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방산충

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요 약: 방산충은 넓은 지리적 분포를 가진 원생동물로서 방산충 연니를 형성하기도 한다. 고생대 캄브리아기 이후의 생층서 대비와 퇴적환경을 해석하는데 유용하게 사용되며, 석회질 미화석이 드물게 산출되는 곳의 연구에도 매우 중요하다. 방산충은 골격의 형태와 대칭성에 의하여 Spumellaria 아목과 Nassellaria 아목으로 구분되며, 방산충의 화석기록은 Lower cambrian 초부터 시작하였고 Nassellaria 아목은 중생대 트라이아스기에 출현 하였다. 우리나라에서의 방산충 연구는 포항분지의 제 3기층을 중심으로 이루어 졌으며, 김봉균(1965, 1984)은 유공충을 연구하던 중 포항분지 송학동층(학전층)으로부터 처음으로 방산충을 감정하고 방산충 미화석의 분대를 설정하였다. 그 후 박영숙 외(1996, 1997, 1999)는 포항분지 연일층군의 9개 지역에서 총 325개의 샘플을 채취하였고, 그 중 학전층과 두호층에서 방산충 화석을 발견하였으며 총 56속 103종 2아종의 방산충을 동정하고 기재하였다.

서 론

방산충은 해양 부유성 원생동물로서 골격의 평균 크기는 50-200 ㎛ 정도이다. 캄브리아기에 첫 출현하여 현재까지 긴 지질시대를 가지며, 남극에서 북극, 표면에서 심해까지 넓은 지리적 분포를 가진다. 1887년 Haeckel이 제안한 방산충 분류체계는 4개의 주요 taxa로 나누어 졌었다. 1) Spumellaria, 2) Nassellaria, 3) Phaeodaria, 4) Acantharia. 그러나 계속되는 많은 종들의 발견으로 Haeckel의 고전적 체계를 더 이상 받아들이지 않게 되었으며 현재 사용되는 분류체계는 Spumellaria와 Nassellaria목의 골격의 형태에 근거를 둔다. 분류체계는 원생동물문(Phylum Protozoa), 방사족충강(Class Actinopodea), 방산충아강(Subclass Radiolaria)에 속하며 Polycystina목, Phaeodarian목과 Acantharea목으로 나누어진다. Polycystina목은 단단한 오팔린 실리카로 구성된 골격을 가지고 있으며 화석으로서 잘 보존되고 Spumellaria아목과 Nassellaria아목으로 구분된다. Phaeodarian목은 실리카와 유기물질의 혼합으로 구성된 속이 빈 골격구조를 가지고 있고, Acantharea목은 일반적으로 근해에서 서식하나 화석으로서 보존되기 어렵다.

방산충은 대부분이 평균 염도를 가진 수 백미터 수심이상의 해양에서 산출된다. 근해로 갈수록 다양성과 개체수가 현저하게 감소하며, 고위도에서는 열대해역에서 산출되는 종의 수보다 적지만 개체수는 풍부하다. 방산충 연니는 석회질 미화석의 용해속도가 퇴적속도를 초과하여 퇴적의 속도가 감소하는 곳인 열대해역의 석회질-규질 연니의 가장자리 부근에서 발달되며 방산충 연니의 퇴적속도는 약 4-5m/m.∨y.이다. 방산충의 골격은 석회질 미화석 보다는 지질학적 기록에서 넓게 산출되지는 않지만 탄산칼슘보상심도에 의해 영향 받지 않으므로 고기의 퇴적물에서 잘 발견된다. 따라서, 방산충은 석회질 미화석이 드물게 산출되는 곳의 연구에 매우 중요하며, 세계적으로 분포하고 시대를 통하여 다양성이 좋기 때문에 생층서 대비와 퇴적환경을 해석하는데 유용하게 사용된다.

연구사

방산충에 대한 연구 역사는 크게 6기로 나눌 수 있다 (Casey, 1993).

1기: 방산충의 현생과 화석 형태에 대한 인식
1800년대 초에 처음으로 현생과 화석 방산충이 기재 되었다. Ehrenberg는 1800년대 중반에 처음으로 신생대 방산충을 분류하였고 Polycystina 그룹이라고 명했다. 또한 Müller는 지중해의 현생종을 연구하여 처음으로 방산충이라고 명명하였다.

2기: Haeckel의 연구
Haeckel(1881, 1887)은 HMS challenger 탐험에서 수집된 방산충을 토대로 새로운 분류체계를 포함한 방산충에 대한 폭 넓은 연구를 공표하였다. Haeckel의 논문은 거의 100년동안 기본적인 방산충 문헌으로 사용되었다.

3기: 현생 방산충에 대한 연구
1900년대 초의 방산충 연구는 주요 해양탐사로부터 수집된 현생 형태의 동물지리학(Zoogeography)과 관계된 연구 였다.

4기: Riedel에 의한 방산충 연구의 부활
1900년대 중반에 Riedel이 제 3기 열대(tropical)해역 방산충 층서 연구를 발달시킴으로 미국에서 현대 방산충의 연구가 시작되었다. 같은 시기에 러시아에서는 Reshetnjak, Petrushevskaya, Lipman, Strelkov와 Zhamoida에 의해 방산충 연구가 발달 되었다.

5기: 심해저 탐사(Deep Sea Drilling Project)와 대양저 탐사(Ocean Drilling Program) 연구
1960년대 후반에 심해 시추기술의 발달과 함께 방산충이 유용하게 되었으며 Riedel은 열대해역 생층서 분대(tropical biostatigraphic zonation)를 설정하였다. Riedel의 몇몇 제자들은 Plankton과 현생 퇴적물에서 현생 방산충의 분포나 고해양학적 해석 등을 포함한 여러 방면에서의 방산충 연구를 시도하였다.

6기: 현재의 다양한 연구들
1960년대 말에서 1980년대 말까지 방산충 생층서와 지자기층서와의 대비, 고해양학적 지시자로서의 방산충 이용 등으로 연구가 활발한 시기였다. 이시기의 가장 중요한 진보는 Anderson의 현생 방산충에 대한 연구이다. Anderson은 실험실에서 방산충을 배양하였으며 1983년에 Radiolaria라는 책을 발간하였다. 또한 중생대과 고생대의 방산충에 대한 연구가 1900년대 말에 유럽, 러시아, 일본과 미국 등지에서 이루어 졌다. 오늘날 대부분의 방산충 연구자들은 Riedel과 Petrushevskaya의 분류체계를 결합시켜 사용하며, 현생과 마이오세의 방산충의 연구는 Nigrini와 Moore, Nigrini와 Lombari의 문헌을 사용한다.

형태 및 화석기록

방산충은 골격이 방사대칭인 Spumellaria와 좌우 대칭인 Nassellaria로 나뉜다. Nassellaria는 다시 원추형 골격을 가진 cyrtida와 D자 모양의 시상 고리(sagittal ring)를 가진 spyroida로 구분된다. Spumellaria와 Nassellaria 모두 침상체(spicule)를 가지고 있으며 spumellaria의 침상체는 둥근모양이며(Fig. 1) nassellaria의 침상체는 면을 가지고 있다(Fig. 2).

spumellaria의 내부 각을 medullary shell이라 하며 가장 바깥에는 외각으로서 cortical shell이 존재한다. bar와 beam은 각들과 내부 구조들을 연결하는 기능을 한다. 내부를 관통하고 방사상의 bar들에 의해 지탱되는 spine을 main spine이라 한다. pore의 형태와 배열도 매우 다양하며 기본적인 3가지 형태로 격자형벽(latticed wall), 다공질벽∧(spongy wall), 다공질판벽(perforate plate wall)이 있다(Fig. 3).

Nassellarian의 경우 median bar와 spine들은 머리부인 cephalis와 두 번째 chamber인 thorax사이

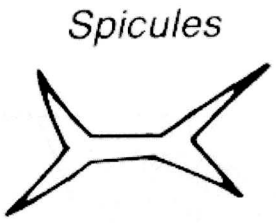

Fig. 1. Spumellarian spicules (Lipps, 1993).

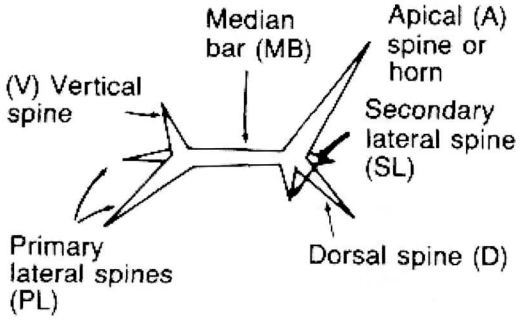

Fig. 2. Nassellarian spicules (Lipps, 1993).

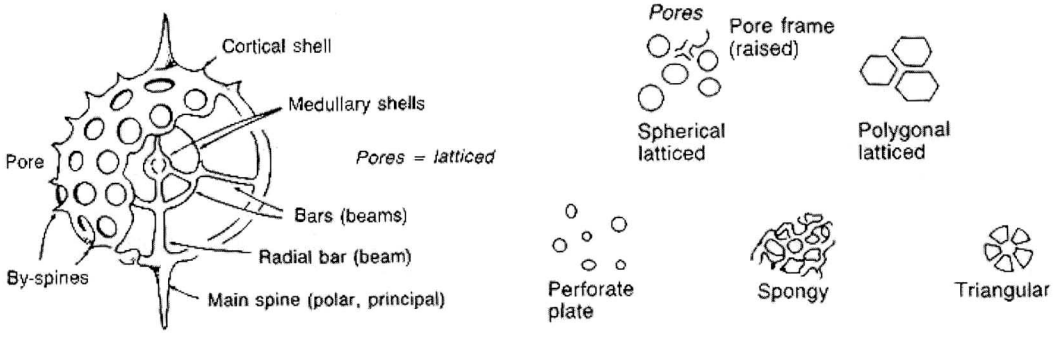

Fig. 3. Spumellarian skeletal morphology and shape of the pores (Lipps, 1993).

collar strictures내에 배열되어 있다. thorax다음 마디인 abdomen은 lumbar stricture에 의해 구분된다. abdomen이후의 나머지 마디들을 post - abdominal 이라 부르며 마지막 마디에는 aperture를 가진다(Fig. 4).

현생 방산충의 연질 조직으로서 외형질(ectoplasm)은 운동이나 외부의 자극을 받아들이는 작용을 하며 내형질(endoplasm)은 생식작용, 동화작용, 이화작용을 담당한다. 이들 사이에는 내형질과 외형질을 분리시키는 역할을 하며 작은 구멍을 가져 내형질과 외형질이 상호교환을 할 수 있게 해주는 중심막(central capsule membrane)이 존재한다. 위족으로서 길고 직선이며 내형질과 외형질 내부를 관통하는 Axopodia와 얇고 섬세하며 세포질의 말초에 분포하는 Filopodia가 있다(Fig. 5).

방산충은 보통 이분법(binary) 혹은 다분법(multiple fission)과 같은 무성생식에 의해 번식하고 배우자 형성에 의한 유성생식이 추정되지만 확실히 증명된 바 없다. 생식활동은 규산을 가진 물에서 일시적으로 일어나며 계절적이거나 주기적이다. 활동적인 수평이동력을 가지지 못하며, 방산충 분산의 대부분이 해류에 의존되나 활동적으로 움직여서 얻어지는 것보다 넓은 분포를 가지게 한다. 열대 해역의 해수에서 가장 풍부하고 표층에서 사는 원양종 들은 많고 가는 침과 큰 pore를 가지며 pore의 bar가 크지만 심해종의 경우 단단하며 짧은 침을 가지고 작은 pore를 갖는 것이 보통이다.

방산충의 화석 기록은 Lower Cambrian 초부터 시작되었으며 단순한 Paleoactinommid와 몇몇 방산충들이 캄브리아 암석에 존재한다. 가장 오래되고 잘 보존된 방산충은 Spitsbergen의 Lower Ordovician 석

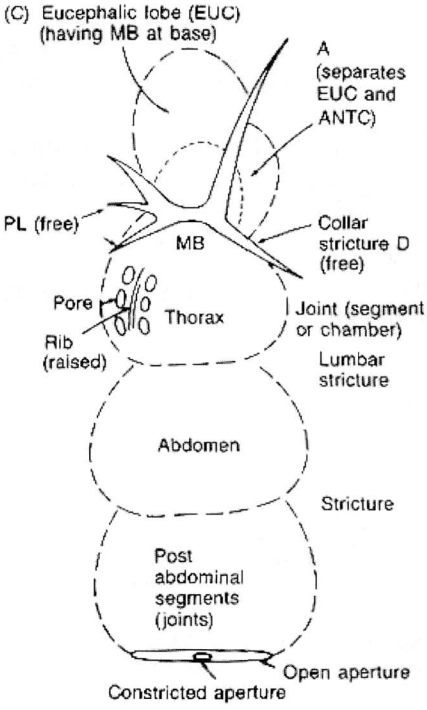

Fig. 4. Nassellarian skeletal morphology (Lipps, 1993).

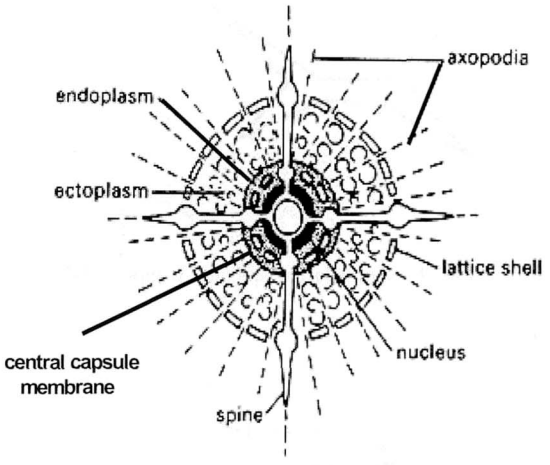

Fig. 5. Cross section through a spumellarian (Lipps, 1993).

회암에서 산출되었으며, 방산충의 기본적인 골격형태는 침형(spicule), 구형(sphere), 원추형(cone)을 가지고 천해환경에서 퇴적되었다. 한류종(cold water)와 난류종(warm water) 방산충은 캄브리아기에도 구별되며 심해 방산충은 실루리아기에 발달되었다. 고생대 중반에 한류의 유입으로 심해, 한류종의 진화가 일어났고 고생대 말의 한류로 인해 심해, 한류종들이 재구성되었다. 페름기의 방산충은 다양하였으나 고생대 말과 고생대-중생대 전이시기에 대륙들의 충돌로 인한 표층수의 감소와 수괴환경의 변화, 페름기 빙하작용에 의한 부영양화의 결과로 주요 방산충들의 재구성이 일어났다. Nassellarian 방산충은 트라이아스기에 처음 출현하였으며 현존 그룹의 절반이상이 중생대 동안에 진화했다. 다른 미화석 그룹들이 중생대-신생대 전이시기에 급격히 다양성이 줄어든 반면 주요 방산충 동물군은 중생대 말과 중생대-신생대 전이시기동안에 중생대 그룹이 대량 멸종되지 않았으며 신생대 그룹으로 진화했다. 마지막 주요 방산충의 재구성은 고 제3기-신 제3기에 일어났으며 이 시기에 다양성과 풍부성이 증가하였다 (Anderson, 1983) (Fig. 6).

우리나라의 방산충 연구 역사 및 연구 방법

우리나라에서의 방산충 연구는 포항분지의 제 3기층을 중심으로 이루어 졌다. 한반도에서 제3기층의 분포는 동해안을 따라 소규모로 산재 분포하고 있으며, 연구 대상지역인 포항분지는 남한에서 규모가 가장 크고 대략 북북동-남남서 방향으로 분포하고 있다. 김봉균(1965, 1984)은 유공충을 연구하던 중 포항분지 송학동층(학전층)으로부터 처음으로 방산충을 감정하고 방산충 미화석의 분대를 설정하였으나 고생물학적인 종 분류나 기재를 다루지는 않았다.

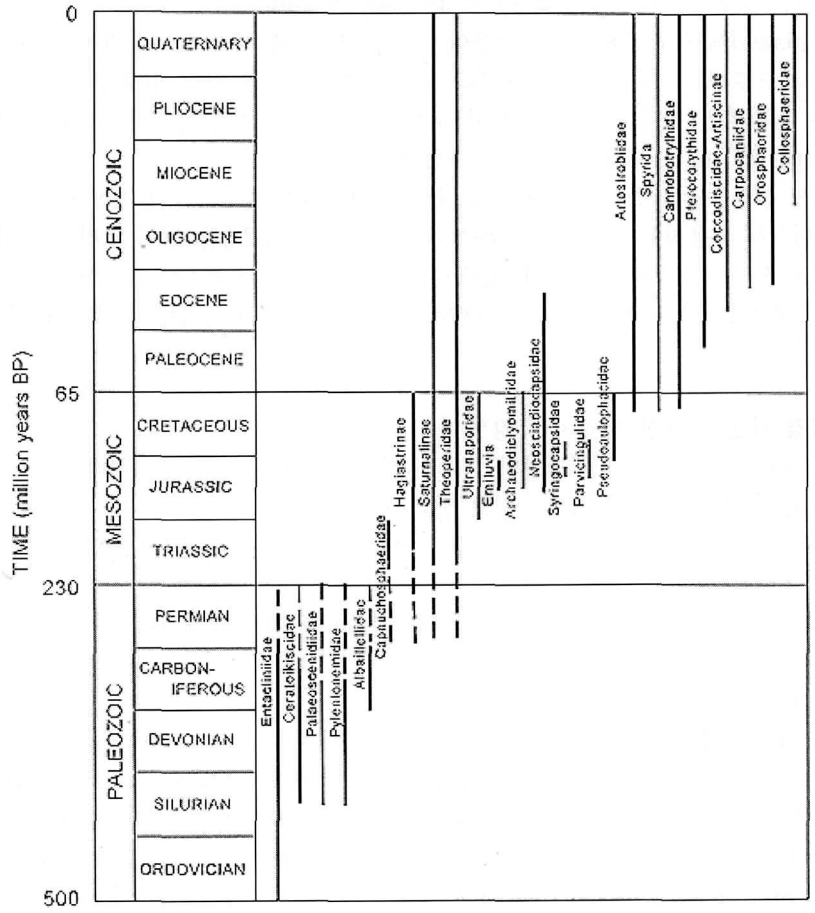

Fig. 6. Time range of radiolarian taxa (mostly families) which are believed to represent natural groupings, to show the pronounced changes near the Paleozoic/mesozoic and Mesozoic/Cenozoic boundaries. Broken lines indicate doubtful limits (Riedel and Sanfilippo, 1981).

박영숙 외(1996, 1997, 1999)는 포항분지 연일층군의 9개 지역에서 총 325개의 샘플을 채취하였고, 그 중 학전층에 속하는 동산리, 덕성리, 송라지역과 두호층에 해당되는 소동리지역에서 방산충 화석을 발견하였다. 산출된 방산충의 분류는 Riedel (1971, 1978, 1981, 1990), Riedel과 Sanfilippo (1970, 1971, 1977, 1978, 1986), Petrushevskaya (1965, 1967, 1973, 1975, 1979)을 기초로 하였으며, Modern과 MIocene 방산충의 목록을 작성한 Nigrini and Moores (1979)와 Nigrini and Lombari (1984)의 연구를 참조하여 실시하였다. 이들 지역에서 총 56속 103종 2아종의 방산충을 동정하고 기재하였으며 층서와 고 환경 해석에 이용하였다.

방산충 추출 실험방법

방산충 추출을 위한 실험 방법은 Sanfilippo *et al.*(1985)의 절차를 기본으로 하였다.

1) 광학현미경 관찰을 위한 시료처리 방법

① 시료 5 g을 500 ㎖의 비이커에 담는다.

② 10%묽은 염산 25 ㎖와 과산화수소수 15 ㎖를 첨가한다.
③ Hot plate위에서 과산화수소의 반응이 완전히 끝날 때 까지 약 1시간동안 가열한다. 이때 비이커 밖으로 끓어 넘치는 것을 방지하기 위해서 증류수를 약간 첨가해 준다.
④ 남은 침전물은 산이나 부유성 물질을 모두 제거하기 위해 증류수로 세 번이상 세척한 후 (decant) 250 ㎛와 38 ㎛의 체를 사용하여 걸러준다.
⑤ 걸러진 침전물을 500㎖비이커에 넣고 눈금 300㎖까지 증류수를 첨가한다.
⑥ 스포이드를 이용하여 슬라이드 글라스 위에 침전물을 1-2방울 떨어 뜨려 건조시킨다.
⑦ 건조된 슬라이드 글라스에 카나다발삼을 이용하여 커버 글라스를 덮는다.
⑧ 광학현미경을 이용하여 방산충을 관찰하고, 보존이 좋거나 주요한 종들을 대상으로 사진을 촬영한다.

2) 전자현미경 관찰을 위한 시료처리 방법

① 광학현미경 관찰을 위한 처리방법중 ④번 까지 동일한 순으로 실험한다.
② 걸러진 침전물을 CBC bottle에 담고 증류수를 채운다.
③ 스포이드를 사용하여 직경 13 ㎜의 둥근 커버글라스에 한 두방울 떨어뜨린 후 hot plate위에서 건조시킨다.
④ 양면테이프를 이용하여 건조된 커버 글라스를 stub위에 장착시킨다.
⑤ 전자현미경 관찰을 위하여 금코팅한다.
⑥ 전자현미경으로 관찰하면서, 사진을 촬영한다.

· 화석의 동정 및 해석: 방산충 미화석의 산출은 각 시료의 슬라이드를 관찰하면서, 종의 수가 26개체 이상이면 A(abundance), 11-25개체 C(common), 6-10개체 F(few), 2-5개체 R(rare), 1개체 T(trace)로 표기한다. 보존상태는 세가지로 분류하는데 specimen의 반절이상이 용해되지 않고 깨어지지 않았을때 G(good)로 표시하며, 약간 용해되거나 반절이상이 깨어지지 않았을 때는 M(moderate), 용해가 심하고, 대부분이 깨져있을 때에는 P(poor)로 나타낸다.

SYSTEMATIC DESCRIPTIONS

Phylum PROTOZOA
Class ACTINOPODA
Subclass RADIOLARIA Muller, 1858
Order POLYCYSTINA Ehrenberg, 1838, emend. Ridel, 1967b
Suborder SPUMELLARIA Ehrenberg, 1875

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

Genus *Actinomma* Haeckel, 1862, emend. Nigrini, 1967
Type species: *Haliomma trinacrium* Haeckel, 1860

Actinomma spp. Nigrini and Lombari, 1984
pl. 1, fig. 1-3, 12

1984 *Actinomma* spp. - Nigrini and Lombari, S13, pl. 2, figs. 1a-d.

Description: Shell is composed of three or four concentric lattice shells. Medual shells are spherical to subspherical. 7-12 connector beams join Medullary and cortical shells. Conical accessory spines are observed on the outer surface of the cortical shell.
Dimensions (in ㎛): Diameter of cortical shell 100-126; diameter of meduallary shell 30-48.

Genus *AXOPRUNUM* Haeckel, 1887, emend. Petrushevskaya & Koslova, 1972
Type species: *Axoprunum stauraxonium* Haeckel, 1887, pl. 48, fig. 4.

Axoprunum angelinum (Campbell & Clark, 1944)
pl. 4, fig. 2

1944 *Stylosphaera angelina* sp. nov. - 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* - Pisias & Moore, p. 846, pl. 1, fig. 4.
1981 *A. angelinum* - Weaver et al., p. 83, pl. 3, figs. 3-4.
1985 *A. angelinum* - Perez-Guzman, p. 328, pl. 1, fig. 1.
1990 *A. angelinum* - Lazarus, p. 717.

Remarks: Generally, this species having the short by spines in the surface of the cortical shell. But the specimens from the Duho Formation of the Pohang Basin are smooth cortical shell. Forms with smooth cortical shell are common in Neogene and Quaternary samples (Kling, 1973).
Dimensions (in ㎛): Diameter of innermost shell 13-20; diameter of second shell 45-53; diameter of cortical shell 164-175. length of spines 86-94.

Genus *Druppatractus* Haeckel, 1887
Type species: *Druppatratus hippocampus* Haeckel, 1887, p. 324, pl. 16, figs. 10, 11.

Druppatractus irregularis Popofsky, 1912
pl. 3, fig. 12; pl. 4, fig. 1

1912 *Druppatractus irregularis* sp. nov. - Popofsky, p. 114, text-figs. 24-26.
1982 *D. irregularis* Popofsky - Blueford, p. 206, pl. 6, figs. 7a-b.

Remarks: *Druppatractus irregularis* is different from *D. nanus* and *D. hastatus* by its characteristic pyriform medual shell.
Dimensions (in ㎛): Diameter of cortical shell 81-90; diameter of inner shell 36-43, length of larger spine 53-58; length of shorter spine 24-27.

Druppatractus nanus Blueford, 1982
pl. 3, fig. 10, 11; pl. 4, fig. 3, 7

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

Remarks: *Druppatractus nanus* differs from *D. irregularis* Popofsky, 1912 by its spherical inner shell.
Dimensions (in ㎛): Diameter of the cortical shell 86-91; diameter of inner shell 32-38. Length of the long spine 64-71; length of the shorter spine 23-29.

Genus *Lithatractus* Haeckel, 1887
Type species; *Lithatractus fragilis* Haeckel, 1887, p. 319, pl. 16, fig. 3

Lithatractus timmsi Campbell and Clark, 1944
pl. 4, fig. 4-6

1944 *Lithatractus timmsi* sp. nov. - Campbell and Clark, p. 19, pl. 2, fig. 19
1986 *L. timmsi* Campbell and Clark - Mullineaux and Westberg-Smith, p. 64, pl. 1, fig. 4

Remarks: Forms with small pores similar to *D. irregular*, but having bladed polar spine clusters.
Dimensions (in ㎛): Length of cortical shell 177-186 (including of polar spines), Diameter of cortical shell 86-98; diameter of medullary shell 38-43.

Genus *Stylosphaera* Ehrenberg, 1847
Type species: *Stylosphaera hispida* Ehrenberg, 1854b.

Stylosphaera minor Clark and Campbell, 1942
pl. 4, fig. 8

1942 *Stylosphaera minor* sp. nov. - Clark and Campbell, p. 27, pl. 5, figs.1,2, 2a, 12
1945 *S. monor* - Clark and Campbell, p. 11, pl. 1, figs. 13-19.
1972 *S. minor* Clark and Campbell - Petrushevskaya & Kozlova, p.529, pl.10, fig. 9.
1975 *S. minor* Clark and Campbell - Petrushevskaya, p. 569.
1988 *S. minor* Clark and Campbell - emend. Blueford, p. 247, pl. 4, figs. 4-6.

Remarks: This species is characterized by spherical inner shell and same-sized pores.
Dimensions (in ㎛): Diameter of cortical shell 129-135; diameter of medullary shell 48-54. Length of cortical shell (including of spine) 303-314.

Family COLLOSPHAERIDAE Muller, 1858

Family LIHTELIIDAE Haeckel, 1862

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

Lithelius minor Jorgensen, 1900
pl. 1, fig. 4

1900 *Lithelius minor* sp. nov. - Jorgensen, p. 65, pl. 5, fig. 24
1966 *L. minor* Jorgensen - Benson, p. 262, pl. 17, fig. 10
1979 *L. minor* Jorgensen - Nigrini & Moore, p. 135, pl. 17, figs. 3, 4a, b
1984 *L. minor* Jorgensen - Nigrini & Lombari, p. 95, pl. 14, figs. 1a, b

Remarks: The specimens are exhibited to doubly spiral or concentric inner shells by Benson (1966). The species from the Pohang Basin has concentric inner shells.
Dimensions (in ㎛): Diameter of the shell 69.

Lithelius nautiloides Popofsky, 1908
pl. 1, fig. 5; pl. 5, fig. 3

1908 *Lithelius nautiloides* sp. nov. - 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 & Lombari, p. 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 & Lombari (1984) considered both single and double-spiraled forms to be conspecific. In this paper, the specific forms proposed by Nigrini & Lombari (1984) are accepted.
Dimensions (in ㎛): Diameter of shell of five whorls 75-109.

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. 3, fig. 2

1847 *Haliomma humboldtii* - Ehrenberg, p. 55.
1854b *H. humboldtii* - Ehrenberg, pl. 36, fig. 27.
1873 *Periphaena decora* sp. nov. - 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.
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.

Remarks: This species is distinguished from all others of the genus by having a girdle of varying width.
Dimensions (in ㎛): Maximum diameter of cortical shell 207-250; minimum diameter of cortical shell 181-219.

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. 5, fig. 2

1944 *Prunopyle titan* sp. nov. - 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* - Abelmann, p. 693, pl. 3, fig. 16.

Remarks: *Prunopyle titan* is distinguished from *P. hayesi* by egg-shaped outer shell. This species from the Pohang basin has variable size.
Dimensions (in ㎛): Length of the shell 159-195. Width of the shell 123-150; width of the osculum 27-59.

Family SPONGODISCIDAE Haeckel, 1862, emend. Riedel, 1967a

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

Spongodiscus pulcher Clark & Campbell, 1945
pl. 1, fig. 9

1942 *Spongotrochus echinodiscus* - Clark & Campbell, p. 48, pl. 2, fig. 3
1945 *Spongodiscus pulcher* sp. nov. - Clark & Campbell, p. 57, pl. 4, fig. 5
1973 *S. pulcher* Clark & Campbell - Sanfilippo & Riedel, p. 525, pl. 12,figs. 3-5;, pl. 29, figs. 3, 4
1988 *S. pulcher* Clark & Campbell - Blueford, pl. 7, figs. 2, 3

Remarks: This species resembles *S. biconcavus* in having densely central portions.
However, it is distinguished from *S. biconcavus* by distinctive central eyelike structure and has spongy meshes.
Dimensions (in ㎛): Diameter of shell 164-183.

Genus *Spongopyle* Dreyer, 1889

Type species; *Spongopyle setosa* Dreyer, 1889, p. 43, figs. 97, 98

Spongopyle osculosa Dreyer, 1889
pl. 1, fig. 8; pl. 4, fig. 12; pl. 5, fig. 1

1889 *Spongopyle osculosa* sp. nov. - 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 & Lombari, s115, pl. 15, fig. 1

Remarks: This species is characterized by spongy biconvex lens with distinct margin and well-developed pylome.
Dimensions (in ㎛): Width of shell 171-196, Length of shell 187-210.

Spongotrochus venustum (Bailey, 1856)
pl. 4, fig. 10

1856 *Perichlamydium venustum* - Bailey, p. 5, pl. 1, figs. 16-17.
1887 *Stylochlamydium venustum* (Bailey) - Haeckel, p. 515.
1979 *Spongotrochus venustum* (Bailey) comb. nov. - Nigrini & Moore, p. S119, pl. 15, figs. 3a, b.
1984 *S. venustum* (Bailey) - Nigrini & Lombari, p. S81, pl. 11, fig. 3.

Remarks: Concentric rings of S. venustum from the Pohang basin are well developed.
Dimensions (in ㎛): Diameter of the shell 138-152.

Genus *Stylochlamydium* Haeckel, 1887

Type species: *Stylochlamydium asteriscus* Haeckel, 1887, p. 514, pl. 41, fig. 10

Stylochlamydium asteriscus Haeckel, 1887
pl. 3, fig. 1

1887 *Stylochlamydium asteriscus* sp. nov. - Haeckel, p. 514, pl. 41, fig. 10
1979 *S. asteriscus* Haeckel - Nigrini & Moore, s113, pl. 14, fig. 5
1984 *S. asteriscus* Haeckel - Nigrini & Lombari, s75, pl. 10, fig. 4

Remarks: This genus is most similar to *Perichlamydium* Ehrenberg, 1847 by having central structure, which consists of concentric rings. *S. asteriscus* differs from *P. praetextum* by the absence of a polar opening of pylome.
Dimensions (in ㎛): Diameter of central shell 12-16; diameter of shell 110-133.

Genus *Stylodictya* Ehrenberg, 1847, emend. Koslova, 1972 of Petrushevskaya & Kozlova, 1972
Type species: *Stylodictya gracilis* Ehrenberg, 1854b.

Stylodictya validispina Jorgensen, 1905
pl. 3, fig. 3

1905 *Stylodictya validispina* sp. nov. - Jorgensen, 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.
1984 *S. validispina* - Nigrini & Lombari, p. S71, pl. 10, fig. 2.
1990 *S. validispina* - Abelmann, p. 693, pl. 3, fig. 10.

Remarks: Nigrini & Lombari (1984) are described as following; Radial spines arranged very irregularly number 12-16 along periphery of disk with five rings. However, radial spines are not counted at these specimens, because these spines are brokened.
Dimensions (in μm): Diameter of central chamber 11-15; diameter of first ring 29-35; diameter of second ring 47-55; diameter of third 65-80; diameter of fourth 87-100; diameter of five 114-128. Diameter of disk with six rings about 130-146.

Family SPONGURIDAE Haeckel, 1862, emend. Petrushevskaya, 1975

Genus *Spongocore* Haeckel, 1887
Type species: *Spongocore velata* Haeckel, 1887, p. 346

Spongocore cylindrica (Haeckel, 1862)
pl. 2, fig. 8

1862 *Spongurus cylindricus* sp. nov. - Haeckel, p. 465, pl. 27, fig. 1.
1887 *Spongocore puella* - Haeckel, p. 347, pl. 48, fig. 6.
1970 *S. puella* - Nigrini, p. 168, pl. 2, fig. 3.
1973 *S. puella* - Kling, p. 635-636, pl. 7, figs. 18-22.
1984 *Spongocore cylindrica* (Haeckel) comb. nov. - Nishimura & Yamauchi, p. 39-40, pl. 16, figs. 5-6; pl. 52, figs. 8, 9.
1992 *S. cylindrica* (Haeckel) - Yu-jing Wang & Qun Yang, p. 101, pl. 2, figs. 12-14.

Remarks: Shell is a cylindrical dumbbell - shaped and composed of solid spongy framework. The species from the Pohang Basin has no mantle - shell and has smooth outline.
Dimensions (in μm): Width of the shell 67; Length of the shell 186.

Genus *Spongurus* Haeckel, 1860
Type species: *Spongurus cylindricus* Haeckel, 1860.

Spongurus (?) sp. A Nigrini & Lombari, 1984
pl. 2, 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 & Lombari, S33, pl. 5, figs. 1a, b

Remarks: *Spongurus* sp. A are similar to figure 1b of plate 5 reported by Nigrini & Lombari (1984). This species characterized by possessing an irregular outline and looser spongy meshwork.
Dimensions (in ㎛): Width of shell 80 - 96, Length of shell 130 - 145.

Spongurus (?)sp. B Nigrini & Lombari, 1984
pl. 2, fig. 6-7

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.
Dimensions (in ㎛): Width of shell 71 - 77, length of shell 130 - 136.

Genus *Styptosphaera* Hackel, 1887
Type species; *Styptosphaera spumacea* Haeckel, 1887, p. 87

Styptosphaera spumacea Haeckel, 1887
pl. 1, fig. 6; pl. 4, fig. 11

1887 ?*Styptosphaera spumacea* sp. nov. - Haeckel, p. 87
1970 *S. spumacea* Haeckel - Nigrini, p. 167, pl. 1, figs. 7, 8
1979 *S. spumacea* Haeckel - Nigrini & Moore, s71, pl. 8, figs. 6a, b
1984 *S. spumacea* Haeckel - Nigrini & Lombari, s37, pl. 5, fig. 3

Remarks: Forms occurs in Miocene sediments are usually larger in diameter; 172㎛ - 263㎛. However, forms found in the study area are generally smaller in diameter(136㎛) than those found in other Miocene section.
Dimensions (in ㎛): Diameter of shell 136 - 150.

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

Genus *Liriospyris* Haeckel, 1881, emend. Goll, 1968
Type species: *Liriospyris hexapoda* Haeckel, 1887

Liriospyris mutuaria Goll, 1968
pl. 5, fig. 12

1968 *Liriospyris mutuaria* sp. nov. - 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.

Remarks: *Liriospyris mutuaria* differs from *L. elevata* Goll, 1968 in having four lattices bars that are joined to the sagittal ring. Also, It differs from *L. globosa* in possessing a sagittal ring that is joined directly to the front and back of the lattice shell.
Dimensions (in ㎛): width of sagittal ring 56 - 79, Height of sagittal ring 66 - 90.

Genus *Tholospyris* Haeckel, 1887
Type species: *Tholospyris tripodiscus* Haeckel, 1887, p. 1079, pl. 89, fig. 1

Tholospyris cortinisca (Haeckel, 1887)
pl. 2, fig. 4

1887 *Tripospyris cortiniscus* sp. nov. - Haeckel, p. 1026, pl. 84, fig. 6
1969 *Tholospyris. cortinisca* (Haeckel)comb. nov. - Goll, p. 325, pl. 56, figs. 3, 5 - 6, 8.
1973 *T. cortinisca* (Haeckel) - Sanfilippo et al. , p. 219, pl. 3, figs. 13 - 16.

Remarks: *Tholospyris cortinisca* is characterized by a stout apical horn and smooth lattice shell. This species differs from *T. scaphipes* Haeckel, 1887 in having a lattice shell surrounds the apex of the sagittal ring. This species occur one specimen from the Duho Formation in the Pohang basin.
Dimensions (in ㎛): Width of latticed shell 89, Height of sagittal ring 46, total length, including horn and feet 112.

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. 5, fig. 7

1887 *Peripyramis circumtexta* sp. nov. - 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

Remarks: *Peripyramis circumtexta* differs from *Plectopyramis dodecomma* Haeckel, 1887 in the absence of transverse bars that are continuos around the circumference.

Dimensions (in ㎛): Total length 98 - 110, Maximum breadth 67 - 96.

Family CANNOBOTRYIDAE Haeckel, 1881 emend. Riedel, 1967b

Genus *Botryopyle* Haeckel, 1881

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

Botryopyle dictyocephalus Haeckel, 1887
pl. 5, fig. 11; pl. 6, fig. 9, 12

1887 *Botryopyle dictyocephalus* sp. nov. - Haeckel
1971 *B. dictyocephalus* Haeckel - comb. nov. , 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. 54, 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: Eucephalic lobe is large, higher than antecephalic lobe. Thorax is subcylindrical form, with perforated plate wall. Pores are very small and numerous. Tube of antecephalic lobe is situated on the level of the basal plate.
Dimensions: Length of the shell 127 - 160, Width of the shell 95 - 130, Height of the Eucephalic lobe 55 - 73; height of the antecephalic lobe 36 - 65.

Genus *Saccospyris* Haecker, 1907

Type species: *Saccospyris antarctica* Haecker, 1907

Saccospyris antarctica Haecker, 1907
pl. 3, fig. 5

1907 *Saccospyris antarctica* sp. nov. - 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.
1968a *S. antarctica* Haecker - Petrushevskaya, p. 149 - 150.
1975 *S. antarctica* Haecker - Petrushevskaya, p. 589, pl. 13, figs. 21, 28.
1990 *S. antarctica* Petrushevskaya - Abelmann, p. 697.

Remarks: *S. antarctica* is less developed antecephalic tube and outer spines than in *S. preantarctica* Petrushevskaya, 1975
Dimensions (in ㎛): Length of the cephalis 65 - 90; length of the thorax 93 - 124.

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. Riedel & Sanfilippo, 1971
pl. 6, fig. 10 - 11

1971 *Carpocanarium* spp. - Riedel & Sanfilippo, p. 1599-1600, pl. 1I, figs. 17 - 25; pl. 2J, figs. 8, 9.

Remarks: Riedel & Sanfilippo(1971) are assigned to the Artostrobiidae, although genus *Carpocanarium* does not have the transversely aligned pores characteristic of most members of the Family. Nigrini & Lombari (1984) are assigned to the Family Carpocaniidae Haeckel 1881, emend. Riedel 1967b, by shell consists of cephalis and thorax, with the poreless peristome. This genus is distinguished from genus *Carpocanistrum* Haeckel, 1887, in distinct collor stricture.
Dimensions (in ㎛): Length of cephalis; 18 - 25, length of thorax; 64 - 71, maximum breadth of thorax; 59 - 68

Family LOPHOPHAENIDAE Haeckel, 1881

Genus *Arachnocorallium* Haeckel, 1881
Type species; *Arachnocorys hexaptera* Haeckel, 1887

Arachnocorallium spp. Petrushevskaya, 1975
pl. 2, fig. 1 - 2

1975 *Arachnocorallium* spp. - Petrushevskaya, pl. 9, figs. 17 - 19.
1984 *A.* spp. Petrushevskaya Westberg - Smith & Riedel, pl. 4, fig. 2.
1986 *A.* spp. Petrushevskaya - Mullineaux & Westberg - Smith, pl. 2, fig. 11
1989 *Peridium* spp. - Lazarus & Pallant, p. 358, pl. 2, figs. 13 - 16.

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. But, *A.* spp. is continuously yield in the Pohang Basin.
Dimensions (in ㎛): Length of cephalis 70 - 110; of thorax 26 - 40, Width of cephalis 61 - 100; of thorax 75 - 96

Family LYCHNOCANIIDAE Haeckel, 1881

Genus *Lychnocanium* Ehrenberg, 1847
Type species: *Lychnocanium fakiferum* Ehrenberg, 1854a, pl. 36, fig. 7

Lychnocanium grande Campbell & Clark, 1944
pl. 5, fig. 6

1944 *Lychnocanium grande* sp. nov. - Campbell & Clark, p. 42, pl. 6, fig. 3 - 6
1973 *Lychnocanoma grande* - Kling, p. 637, pl. 10, figs. 10 - 14
1985 *Lychnocanoma grande* - Perez-Guzman, p. 332, pl. 2, fig. 5

Remarks: This species is characterized by shorter horn, smaller cephalis.
Dimensions (in ㎛): Width of the thorax 119 - 125, length of the shell (including with apical spine and basal feet) 192 - 200.

Family PLAGIOCANTHIDAE Hertwig, 1879, emend. Goll, 1980

Genus *Callimitra* Haeckel, 1881, emend. Goll, 1980
Type species; *Callimitra carolatae* Haeckel, 1887, (by subsequent designation of Campbell, 1954)

Callimitra atavia Goll, 1980
pl. 7, fig. 11

1980 *Callimitra atavia* sp. nov. - Goll, p. 388, pl. 5, figs. 1, 5 - 9, 11.

Remarks: *C. atavia* is distinguished from other species by the composition and number of the lattice panels.
Dimensions (in ㎛): Maximum diameter of cephalis 91, width of thorax 117

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

Genus *Antarctissa* Petrushevskaya, 1967
Type species: *Lithobotrys denticulata* Ehrenberg, 1844

Antarctissa strelkovi Petrushevskaya, 1967
pl. 5, fig. 9

1908 *Helotholus histricosa* - 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* sp. nov. - 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: Shell consists of the two segments, with the by spine on the surface. Cephalis is separated from thorax by a slight constriction. The ratio of cephalis width to thorax width is 1:1.73. Pores on the cephalis and thorax are rounded and irregular arrangement.
Dimensions (in ㎛): Length of the cephalis 36-45; width of the cephalis 47 - 52, Length of the thorax 63 - 69; width of the thorax 79 - 84, overall length of the shell is up to 99 - 104.

Genus *Lithomelissa* Ehrenberg, 1847, emend. Petrushevskaya, 1971a
Type species: *Lithomelissa microptera* Ehrenberg, 1854a, pl. 36, fig. 2

Lithomelissa cheni Caulet , 1991
pl. 7, fig. 7 - 8, 10

1975 *Lithomelissa* sp. A aff. *L. ehrenbergi* (?) Butschli - chen, p. 458, pl. 11, figs. 1, 2.
1985 *Lithomelissa ehrenbergi* Butschli - Caulet, p. 853, table3, pl. 2, fig. 7
1991 *Lithomelissa cheni* sp. nov. - Caulet, p. 533, pl. 2, figs. 1, 2.

Remarks: *L. cheni* is also distinguished from *L. ehrenbergi* by a prominent horizontal vertical spine.
Dimensions (in ㎛): Length of apical horn 17 - 26; length of cephalis 36 - 45; length of thorax 69 - 76; Maximum breadth of cephalis 47 - 69; breadth of thorax 80 - 100.

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)
pl. 5, fig. 4

1963 *Sethocyrtis japonica* sp. nov. - Nakaseko, p. 176, pl. 1, fig. 10, fig. 6.
1973 *S. japonica* - Nakaseko & Sugano, 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.
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 conical thorax.
Dimensions (in ㎛): Length of the shell 106 - 115; length of the cephalis 30 - 41; length of the thorax 57 - 65

Genus *Lamprocyclas* Haeckel, 1881
Type species: *Lamprocyclas nuptialis* Haeckel, 1887, pl. 74, fig. 15

Lamprocyclas maritalis Haeckel, 1887
pl. 5, fig. 10

1887 *Lamprocyclas maritalis* sp. nov. - 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 & Lombari, N163, pl. 30, figs. 1a, b

Description: Shell is campanulate, divided into three segments. Cephalis is cylindrical and quadrangular with stout apical spine. Between the apical spine the cephalis has a hole. Collar and lumnar strictures are not distinct. Subterminal teeth on the abdomen just above the peristome are conical or thorn - like. Pores on the thorax

and abdomen are arranged to concentric circle over both two segments.
Dimensions (in ㎛): Total length 119 - 173, length of cephalis 27 - 36; length of thorax 45 - 63; length of a abdomen 45 - 72, Maximum breadth of thorax 81 - 90; breadth of abdomen 100 - 128.

Genus *Lipmanella* Loeblich & Tappan, 1961
Type species: *Lithornithium dictyoceras* Haeckel, 1860, p. 840

Lipmanella irregularis (Cleve, 1899)
pl. 7, fig. 5

1899 *Pterocorys irregularis* sp. nov. - Cleve, p. 32, pl. 4, fig. 1
1972 *Lipmanella irregularis* (Cleve)comb. nov. - Dumitrica, p. 840, pl. 25, fig. 2

Remarks: This species is characterized by poreless cephalis and thoracic spines.
Dimensions (in ㎛): Diameter of cephalis 30 - 35; width of thorax 75 - 85; width of abdomen 70 - 88, Length of thorax 50 - 55; of abdomen 40 - 50.

Family THEOPERIDAE Haeckel, 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 cornuta (Haeckel, 1887)
pl. 3, fig. 7 - 8; pl. 6, fig. 4 - 6

1887 *Cyrtocapsa (Cyrtocapsella) cornuta* sp. nov. - Haeckel, p. 1513, pl. 78, fig. 9
1970 *Cyrtocapsella cornuta* Haeckel comb. nov. - Sanfilippo & Riedel, p. 453, pl. 1, figs. 19 - 20
1984 *C. cornuta* Haeckel - Nigrini & Lombari, N101, pl. 23, fig. 1

Remarks: This species is distinguished from *C. tetrapera* in having the pronounced change in contour between the second and third segments, and third segment is wider than forth segment.
Dimensions (in ㎛): Total length (excluding horn) 173 - 190. Length of second segment 27 - 45; of third segment 59 - 65; of fourth segment 55 - 70, Maximum breadth 132 - 145.

Cyrtocapsella japonica (Nakaseko, 1963)
pl. 6, fig. 7

1963 *Eusyringium japonica* sp. nov. - 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 & Lombari, N107, pl. 23, figs. 4a - c

Remarks: This species is distinguished from *C. tetrapera* by having the aperture of the third segment constricted.
Dimensions (in ㎛): Total length 120-135, length of cephalis 11 - 25; length of the thorax 33 - 60; length of the abdomen 87 - 100.

Cyrtocapsella tetrapera Haeckel, 1970
pl. 3, fig. 9; pl. 6, fig. 1 - 3, 8

1970 *Cyrtocapsella tetrapera* sp. nov. - Haeckel
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 and third segments are wider than forth segment. Theyer et al. (1978) shows the first occurrence of *C. tetrapera* at 21.75 Ma and the last occurrence of this species at 11.95 Ma in Equatorial Pacific.
Dimensions (in ㎛): Total length (excluding horn and fifth segment) 207 - 240, length of second segment 32 - 45;length of third segment 44 - 60; length of fourth segment 49 - 75; length of fifth segment 59 - 87, Maximum breadth 103 - 115.

Genus *Eucyrtidium* Ehrenberg, 1847, emend. Nigrini, 1967
Type species: *Lithocampe acuminata* Ehrenberg, 1844

Eucyrtidium calvertense Martin, 1904
pl. 2, fig. 9

1904 *Eucyrtidium calvertense* sp. nov. . - 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.
1976 *E. calvertense* Martin - Weaver, p. 121, pl. 3, figs. 1, 2.
1990 *E. calvertense* Martin - Abelmann, p. 696, pl. 6, figs. 4, 5a - 5c.
1990 *E. calvertense* Martin - Lazarus, p. 716, pl. 6, figs. 4 - 6.

Remarks: This species is distinguished from *E. cienkowskii* by the relatively large size of the cephalis, and terminal of fifth segment is wider than *E. cienkowskii*.
Dimensions (in ㎛): Length of the shell 168 - 185, Width of the shell 109 - 130.

Eucyrtidium cienkowskii Haeckel, 1887
pl. 2, fig. 10 - 12; pl. 5, fig. 8

1887 cf. *Eucyrtidium cienkowskii* sp. nov. - Haeckel, p. 1493, pl. 80, fig. 9.
1927 cf. *Dictyomitra multicostata* - Lucchese, p. 106, pl. 8, fig. 8.

1973 *Eucyrtidium cienkowskii* Haeckel group - Sanfilippo et al., p. 221, pl. 5, fig. 7 - 11.
1975 *E. cienkowskii* Haeckel group - Chen, p. 495, pl. 15, fig. 7.
1976 *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.

Remarks: *E. cienkowskii* is distinguished by its inflated thorax, indented thorax - abdomen suture, generally a crock form post - thoracic shell, and strongly developed longitudinal pore rows.
Dimensions (in ㎛): Length of the shell 133 - 145; length of cephalis 16 - 20; length of thorax 24 - 36, Width of Maximum 69 - 100.

Genus *Theocorys* Haeckel, 1881
Type species: *Theocorys veneris* Haeckel, 1887, pl. 69, fig. 15

Theocorys redondoensis Campbell & Clark, 1944
pl. 5, fig. 5; pl. 7, fig. 1-3

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

Remarks: Wolfart (Leg.63) shows the first appearance of *T. redondoensis* within the *D. alata* Zone. This species is characterized by globular cephalis with sharp collar stricture and hemispherical thorax.
Dimensions (in ㎛): Total Length of the shell 173 - 200; length of cephalis 41 - 65; length of thorax 64 - 90; length of abdomen 78 - 100

Family TRIOSPYRIDIDAE Haeckel, 1881

Genus *Desmospyris* Haeckel, 1881
Type species: *Desmospyris mammilata* Haeckel, 1887, pl.83, fig.14

Desmospyris rhodospyroides Petrushevskaya, 1975
pl. 2, fig. 5

1972 (?) *Rhodospyris* sp.A, - Petrushevskaya & Kozlova, p.531, pl.38, fig.11
1975 *Desmospyris rhodospyroides* sp. nov. - Petrushevskaya, p.593, pl.10, figs. 27 - 29, 31, 32.

Description: Shell is smooth, divided into two-segmented. The sagittal ring is included the cephalic wall. Cephalis

is wider than thorax. The shell mouth is constricted, without any special tooth. Pores are irregular, rounded.
Dimensions (in ㎛): Length of the shell 160-196, Width of the shell 110 - 155

Desmospyris spongiosa Hays, 1965
pl. 3, fig. 4; pl. 7, fig. 4

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

Remarks: This species is similar to *D. rhodospyroides* Petrushevskaya, 1975.
However, the walls of *D. spongiosa* are spongy and thick.
Dimensions (in ㎛): Length of the shell 132 - 150, Width of the shell 106 - 125.

Genus *Triceraspyris* Haeckel, 1881
Type species: *Triceraspyris giraffa* Haeckel, 1887, pl. 84, fig. 11.

Triceraspyris antarctica Haecker, 1908
pl. 3, fig. 6

1908 *Triceraspyris antarctica* sp. nov. - 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.
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. Sagittal ring approximately D shape. The surrounding pores are rounded and irregular size. This species possesses three weak feet.
Dimensions (in ㎛): Width of the shell 98-120, length of feet 46 - 60.

Radiolaria

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Abstract: Radiolarian are holoplanktic protozoans with the widest biogeography, and they are preserved as radiolarian oozes. Radiolarians are used extensively in biostratigraphy, in paleoceanography ever since the Cambrian period of the Paleozoic era. Also, it is important to deeper regions than calcite compensation depth. Polycystine radiolarians are usually divided into spumellaria and nassellaria, based on a skeletal symmetry. Radiolarian first appeared in the Cambrian and the unquestionable nassellarians appear in the Triassic. In Korea, Kim (1965, 1984) is established

three biozones, one zone based on radiolarians and the other two zones based on foraminifers in the Yeonil Group of the Tertiary. Bak, *et al.* (1996, 1997, 1999) are collected to 325 samples at nine localities in the Pohang basin. They are identified to 103 species and 2 subspecies of radiolarians belonging to 56 genera from the Hagjeon and Duho Formations of the Yeonil Group.

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[Plate 1]

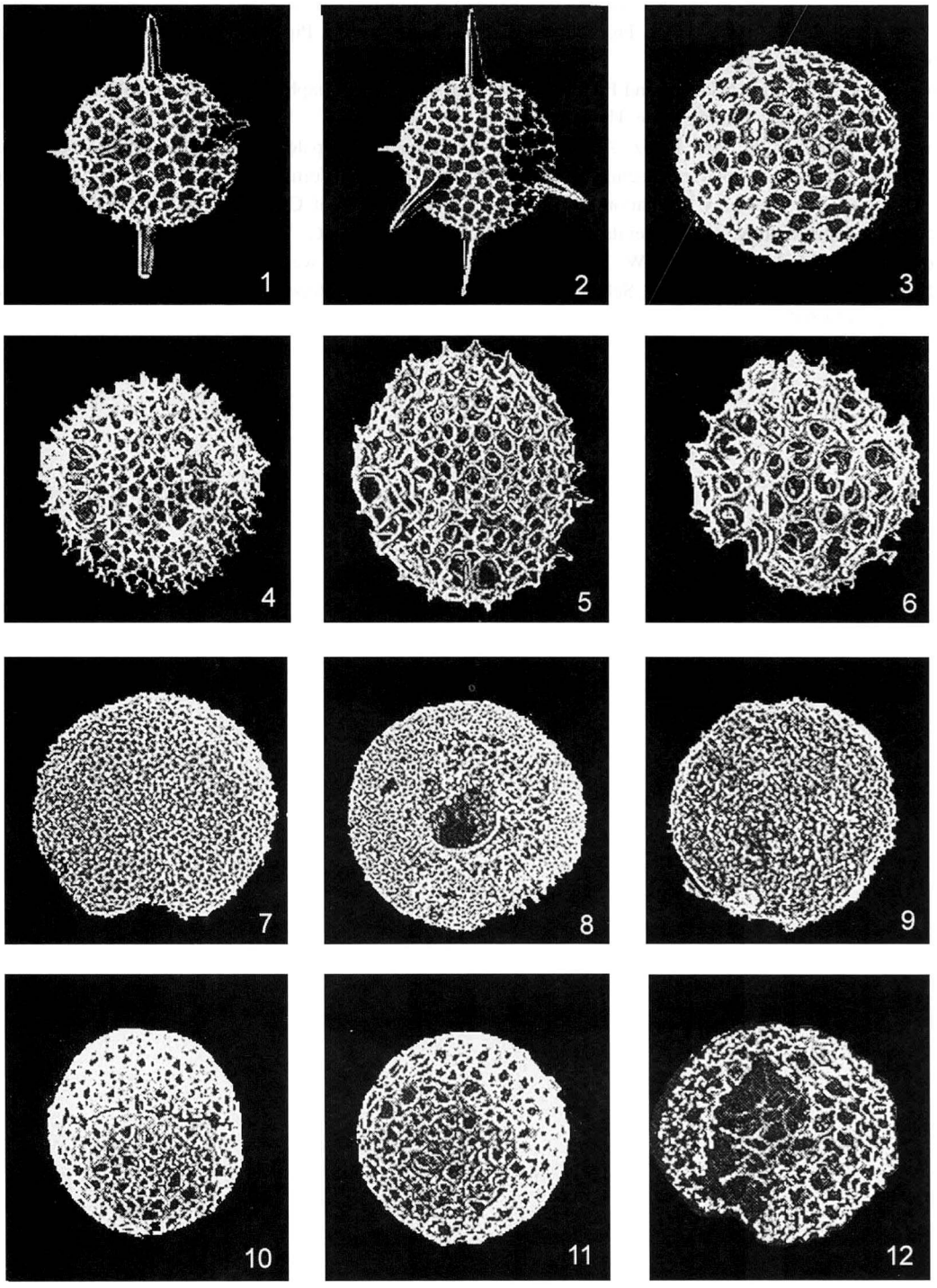

Fig. 1. *Actinomma* spp. Nigrini & Lombari, 1984, I16, X300. Fig.2. *A.* spp. Nigrini & Lombari, 1984, G54, X300. Fig.3. *A.* spp. Nigrini & Lombari, 1984, H31, X400. Fig.4. *Lithelius minor* Jorgensen, 1900, C41, X640. Fig.5. *L. nautiloides* Popofsky, 1908, C32, X360. Fig.6. *Styptosphaera spumacea* Haeckel, 1887, C51, X400. Fig.7. *Spongodiscus* spp. C31, X200. Fig.8. *Spongopyle osculosa* Dreyer, 1889, C41, X240. Fig.9. *Spongodiscus pulcher* Clark & Campbell, 1945, H15, X320. Fig.10. *Collosphaera* spp. H18, X300. Fig.11. *C.* spp. H17, X300. Fig.12. *Actinomma* spp. Nigrini & Lombari, 1984, G57, X400.

[Plate 2]

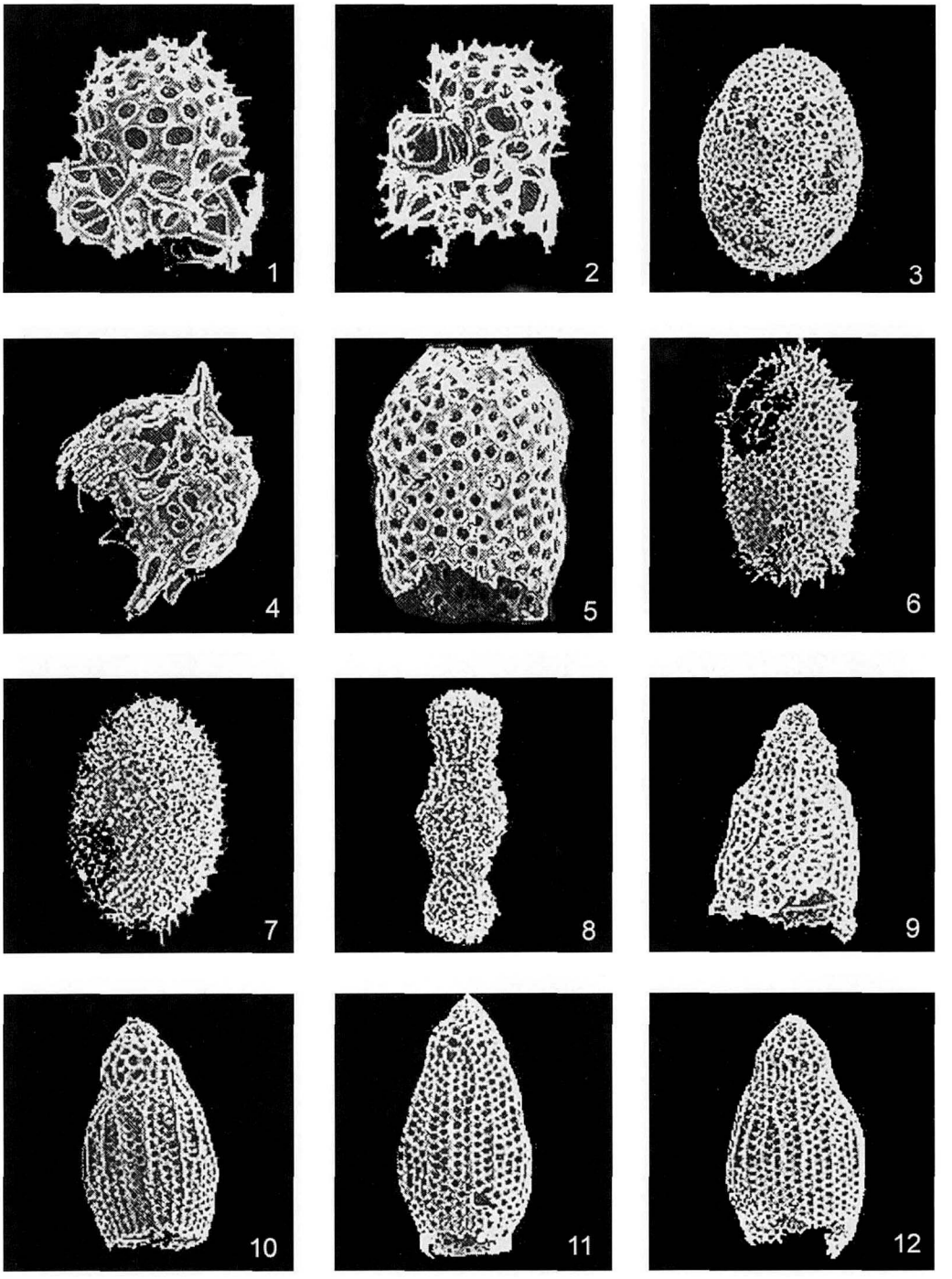

Fig.1. *Arachnocollarium* spp. Petrushevskaya, 1975, C32, X500. Fig.2. *A.* spp. Petrushevskaya, 1975, C41, X470. Fig.3. *Spongurus* sp.A Nigrini & Lombari, 1984, C31, X360. Fig.4. *Tholospyris cortinisca* (Haeckel, 1887) Goll, 1969, H14, X440. Fig.5. *Desmospyris rhodospyroides* Petrushevskaya, 1975, H14, X360. Fig.6. *Spongurus* sp.B Nigrini & lombari, 1984, G511, X360. Fig.7. *S.* sp.B Nigrini & lombari, 1984, C41, X360. Fig.8. *Spongocore cilindrica* (Haeckel, 1862) Nishimura & Yamauchi, 1984, H16, X300. Fig.9. *Eucyrtidium calvertense* Martin, 1904, H13, X320. Fig.10. *E. cienkowskii* Haeckel, 1887, G511, X360. Fig.11. *E. cienkowskii* Haeckel, 1887, H13, X350. Fig.12. *E. cienkowskii* Haeckel, 1887, H14, X320.

[Plate 3]

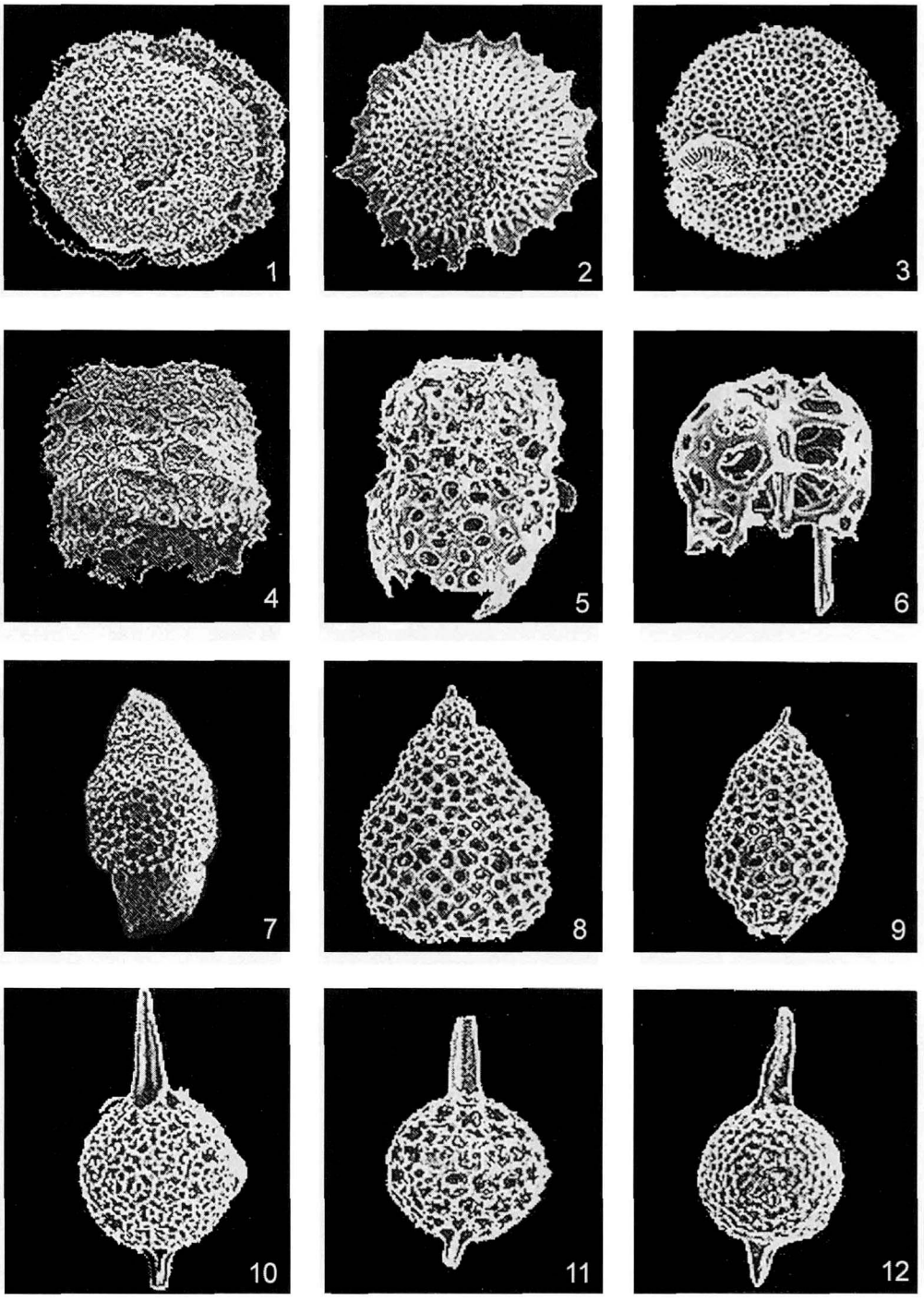

Fig.1: *Stylochlamydium asteriscus* Haeckel, 1887, H16, X240. Fig.2: *Periphaena decora* Ehrenberg, 1873, H11, X200. Fig.3: *Stylodictya validispina* Jorgensen, 1905, H111, X270. Fig.4: *Desmospyris spongiosa* Hays, 1965, H14, X260. Fig.5: *Saccospyris antarctica* Haecker, 1907, H13, X270. Fig.6: *Triceraspyris antarctica* Haecker, 1908, H17, X330. Fig.7: *Cyrtocapsella cornuta* (Haeckel, 1887) Sanfilippo & Riedel, 1970, H11,X160. Fig.8: *C. cornuta* (Haeckel, 1887) Sanfilippo & Riedel, 1970, H19, X220. Fig.9: *C. tetrapera* Haeckel, 1970, H17, X230. Fig.10: *Druppatractus nanus* Blueford, 1982, H12, X270. Fig.11: *D. nanus* Blueford, 1982, H14, X290. Fig.12: *D. irregularis* Popofsky, 1912, H111, X290.

[Plate 4]

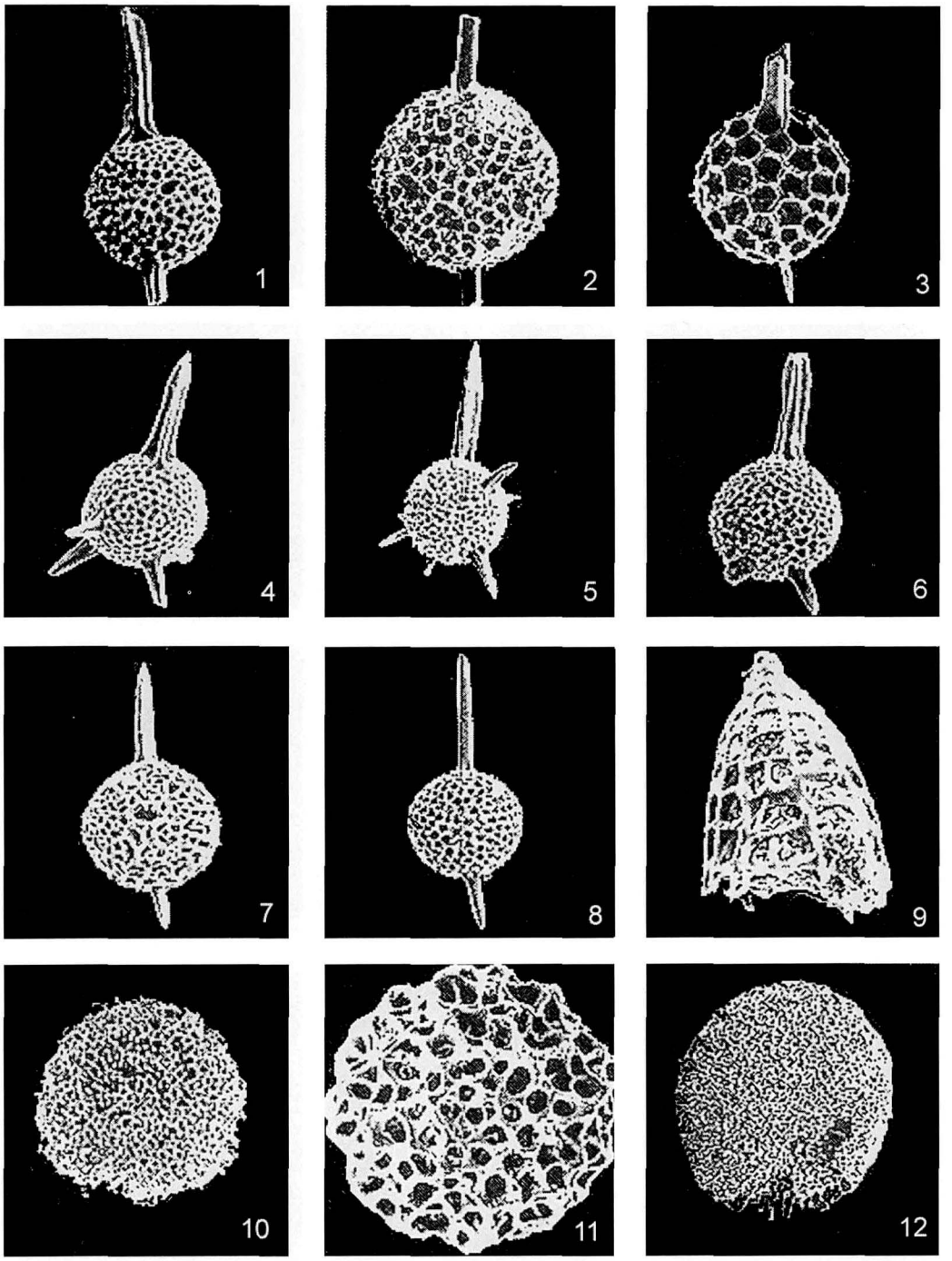

Fig.1. *Druppatractus irregularis* Popofsky, 1912, C32, X360. Fig.2. *Axoprunum angelinum* (Campbell & Clark) Kling, 1973, H14, X400. Fig.3. *Druppatractus nanus* Blueford, 1982, H12, X400. Fig.4. *Lithatractus timmsy* Campbell & Clark, 1944, C42, X320. Fig.5. *L. timmsy* Campbell & Clark, 1944, C51, X320. Fig.6. *L. timmsy* Campbell & Clark, 1944, I33, X320. Fig.7. *Druppatractus nanus* Blueford, 1982, H14, X360. Fig.8. *Stylosphaera minor* (Clark & Campbell, 1942) Blueford, 1988, H12, X190. Fig.9. *Peripyramis circumtexta* Haeckel, 1887, I52, X350. Fig.10. *Spongotrochus venustum* (Bailey, 1856) Nigrini & Moore, 1979, H316,X320. Fig.11. *Styptosphaera spumacea* Haeckel, 1887, C51, X200. Fig.12. *Spongopyle osculosa* Dreyer, 1889, I22, X240.

[Plate 5]

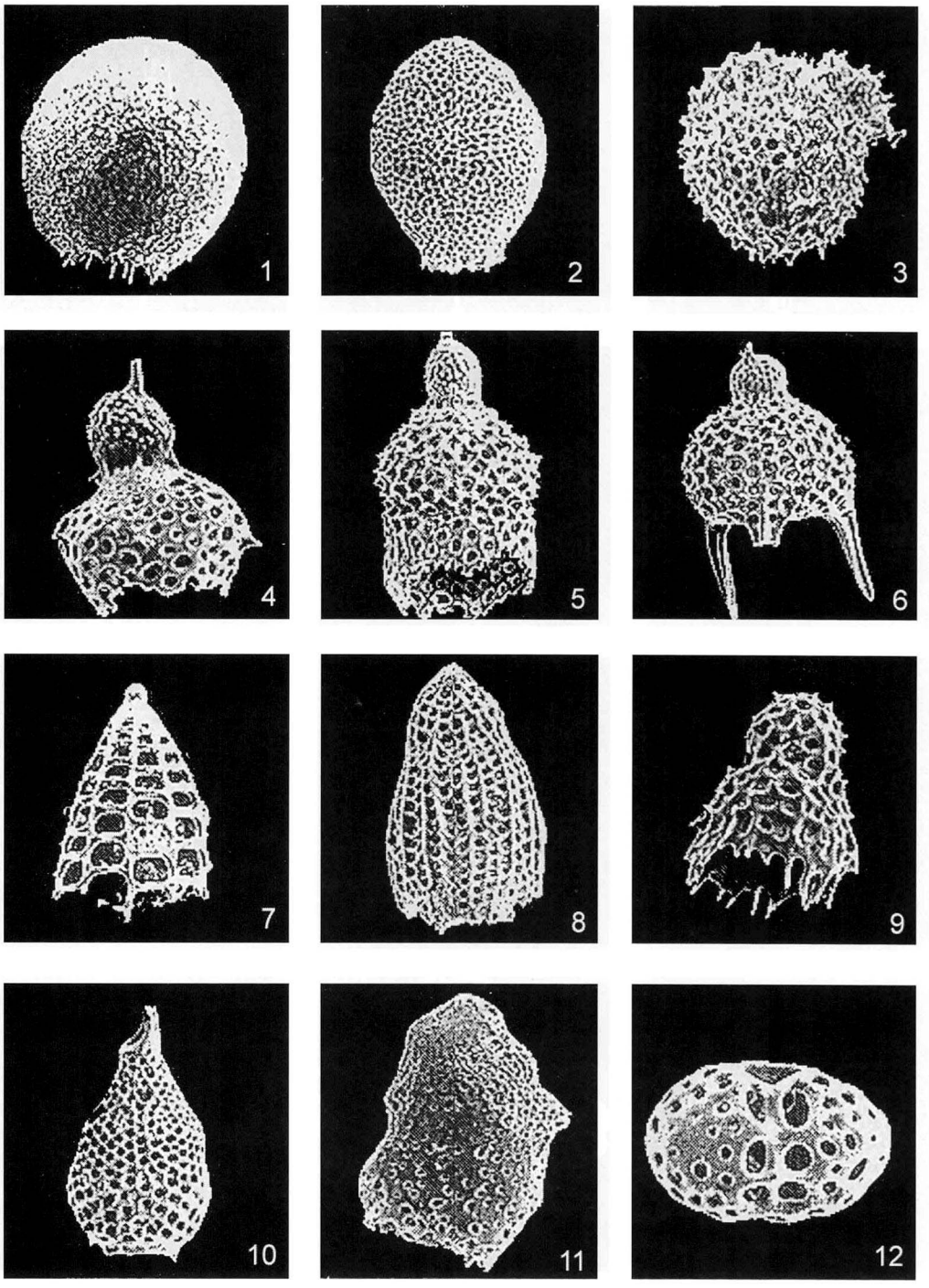

Fig.1: *Spongopyle osculosa* Dreyer, 1889, H13, X277. Fig.2: *Prunopyle titan* Campbell & Clark, 1944, H14, X240. Fig.3: *Lithelius nautiloides* Popofsky, 1908, H13, X330. Fig.4: *Gondwanaria japonica* (Nakaseko, 1963) Petrushevskaya, 1975, H17, X390. Fig.5: *Theocorys redondoensis* Campbell & Clark, 1944, H16, X260. Fig.6: *Lychnocanoma grande* Campbell & Clark, 1944, H14, X230. Fig.7: *Peripyramis circumtexta* Haeckel, 1887, H110, X350. Fig.8: *Eucyrtidium cienkowskii* Haeckel, 1887, H18, X260. Fig.9: *Antarctissa strelkovi* Petrushevskaya, 1967, H13, X360. Fig.10: *Lamprocyclas maritalis* Haeckel, 1887, H14, X230. Fig.11: *Botryopyle dictyocephalus* Haeckel, 1887, H17, X320. Fig.12: *Liriospyris mutuaria* Goll, 1968, H13, X300.

[Plate 6]

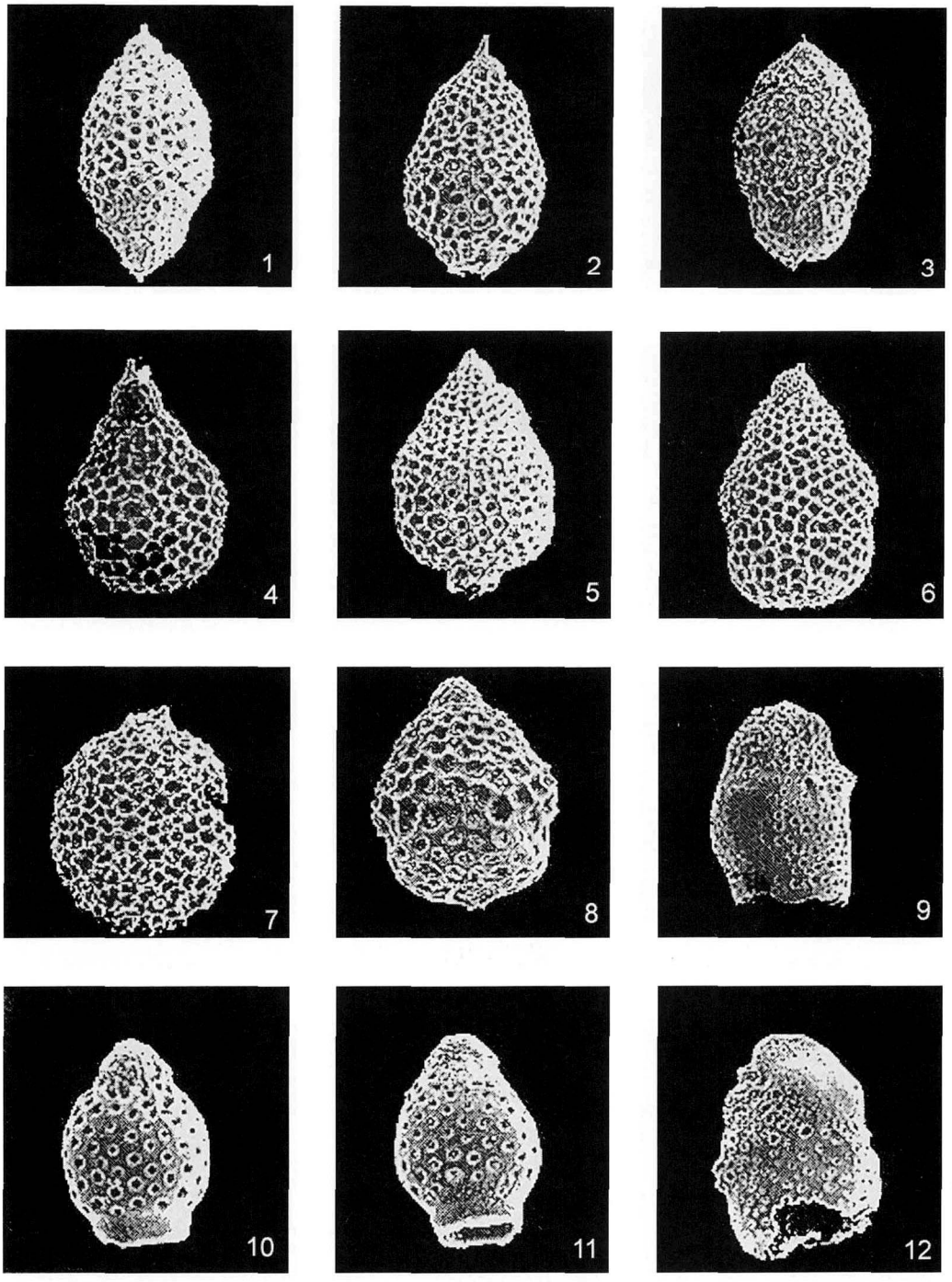

Fig.1. *Cyrtocapsella tetrapera* Haeckel, 1870, C41, X280. Fig.2. *C. tetrapera* Haeckel, 1870, C51, X330. Fig.3. *C. tetrapera* Haeckel, 1870, H17, X300. Fig.4. *C. cornuta* (Haeckel, 1887) Sanfilippo & Riedel, 1970, H11, X360. Fig.5. *C. cornuta* (Haeckel, 1887) Sanfilippo & Riedel, 1970, H11, X320. Fig.6. *C. cornuta* (Haeckel, 1887) Sanfilippo & Riedel, 1970, H11, X320. Fig.7. *C. japonica* (Nakaseko, 1963) Sanfilippo & Riedel, 1970, H18, X320. Fig.8. *C. tetrapera* Haeckel, 1870, H13, X400. Fig.9. *Botryopyle dictyocephalus* Haeckel, 1887, I22, X400. Fig.10. *Carpocanarium* spp. Riedel & Sanfilippo, 1971, C53, X560. Fig.11. *C.* spp. Riedel & Sanfilippo, 1971, I22, X480. Fig.12. *Botryopyle dictyocephalus* Haeckel, 1887, G511, X400.

[Plate 7]

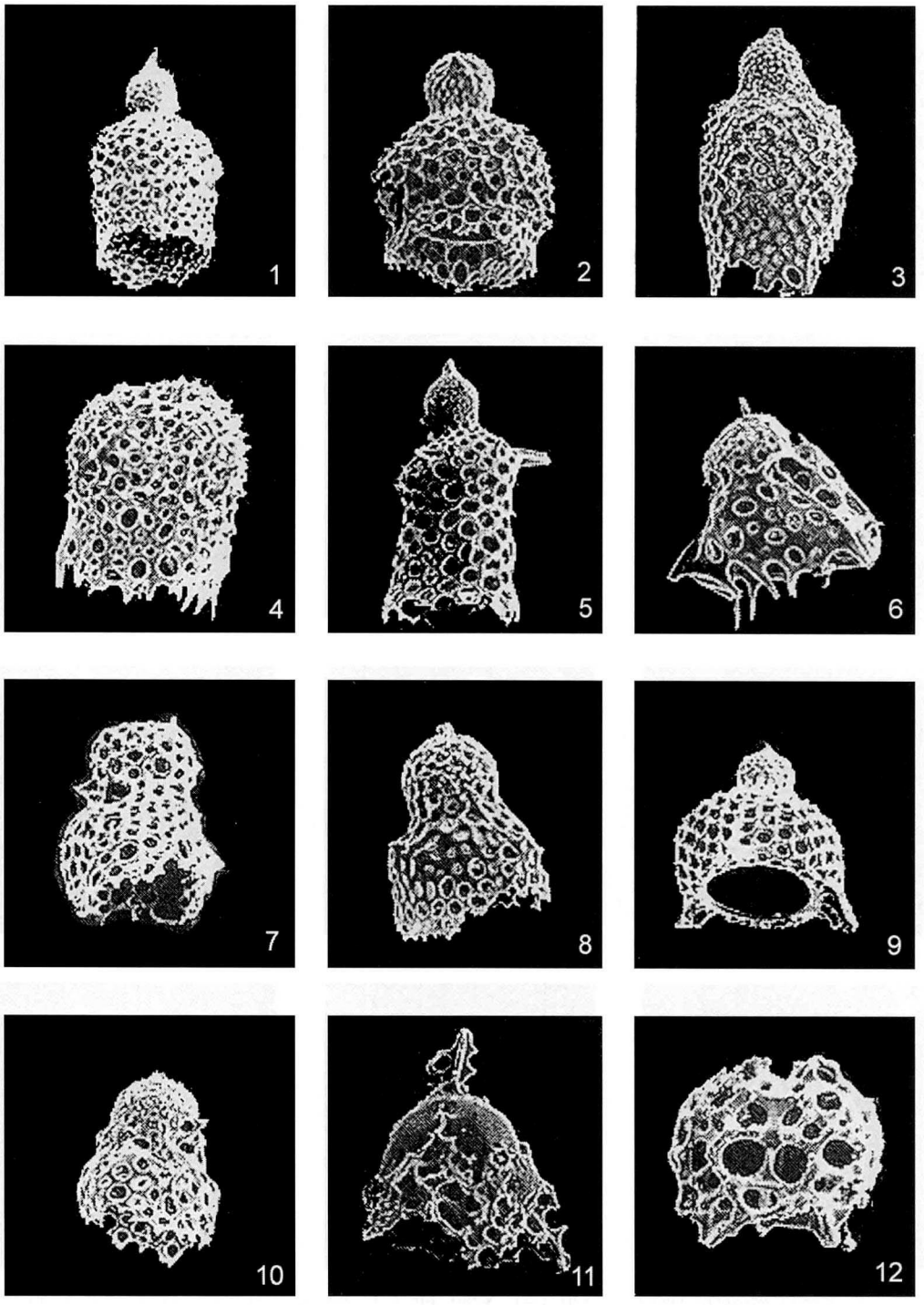

Fig.1. *Theocorys redondoensis* Campbell & Clark, 1944, H23, X320. Fig.2. *T. redondoensis* Campbell & Clark, 1944, I52, X360. Fig.3. *T. redondoensis* Campbell & Clark, 1944, H16, X300. Fig.4 *Desmospyris spongiosa* Hays, 1965, H13, X360. Fig.5. *Lipmanella irregularis* (Cleve, 1899) Dumitrica, 1972, I51, X300. Fig.6. *Dictyophimus* sp. H13, X420. Fig.7. *Lithomelissa cheni* Caulet, 1991, H13, X450. Fig.8. *L. cheni* Caulet, 1991, H18, X480. Fig.9. *Lychnocanium grande* Campbell & Clark, 1944, H14, X400. Fig.10. *Lithomelissa cheni* Caulet, 1991, H111, X400. Fig.11. *Callimitra atavia* Goll, 1980, H13, X350. Fig.12. *Trissocyclid* sp. H18, X480.