : (designated by Campbell, 1954, p. 143) *Cyrtocapsa tetrapera* Haeckel, 1887, p. 1512, pl. 78, fig. 5

Cyrtocapsella cornuta (Haeckel, 1887), Sanfilippo & Riedel, 1970

Pl. 2, figs. 7-8

1887 *Cyrtocapsa* (*Cyrtocapsella*) *cornuta* n.sp. - Haeckel, p. 1513, pl. 78, fig. 9

1970 *Cyrtocapsella cornuta* (Haeckel) comb. nov. - Sanfilippo & Riedel, p. 453, pl. 1, figs. 19-20

1973 *C. cornuta* (Haeckel) - Kling, p. 636, pl. 11, figs. 16-18

1984 *C. cornuta* Haeckel - Nigrini & Lombardi, N101, pl. 23, fig. 1

Description : Shell is pyriform, composed of four-segmented. Cephalis is spherical with a few small pores. In general, short apical horn is present. Collar stricture is pronounced. Thorax is small inflated conical, separated from the much wider third segment by a very pronounced change in contour. Third segment is truncate-hemispherical and fourth segment is inverted-hemispherical.

Dimensions : Total length (excluding horn) 173 μm . Length of second segment 27 μm ; of third segment 59 μm ; of fourth segment 55 μm , Maximum breadth 132 μm .

Abundance : Trace to rare

Cyrtocapsella japonica (Nakaseko, 1963)

Pl. 3, fig. 9

1963 *Eusyringium japonica* n.sp. - Nakaseko, p. 193, text-figs 20-21, pl. 4, figs. 1-3.

1970 *Cyrtocapsella japonica* (Nakaseko) Comb. nov. - Sanfilippo & Riedel, p. 452, pl. 1, figs. 13-15.

1984 *C. japonica* (Nakaseko) - Nigrini & Lombardi, N107, pl. 23, figs. 4a-c

Description : Shell consists of three segments with a constricted mouth. Cephalis is spherical with a few small circular pores and a short apical horn. Collar stricture is not distinct in contour, because base of cephalis is generally enclosed in the thoracic wall. Pores of thorax and abdomen are generally regular in size and arrangement.

Dimensions : Total length 135 μm , Length of cephalis 11 μm ; of the thorax 33 μm ; of the abdomen 87 μm .

Abundance : Trace

Cyrtocapsella tetrapera (Haeckel, 1887), Sanfilippo & Riedel, 1970

Pl. 2, fig. 9

1887 *Cyrtocapsa tetrapera* Haeckel, p. 1512, pl. 78, fig. 5

1970 *Cyrtocapsella tetrapera* n.sp. Haeckel - Sanfilippo & Riedel, pl. 1, figs. 16-18.

1970 ?*C. cornuta* Haeckel - Sanfilippo & Riedel, pl. 1, fig. 19.

- 1970 ?*C. elongata* (Nakaseko) - Sanfilippo & Riedel, pl. 1, figs. 11–12.
 1970 ?*C. japonica* (Nakaseko) - Sanfilippo & Riedel, pl. 1, figs. 13–15.
 1975 ?*Lithocampe* (*Cyrtocapsella*) *cylindroides* Principi - Petrushevskaya, pl. 4, figs. 14–15.
 1975 *Cyrtocapsella tetrapera* Haeckel - Chen, pl. 20, fig. 1.
 1985 *C. tetrapera* Haeckel - Pérez-Guzmán, p. 332, pl. 2, fig. 3.
 1989 *C. tetrapera* Haeckel - Lazarus & Pallant, pl. 360, pl. 3, figs. 7,13.

Description : Shell has four or five segments, with rounded termination. Cephalis is spherical, and possesses a short apical horn. Collar stricture is moderately pronounced. Thorax is conical to hemispherical ; third segment is annular ; fourth segment is hemispherical with a strongly constricted mouth. In some specimens, a more delicate fifth segment is present.

Dimensions : Total length(excluding horn and fifth segment) 207 μm , Length of second segment 32 μm ; of third segment 44 μm ; of fourth segment 49 μm ; of fifth segment 59 μm , Maximum breadth 103 μm .

Abundance : Trace

Genus *EUCYRTIDIUM* Ehrenberg, 1847, emend. Nigrini, 1967

Type species : *Lithocampe acuminata* Ehrenberg, 1844

Eucyrtidium calvertense Martin, 1904

Pl. 3, fig. 7

- 1904 *Eucyrtidium calvertense* n.sp. - Martin, p. 450, pl. 130, fig. 5.
 1965 *E. calvertense* Martin - Hays, p. 181, pl. 3, fig. 4.
 1970 *E. calvertense* Martin - Hays, p. 213, pl. I, fig. 6
 1973 *E. calvertense* Martin - Kling, p. 636, pl. 4, fig. 16,18,19 ; pl. 11, fig. 1–15
 1975 *E. calvertense* Martin - Chen, p. 495, pl. 15, fig. 9.
 1976b *E. calvertense* Martin - Weaver, p. 121, pl. 3, figs. 1,2.
 1990 *E. calvertense* Martin - Abelman, p. 696, pl. 6, figs. 4, 5a-5c.
 1990 *E. calvertense* Martin - Lazarus, p. 716, pl. 6, figs. 4-6.

Description : Shell consists of 5–6 segments. Cephalis is hemispherical and has shorter conical spines. Thorax is conical with subcircular pores, arranged in longitudinal rows. Abdomen is conical, which has longitudinal rows of pores. Fourth segment is widest and short. Fifth segment decreased in width. Open mouth exists.

Dimensions : Length of the shell 168 μm , Width of the shell 109 μm .

Abundance : Trace to few

Eucyrtidium cienkowskii Haeckel group, 1887

Pl. 1, fig. 8 ; Pl. 3, fig. 6

- 1887 cf. *Eucyrtidium cienkowskii* n.sp. - Haeckel, p. 1493, pl. 80, fig. 9.

- 1927 *cf. Dictyomitra multicosata* - Lucchese, p. 106, pl. 8, fig. 8.
 1973 *Eucyrtidium cienkowskii* Haeckel group - Sanfilippo, Burckle, Martini & Riedel, p. 221, pl. 5, fig. 7-11.
 1975 *E. cienkowskii* Haeckel group - Chen, p. 495, pl. 15, fig. 7.
 1976b *E. cienkowskii* Haeckel group - Weaver, p. 121, pl. 9, fig. 4, pl. 11, fig. 7.
 1990 *E. cienkowskii* Haeckel group - Abelmann, p. 696, pl. 6, figs. 3a-ad.
 1990 *E. cienkowskii* Haeckel group - Lazarus, p. 716, pl. 6, figs. 1-3.

Description : Shell is smooth and subconical, with six distinct strictures. Cephalis is hemispherical with a shorter apical horn. Pores on the cephalis is circular and regularly aranged in dense transverse rows. Thorax is small, with irregularly arranged pores. The rest segments are a crock form and fifth segments became narrower to the pole.

Dimensions : Length of the shell 133 μm ; of cephalis 16 μm ; of thorax 24 μm , Width of Maximum 69 μm .

Abundance : Trace to common

Genus *THEOCORYS* Haeckel, 1881

Type species : *Theocorys veneris* Haeckel, 1887, pl. 69, fig. 15

Theocorys redondoensis (Campbell & Clark, 1944), Kling, 1973

Pl. 1, fig. 5 ; Pl. 3, fig. 10

- 1944 *Theocyrtis (Theocorusca) redondoensis* n.sp. - Campbell & Clark, p. 49, pl. 7, fig. 4.
 1972 *T. redondoensis* Campbell & Clark - Casey et al., pl. 2, fig. 3.
 1973 *Theocorys redondoensis* (Campbell & Clark) comb.nov. - Kling, p. 638, pl. 11, figs. 26-28.
 1975 *T. redondoensis* (Campbell & Clark) - Chen, p. 505, pl. 20, figs. 2,3.
 1976b *T. redondoensis* (Campbell & Clark) - Weaver, p. 125, pl. 2, fig. 10, pl. 10, figs. 1,2.
 1981 *T. redondoensis* (Campbell & Clark) - Weaver et al., p. 82, pl. 2, figs. 1-2.
 1984 *T. redondoensis* (Campbell & Clark) - Nigrini & Lombardi, p. 143, pl. 26, fig. 4. 1985 *T. redondoensis* (Campbell & Clark) - P rez-Guzm n, p. 332, pl. 2, fig. 8.

Description : Shell possesses two sharp strictures. Cephalis is distinctly globular and neck is distinct. Pores on the cephalis are very tiny. Abdomen is cylindrical and has open termination. Pores on the abdomen are arranged irregularly.

Dimensions : Length of total 173 μm ; of cephalis 41 μm ; of thorax 64 μm ; of abdomen 64 μm , Maximum width 105 μm .

Abundance : Trace to rare

Family TRIOSPYRIDIDAE Haeckel, 1882

Genus *DESMOSPYRIS* Haeckel, 1881

Type species : *Desmospyris mammilata* Haeckel, 1887, pl. 83, fig. 14

Desmospyris spongiosa Hays, 1965

Pl. 2, fig. 4

- 1965 *Desmospyris spongiosa* n.sp. - Hays, p. 173, pl. 11, fig. 1.
 1972 *D. spongiosa* - Keany & Kennett, p. 539, fig. 4, no. 12-13.
 1973b *D. spongiosa* - Petrushevskaya, pl. 3, fig. 22.
 1973 *D. spongiosa* - Petrushevskaya, p. 593, pl. 8.
 1990 *D. spongiosa* - Lazarus, p. 716, pl. 4, figs. 9-11.

Description : The walls are spongy and thick. Cephalis and thorax are nearly of same width. Surface is rough by small papillae. Pores of main wall are intertwined.

Dimensions : Length of the shell 132 μm , Width of the shell 106 μm .

Abundance : Trace to common

Genus *TRICERASPYRIS* Haeckel, 1881

Type species : *Triceraspyris giraffa* Haeckel, 1887, pl. 84, fig. 11.

Triceraspyris antarctica Haecker, 1908

Pl. 2, fig. 6 ; Pl. 4, fig. 8

- 1907 *Phormospyris antarctica* Haeckel, p. 124, fig. 9.
 1908 *Triceraspyris antarctica* n.sp. - Haecker, p. 445, pl. 84, fig. 586.
 1908 *Tripospyris bicornis* - Popofsky, p. 269, pl. 30, fig. 6.
 1908 *T. biloculata* - Popofsky, p. 269, pl. 30, fig. 7.
 1958 *T. antarctica* - Riedel, p. 230, pl. 2, fig. 6,7.
 1965 *T. antarctica* - Petrushevskaya, p. 1121, fig. 1.
 1967 *T. antarctica* - Petrushevskaya, p. 65, pl. 37, fig. 1-3.
 1975 *T. antarctica* - Petrushevskaya, p. 593, pl. 8, fig. 1.

Description : Lattice shell has three pairs of sagittal-lattice pores. The surrounding pores are rounded and of irregular size and . This species possesses approximately three weak feet.

Dimensions : Width of the shell 98 μm , length of feet 46 μm .

Abundance : Trace

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포항분지의 두호층에서 산출된 방산층

박 영 숙*, 이 종 덕*, 윤 혜 수**

*전북대학교 지구환경과학과 **충남대학교 지질학과

요 약

포항 청하면 소동리 지역에 분포하는 두호층 단면에서 채취된 11개의 시료에서 총 62속 103종의 방산층이 추출, 감정되었다. 이들의 보존은 양호한 편이며, 방산층과 더불어 규편모조류, 에브리디안, 해면동물의 침이 다량으로 수반되어 나타났으나 본 논문에서는 연구되지 않았다.

이지역의 방산층 화석군은 Cold-water taxa가 단연우세하게 나타나는데, 이에 속하는 종들은 다음과 같다. ; *Botryopyle dictyocephalus*, *Lithelius minor*, *Spongopyle osculosa*, *Stylo-dictya validispina*, *Antarctissa strelkovi*, *Saccospyris antarctica*, *Peripyramis circumtetxa*, *Trice-raspyris antarctica*. 이로 미루어보아 이지역의 두호층은 한류의 영향을 주로 받았음을 알 수 있다.

층서적으로는 *Cyrtocapsella tetrapera*의 마지막 출현 (LAD)을 근거로 하여 해석할 때 소동리 지역의 두호층은 Late Middle Miocene (11.95 Ma : Theyer et al.1978)보다 젊지는 않다고 할 수 있다.

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