

RADIOLARIAN FAUNAS FROM THE HAGJEON FORMATION (MIDDLE MIOCENE) IN THE SOUTHERN POHANG BASIN, KOREA

Young suk BAK*, Jong Deock LEE* and Hyesu YUN**

*Department of Earth & Environmental Sciences, Chonbuk National University, Jeonju 561-756

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

Abstract : The radiolarian fossils of 42 species belonging to 29 genera are identified from the Hagjeon Formation of the Bomun area near Gyeongju. Generally cold-water species such as *Lithelius minor*, *Lithelius nautiloides*, *Spongodiscus maculatus*, *Spongopyle osculosa*, and *Stylodictya validispina* occur abundantly, whereas warm-water species belonging to *Collosphaera* are suppressed.

Compared with the assemblage from the Duho Formation the fauna of the Hagjeon Formation contains more species of shallow-water radiolaria indicating the Hagjeon Formation of the study area is deposited in the water shallower than 200 m.

INTRODUCTION

Little has been known on the Tertiary Radiolarians from the Pohang Basin (Kim 1965, Bak et al. 1996). However, recent studies suggest possibility of the abundant radiolarian preservation, and its high applicability in biostratigraphy and paleoenvironment of the Pohang Basin (Bak et al. 1996). Samples collected from the Bomun area also yield abundant, well-preserved radiolarian assemblages which are different from those of the Duho Formation from the Sodingri area, northern part of the Pohang Basin.

Therefore, this study aims to describe Middle Miocene radiolarian fossils collected from the Hagjeon Formation in the Bomun area, and to interpret radiolarian stratigraphy and paleoenvironment for the Pohang Tertiary Basin.

MATERIAL AND METHODS

Thirteen samples were collected from five localities in the Bomun area near Gyeongju. The sampling sites are all in the Hagjeon Formation that consists of marine clastic sediments such as sandstone and mudstone occasionally intercalated by thin conglomerate layers (Fig. 1).

For radiolaria about 10 grams of dry samples are processed. Each samples are treated by the hydrogen peroxide and 10% solution of hydrochloric acid. The residues washed three times with the distilled water are sieved with 250 μ m and 63 μ m. Radiolaria are smeared with mounting medium on glass slide. They are photographed with transmitted-light microscope at a magnification of X 150. The detailed preparation procedures are referred to Bak et al. (1996).

The radiolarian abundance observed in each examined slide was represented as followings; A: abundant (> 26 specimens), C: common (11 - 25 specimens), F: few (6 - 10 specimens), R: rare (2 - 5 specimens), T: trace (1 specimen).

RESULTS

A total 42 species belonging to 29 genera are identified for the first time from the Hajeon Formation in the Bomun area (Table 1). Radiolarian fossils are encountered in all samples. Generally they are well preserved, although some specimens show indication of chemical weathering.

The dominant species are *Actinomma* spp., *Arachnocorallium* spp., *Carpocanarium* spp., *Drupptractus irregularis*, *Drupptractus nanus*, *Larcopyle buetschlii*, *Lithelius minor*, *Lithelius nautiloides*, *Lithomitra lineata*, *Spongodiscus maculatus*, *Spongodiscus* spp., *Spongopyle osculosa*, *Spongurus* sp. A, and *Spongurus* sp. B (Table 2).

Qualitative species composition in the Hajeon Formation of the Bomun area is nearly the same as in the Duho Formation of the Sodongri area (Bak et al. 1996). However, both assemblages are quantitatively different from each other.

Among the assemblage of the Hajeon Formation the cosmopolitan species is predominant. Generally, number of the cold-water species such as *Lithelius minor*, *Lithelius nautiloides*, *Spongodiscus maculatus*, *Spongopyle osculosa*, and *Stylocdictya validispina* is higher than the warm-water ones. The warm-water elements are mostly species belonging to *Collosphaera*.

The deep-water dweller species such as *Cornutella profunda* and *Peripyramis circumtexta* (Gupta 1992) are absent in the study area, whereas they occur abundantly in the Duho Formation of the Sodongri area (Bak et al. 1996). *Conutella profunda* is a good indicator of Subarctic intermediate fauna zone (Equator >900m to Arctic >200m) in the Pacific sediments, and *Peripyramis circumtexta*

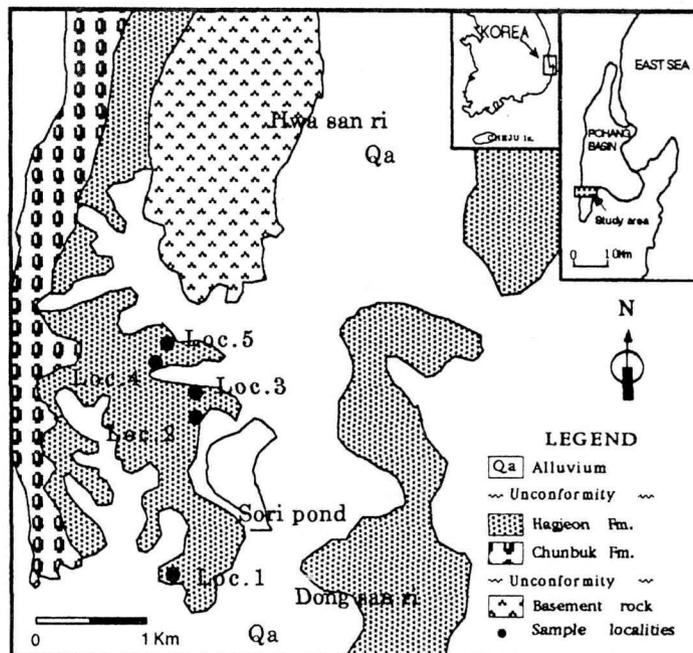


Figure 1. Geologic map of the Bomun area with sample localities. (after Yun 1986)

is present in the Transitional central fauna zone (0-40°N, 200-700m; Casey 1971). Therefore, the Hagjeon Formation of the Bomun area is considered to be deposited in water shallower than 200 m.

SYSTEMATIC DESCRIPTION

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

Genus ACTINOMMA Haeckel, 1862, emend. Nigrini, 1967c

Type species: *Haliomma trinacrium* Haeckel, 1860

Actinomma spp.

Pl. 2, fig. 17.

Description: This species is characterized by medullary and cortical shells, which are spherical to subspherical. These shells are joined by 7-12 connector beams. Conical accessory spines are observed on the outer surface of the cortical shell. But, some specimens have not spines.

Occurrence: SR4; T, SR6; T, SR9; F, SR11; R, SR13; R.

Genus LITHATRACTUS Haeckel, 1887

Lithatractus timmsi Campbell and Clark, 1944

Pl. 1, fig. 7.

1944 *Lithatractus timmsi* n. sp.-Campbell & Clark, p. 19, pl. 2, fig. 19

1986 *Lithatractus timmsi* -Campbell & Clark, Mullineaux & Westberg-Smith, p. 64, pl. 1, fig. 4

Description: Shell is ovate and has two polar spines whose length are different. Bladed polar spine clusters are on one polar end. The other polar spine is long stout, and three-bladed. Those spines are stretched out from the innermost. Onepear -shaped medullary shell is found. Pores are rounded and irregular-sized .

Occurrence: SR10; T, SR11; T.

Family LIHTELIIDAE Haeckel, 1862

Genus LARCOPYLE Dreyer, 1889

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

Larcopyle buetschlii Dreyer, 1889

Pl. 1, figs. 8-9: Pl. 2, figs. 4-5.

1889 *Larcopyle buetschlii* n.sp. - Dreyer, p. 12, pl. 10, fig. 70.

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

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

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

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

Remarks: This species is predominant in the Hagjeon Formation of the Bomun area and the Duho Formation of the Sodongri in Pohang basin. *L. buetschlii* is characterized by irregular outline

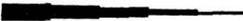
Table 1. Occurrence chart of the radiolarians from Bomun area.

Formation		Hagjeon Fm.												
Localities		LOC.1			L.2	LOC.3			LOC.4		LOC.5			
Species	Sample No.	SR1	SR2	SR3	SR4	SR5	SR6	SR7	SR8	SR9	SR10	SR11	SR12	SR13
<i>Actinomma</i> spp.					T		T			F		R		R
<i>Antarctissa robusta</i>			T			C	T	R		R				
<i>Arachnocorallium</i> spp.					T	R	F	F		F		F		R
<i>Carpocanarium</i> spp.						T				R	R			R
<i>Ceratocyrtis cucularis</i>							R	T						T
<i>Ceratocyrtis historicosus</i>						R				R				
<i>Ceratocyrtis</i> spp.												T		T
<i>Circodiscus microporus</i>													T	
<i>Collosphaera</i> spp.								T				T		
<i>Cyrtocapsella tetrapera</i>										F		R	T	
<i>Cyrtocapsella</i> spp.										R	T			
<i>Desmospyris</i> spp.										T	T		T	
<i>Dorydiscus</i> spp.						T				T	T			
<i>Drupptractus irregularis</i>						R		R		T	T			
<i>Drupptractus nanus</i>						R		R	F	T	T		R	
<i>Gondwanaria japonica</i>										T	R		T	
<i>Larcopyle buetschlii</i>						F						R		
<i>Larcospira minor</i>														R
<i>Liriospyris mutuaria</i>										T				
<i>Lithatractus timmsy</i>											T	T		
<i>Lithelius formanae</i>										T				
<i>Lithelius minor</i>										T	R	R	R	
<i>Lithelius nautiloides</i>								R		T	R	R		
<i>Lithomelissa stigi</i>							T							
<i>Lithomelissa</i> spp.										R	T			
<i>Lithomitra lineata</i> group		T				F	F	C	T	T		T		R
<i>Prunopyle titan</i>											R			
<i>Prunopyle</i> spp.								T						
<i>Pseudocubus obeliscus</i>														T
<i>Saccospyris antarctica</i>						T	T							
<i>Spongodiscus maculatus</i>				R		T	T	F		R		R		T
<i>Spongodiscus</i> spp.					T	F	F	R						
<i>Spongopyle osculosa</i>			T			R				R				
<i>Spongotrochus</i> spp.						R								
<i>Spongurus</i> sp.A of Nigrini & Lombardi 1984								T	R	T			T	
<i>Spongurus</i> sp.B of Nigrini & Lombardi 1984								T	F	T	R		R	T
<i>Spongurus</i> spp.					R	T	R	R		R				
<i>Stylodictya aculeata</i>						T				T				
<i>Stylodictya valdispina</i>														R
<i>Styptosphaera spumacea</i>												T	T	
<i>Theocorys</i> spp.										R				
<i>Zygocircus productus tricarinatus</i>									T					

Table 2. Stratigraphic range chart of the radiolarians from Bomun area.

Epoch		Middle Miocene													
Localities		LOC.1				L.2	LOC.3				LOC.4		LOC.5		
Species	Sample No.	SR1	SR2	SR3	SR4	SR5	SR6	SR7	SR8	SR9	SR10	SR11	SR12	SR13	
<i>Lithomitra lineata</i> group															
<i>Antarctissa robusta</i>															
<i>Spongopyle osculosa</i>															
<i>Spongodiscus maculatus</i>															
<i>Actinomma</i> spp.															
<i>Arachnocorallium</i> spp.															
<i>Spongodiscus</i> spp.															
<i>Spongurus</i> spp.															
<i>Carpocanarium</i> spp.															
<i>Ceratocyrtis historicosus</i>															
<i>Dorydiscus</i> spp.															
<i>Drupptractus irregularis</i>															
<i>Drupptractus nanus</i>															
<i>Larcopyle buetschlii</i>															
<i>Saccospyris antarctica</i>															
<i>Spongotrochus</i> spp.															
<i>Stylodictya aculeata</i>															
<i>Ceratocyrtis cucullaris</i>															
<i>Lithomelissa stigi</i>															
<i>Prunopyle</i> spp.															
<i>Spongurus</i> sp.A of Nigrini & Lombardi 1984															
<i>Spongurus</i> sp.B of Nigrini & Lombardi 1984															
<i>Collosphaera</i> spp.															
<i>Lithelius nautiloides</i>															
<i>Zygocircus productus tricarinatus</i>															
<i>Cyrtocapsella tetrapera</i>															
<i>Cyrtocapsella</i> spp.															
<i>Desmospyris</i> spp.															
<i>Gondwanaria japonica</i>															
<i>Liriospyris mutuarua</i>															
<i>Lithelius formanae</i>															
<i>Lithelius minor</i>															
<i>Lithomelissa</i> spp.															
<i>Prunopyle titan</i>															
<i>Theocorys</i> spp.															
<i>Lithatractus timmsy</i>															
<i>Ceratocyrtis</i> spp.															
<i>Styptosphaera spumacea</i>															
<i>Circodiscus microporus</i>															
<i>Larcospira minor</i>															
<i>Pseudocubus obeliscus</i>															
<i>Stylodictya validispina</i>															

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and internal spiral structure.

Occurrence: SR5; F, SR11; R.

Genus *LITHELIUS* Haeckel, 1860

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

Lithelius foremanae Sanfilippo & Riedel, 1973

Pl. 2, fig. 8.

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

Remarks: This species is characterized by the cortical shell being well differentiated from the internal spiral, even though the two are joined.

Occurrence: SR9; T.

Lithelius nautiloides Popofsky, 1908

Pl. 2, fig. 1.

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, S137.

1984 *L. nautiloides* - Nigrini & Lombardi, S97, pl. 14, figs. 2a, 2b.

1990 *L. nautiloides* - Abelmann, p. 694, pl. 4, fig. 5.

Remarks: According to Petrushevskaya(1967), there is some doubt about the generic placement of this species since the type species(*L. spiralis* Haeckel, 1860) has a double spiral rather than a single one. Nigrini & Lombardi(1984) considered both single and double spiraled forms to be conspecific. In this paper, the specific forms proposed by Nigrini & Lombardi(1984) are accepted.

Occurrence: SR7; R, SR9; R, SR11; R.

Family SPONGODISCIDAE Haeckel, 1862, emend. Riedel, 1967

Genus *PRUNOPYLE* Dreyer, 1889

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

Prunopyle titan Campbell & Clark, 1944

Pl. 2, fig. 9.

1944 *Prunopyle titan* n.sp. - Campbell & Clark, p. 20, pl. 3, figs. 1 - 3.

1965 *P. titan* - Hays, p.173, pl. 2, fig. 4.

1972 *P. titan* - Keany & Kennett, p. 539, fig. 4.

1976 *P. titan* - Weaver, p. 578, fig. 6.

1990 *P. titan* - Abelmann, p. 693, pl. 3, fig. 16.

Remarks; Prunopyle titan is characterized by distinct osculum. This species has variable size. presence of several different sizes of individuals among specimens suggests influence of temperature upon shell formation (Campbell & Clark, 1944). But, rare in the Hageon Formation of Bomun area area.

Occurrence: SR9; R.

Genus *SPONGODISCUS* Ehrenberg, 1854

Type species: *Spongodiscus resurgens* Ehrenberg, 1854, p.246

Spongodiscus maculatus Clark & Campbell, 1944, emend. Blueford, 1988.

Pl. 1, figs. 2 - 3.

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

Remarks; *S. maculatus* is influenced by cool oceanographic currents (Blueford & White, 1984)

Occurrence: SR3; R, SR5; T, SR6; T, SR7; F, SR9; R, SR11; R, SR13; T.

Genus *SPONGOPYLE* Dreyer, 1889

Spongopyle osculosa Dreyer, 1889

Pl. 1, fig. 1; Pl. 2, 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. (?) osculosus* (Dreyer) - Petrushevskaya, p. 42, figs. 20 - 22

1979 *S. osculosa* Dreyer-Nigrini & Moore, S115, pl. 15, fig. 1

1984 *S. osculosa* Dreyer - Nigrini & Lombardi, S115, pl. 15, fig. 1

Remarks; This species is characterized by spongy biconvex lens with distinct margin and well-developed pylome.

Occurrence: SR2; T, SR5; R, SR9; R.

Genus *SPONGURUS* Haeckel, 1860

Type species: *Spongotrochus brevisspinus* Haeckel, 1862.

Spongotrochus spp.

Pl. 2, fig. 2.

Description; Shell is consist of large spongy structure and numerous radial beams. The spongy shell is discoidal and thickened in central region. The radial beams is difficulty in distinguishing. but,

These are arised from the thickend central part of spongy disc.

Occurrence: SR5; R, SR8; T.

Genus *STYLODICTYA* Ehrenberg,1847, emend. Petrushevskaya and Koslova,1972

Type species: *Stylodictya gracilis* Ehrenberg,1854.

Stylodictya aculeata Jorgensen, 1905

Pl. 2, figs. 6, 16.

1905 *Stylodictya aculeata* n.sp. - Jorgensen, 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 & Lombari, p.S69, pl. 10, figs. 1a, 1b.

1990 *S. aculeata* - Abelmann, p.693, pl. 3, fig. 9.

Remarks: This species differs from *S. validispina* Jorgensen, 1905 by possessing irregular concentric chambers, rose-like central structure and larger number of pores.

Occurrence: SR5; T, SR9; T.

Family SPONGURIDAE Haeckel,1862, emend. Petrushevskaya,1975

Genus *SPONGURUS* Haeckel, 1860

Type species: *Spongurus cylindricus* Haeckel,1860.

Spongurus sp. B Nigrini & Lombari, 1984

Pl. 1, fig. 10: Pl. 2, fig. 10.

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

Remarks: This species differs from *Spongurus* sp. A in having a regular outline, compact spongy tissue and concentric meshwork.

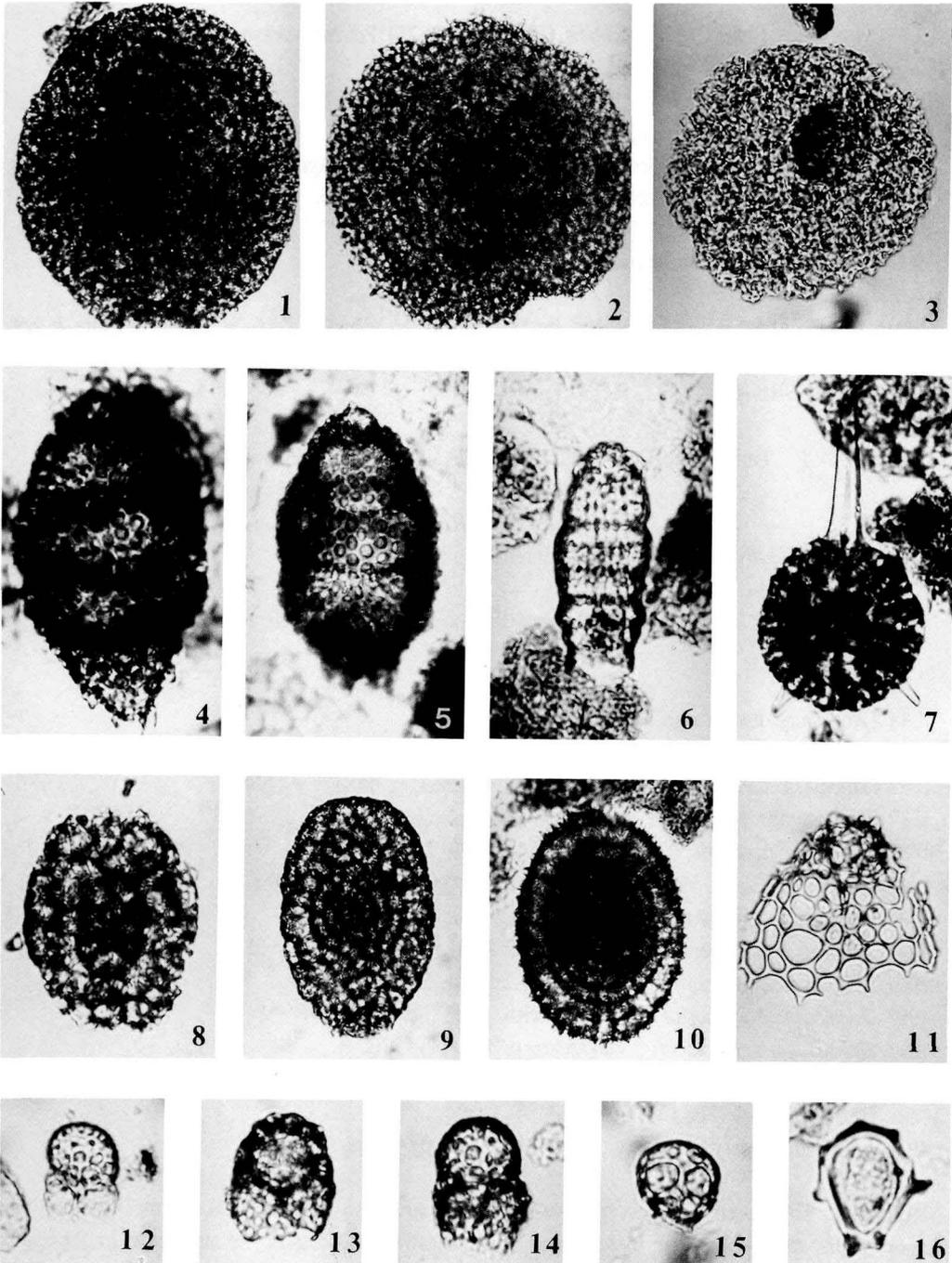
Occurrence: SR6; T, SR7; F, SR8; T, SR9; R, SR11; T, SR12; R, SR13; T.

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

PLATE 1

Fig.1: *Spongopyle osculosa* X230:SR5. Fig.2-3: *Spongodiscus maculatus* X230:SR7;SR3. Fig.4-5: *Cyrtocapsella tetrapera* X230:SR9;X230:SR10. Fig.6: *Lithomitra lineata* group X300:SR7. Fig.7: *Lithatractus timmsi* X230:SR10. Fig.8-9: *Larcopyle buetschlii* X300:SR5;X230:SR11. Fig.10: *Spongurus* sp.B X230:SR10. Fig.11: *Ceratocyrtis cucularis* X300:SR5. Fig.12-15: *Arachnocorallium* spp. X300:SR5;SR6;SR7. Fig.16: *Zygocircus productus tricarinatus* X300:SR7.

PLATE 1



Genus *CERATOCYRTIS* Ehrenberg, 1847

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

Ceratocyrtis cucularis (Ehrenberg, 1875) Petrushevskaya, 1971
Pl. 1, fig. 11.

1875 *Cornutella(?) cucularis* n.sp.- Ehrenberg, pl. 2, 7.

1971 *Ceratocyrtis cucularis*(Ehrenberg) comb. nov. - Petrushevskaya, fig.52(1)

1976 *C. cucularis mashae* - Bjorklund, p. 1125, pl. 17, figs. 1 - 5.

1986 *C. cucularis*(Ehrenberg)- Petrushevskaya, p. 193.

1990 *C. cf. cucularis* - Abelmann, p. 694, pl. 4, fig. 11.

Remarks: This species is distinguished by very small hemispherical cephalis. Collar stricture is not distinct. Thorax is broadly companulate. Size of subcircular pores are increasing downward.

Occurrence: SR6; R, SR7; T, SR13; T.

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

Genus *LITHOMITRA* Butschli,1882

Type species: *Lithomitra pachyderma* Ehrenberg, 1873

Lithomitra lineata(Ehrenberg) Haeckel, 1887
Pl. 1, fig. 6.

1838 *Lithocampe lineata* n.sp. -Ehrenberg, p. 130.

1854 *Lithocampe lineata* -Ehrenberg, pl. 22, fig. 26, pl. 36, fig. 16.

1887 *Lithomitra lineata*(Ehrenberg) comb. nov.-Haeckel, p. 1484.

1887 *Tricolocampe cylindrica* - Haeckel, p. 1412, pl. 66, fig. 21.

1887 *Lithomitra nodosaria* -Haeckel, p. 1484, pl. 79, fig. 1.

1887 *Lithomitra eruca* - Haeckel, p. 1485, pl. 79, fig. 3.

1887 *Siphocampe annulosa*- Haeckel, pl. 79, fig. 10.

1944 *Tricolocampe sanpedroana* - Campbell & Clark, p. 50, pl. 7, fig. 5.

1944 *Lithomitra altamiraensis*- Campbell & Clark, p. 53, pl. 7, fig. 9.

1963 *Tricolocampe cylindrica aff.* - Nakaseko, p. 182, pl. 2, fig. 7.

1963 *Siphocampe annulosa cf.* - Nakaseko, p. 195, pl. 4, fig. 8.

1971 *Lithomitra lineata*(Ehrenberg) group -Riedel & Sanfilippo, p. 1600, pl. 11, fig. 1-11, pl. 21, fig. 14 - 16, pl. 3E, fig. 14.

1973 *Lithomitra lineata*(Ehrenberg) group -Foreman, p. 431 pl. 8, fig. 19.

Remarks: This species is most persistent form observed in Hagjeon and Duho Formation. A picture of this species is similar to specimen (Pl.2I, Fig.10) of *Dorcadospyras alata* zone in Riedel & Sanfilippo (1971). *L. lineata* shows cosmopolitan distribution in temperature.

Occurrence: SR1; T, SR5; F, SR6; F, SR7; C, SR8; T, SR9; T, SR11; T, SR13; R.

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

Genus CARPOCANARIUM Haeckel, 1887

Type species: *Carpocanarium calycothes* stohr, 1880, p. 96, pl. 3, fig. 8

Carpocanarium spp.

Pl. 2, fig. 14.

Description: Shell is consisted of a cephalis and a hemispherical cephalis is distinguishable from thorax by distinct collar stricture. Ovate thorax is possessing a poreless subcylindrical rows on the thorax. Mouth is constricted.

Occurrence: SR5; T, SR9; R, SR10; R, SR13; R.

Family LOPHOPHAENIDAE Haeckel, 1881

Genus ARACHNOCORALLIUM Haeckel, 1887

Type species: *Arachnocorys hexaptera* Haeckel, 1887

Arachnocorallium spp.

Pl. 1, figs. 12 - 15; Pl. 2, fig. 13.

1975 *Arachnocorallium* spp.- Petrushevskaya, pl. 9, figs. 17 - 19.

1984 *Arachnocorallium* spp.-Petrushevskaya, Westberg-Smith & Riedel, pl. 4, fig. 2.

1986 *Arachnocorallium* spp.- Petrushevskaya, Mullineaux & Westberg-Smith, pl. 2, fig. 11

Remarks: This species is possessed large cephalis of irregular size. Petrushevskaya(1975) is reported to good indicators of the Surplus of warm-waters in Antarctic region. *A. spp.* is abundant in rather the Duho Formation of the Sodongri than the Hagjeon Formation of the Bomun area

Occurrence: SR4; T, SR5; R, SR6; F, SR7; F, SR9; F, SR11; F, SR13; R.

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

Genus ANTARCTISSQA Petrushevskaya,1967

Type species: *Lithobotrys denticulata* Ehrenberg, 1844.

Antarctissa robusta Petrushevskaya, 1975

Pl. 2, fig. 7 Pl. 2,fig. 11.

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

1975 ? *A. capita* Popofsky - Petrushevskaya, pl. 11, fig. 24.

1975 ? *A. equiceps* - 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.

Remarks: This species is evolved to *A.denticulata* in the early pliocene and differs in having a cephalis and thorax of almost equal width. Rare in the Hagjeon Formation and the Duho Formation of the Pohang Basin.

Occurrence: SR2; T, SR5; C, SR6; T, SR7; R, SR9; R.

Genus *ZYGOCICUS* Butschli, 1882, emend. Goll, 1980

Type species: *Lithocircus productus* Hertwig, 1879.

Zygocircus productus (Hertwig, 1879) *tricarinatus* Goll, 1980
Pl. 1, fig. 16.

1980 *Zygocircus productus* (Hertwig, 1879) *tricarinatus* n.subsp. Goll, p. 380, -pl. 1, figs. 1 - 2, 5 - 15.

1984 *Zygocircus productus* (Hertwig, 1879) *tricarinatus* - Nigrini & Lombardi, pl. 15, figs. 2a, - 2b.

Remarks: This subspecies are possessed of large sagittal ring and numerous small spines on the surface of sagittal ring. *Z. productus* (Hertwig, 1879) *tricarinatus* is characterized by a sternal spines. But , This specimen is broken the sternal spine.

Occurrence: SR7; T.

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), Petrushevskaya, 1975
Pl. 2, fig. 15.

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

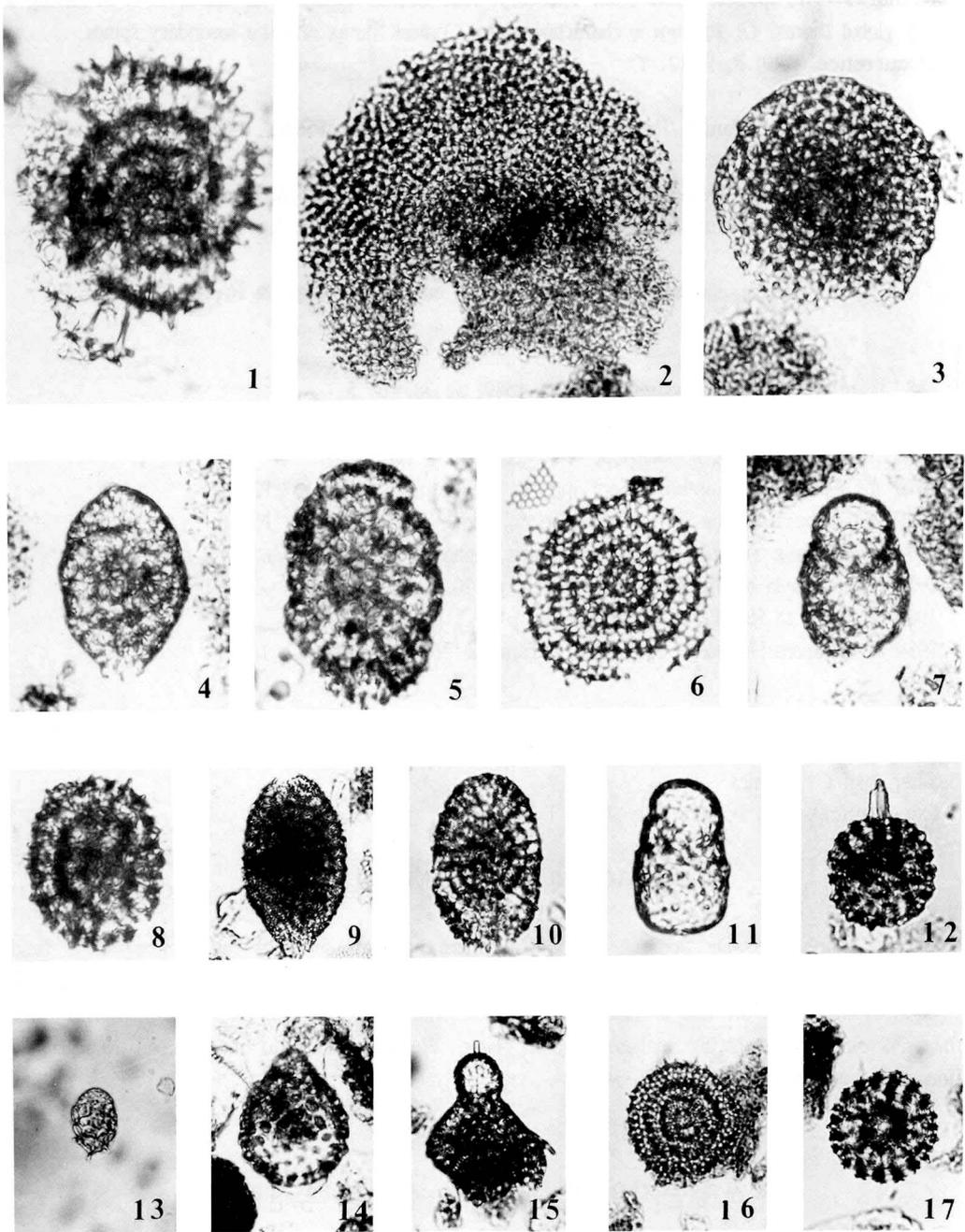
1973 *S. japonica* - Nakaseko & Suchano, pl. 3, fig. 2.

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

PLATE 2

Fig.1: *Lithelius nautiloides* X300:SR7. **Fig.2:** *Spongotrochus* spp. X230:SR8. **Fig.3:** *Spongopyle osculosa* X300:SR5. **Fig.4-5:** *Larcopyle buetschlii* X230:SR5;SR7. **Fig.6:** *Stylodictya aculeata* X300:SR9. **Fig.7:** *Antarctissa robusta* X300:SR5. **Fig.8:** *Lithelius formanae* X230:SR12. **Fig.9:** *Prunopyle titan* X230:SR9. **Fig.10:** *Spongurus* sp.B X230:SR7. **Fig.11:** *Antarctissa antedenticulata* X300:SR5. **Fig.12:** *Dorydiscus* spp. X230:SR9. **Fig.13:** *Arachnocorallium* spp. X230:SR9. **Fig.14:** *Carpocanarium* spp. X300:SR5. **Fig.15:** *Gondwanaria japonica* X230:SR12. **Fig.16:** *Stylodictya aculeata* X230:SR5. **Fig.17:** *Actinomma* spp. X230:SR11.

PLATE 2



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

Remarks; This species differs from *Theocorys redondoensis* Campbell & Clark, 1944 in having a nearly global thorax. *G. japonica* is characterized by Conical thorax and the secondary spines.

Occurrence: SR9; R, SR12; T.

Family Theoperidae Haseckel, 1881, emend. Riedel, 1967b

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

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

Cyrtocapsella tetrapera Haeckel, 1887, emend. Sanfilippo & Riedel, 1970
Pl. 1, fig. 4 - 5

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

1970 *Cyrtocapsella tetrapera* comb.nov. - 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 - Perez-Guzman, p. 332, pl. 2, fig. 3.

1989 *C. tetrapera* Haeckel - Lazarus & Pallant, pl. 360, pl. 3, figs. 7, 13.

Remarks; This species is distinguished from *C. cornuta* in lacking the pronounced change in contour between the second and third segments. Also, the second segment of the *C. tetrapera* is not broader than *C. japonica*.

Occurrence: SR9; F, SR11; R, SR12; T.

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포항분지의 학전층에서 산출된 방산층

박영숙*, 이종덕*, 윤혜수**

*전북대학교 지구환경과학과 **충남대학교 지질학과

요 약 : 보문 지역 소리지 부근에 분포하는 학전층 5개 단면에서 13개의 시료를 채취하였으며 29속 42종의 방산충이 분류되었다.

보문지역에서 산출된 방산충 화석군은 cold-water taxa로서 *Lithelius minor*, *Lithelius nautiloides*, *Spongodiscus maculatus*, *Spongopyle osculosa*, *Stylodictya validispina* 가 풍부하고, warm-water taxa로서 *Collosphaera*가 빈약하게 산출된다.

두호층에서 산출되는 *Cornutella profunda* (Equator>900 m to Arctic>200 m)와 *Peripyramis circumtexta* (0-40N, 200-700m) 같은 deep dweller taxa들이 보문지역에서는 산출되지 않아 적어도 200m 이하의 깊이에서 퇴적되었다고 할 수 있다.

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