

## 25. CENOZOIC ENDOSKELETAL DINOFLAGELLATES IN SOUTHWESTERN PACIFIC SEDIMENTS CORED DURING LEG 21 OF THE DSDP

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### INTRODUCTION

The siliceous spicules of the endoskeletal dinoflagellates constitute a rather significant portion of the assemblage of siliceous microfossils in southwestern Pacific sediments. Although represented by few taxa, their provocative occurrence among radiolarians, silicoflagellates, and other microfossils of increasing interest for biostratigraphy has tempted us to test their potential as supplementary indicators of age. Such work was facilitated by the long sequence of Upper Oligocene-Quaternary sediments cored almost continually at Site 206, and by other sequences of Eocene and Paleocene age cored at Sites 206, 207, and 208, where the siliceous remains constitute a common or a major organic component. The only difficulty was the inadequacy of the taxonomic system currently in use for some of these dinoflagellates, and insufficient knowledge of their morphology and structure.

In this circumstance, before testing the biostratigraphic value of this group, we had to investigate the structure of the star-like spicules known as *Actiniscus*, the most frequent and interesting fossil endoskeletal dinoflagellate, as a basis for a new systematics.

In order to have a better knowledge of this group, the following supplementary samples have been investigated as well:

1) *Oamaru Diatomite* member of Waiareka Volcanic Formation, Taylor's quarry section, Cormacks Siding, New Zealand; sample number S 136/888, Col. A. R. Edwards and N. de B. Hornibrook, 1966. Age: Early Runangan (Upper Eocene).

2) *Egerian* (Upper Oligocene), Wallern, Austria, Col. Alfred Bachmann.

3) *Lower Badenian* (Middle Miocene) from Ameis, Austria, Col. A. Bachmann. Both localities are listed in Bachmann (1970, p. 3-5).

4) *Radiolarian Schist Horizon*, Middle Miocene (*Canartus laticonus* Zone), Subcarpathians, Romania; Col. P. Dumitrică; sample nr. 808, Pluta Valley, locality of Chiojdeanca, district of Prahova; sample nr. 1315, Tilvici Valley, Păusesti Otăsău, district of Râmnicu Vilcea.

5) *Lower Sarmatian diatomite*, Gropoiu Valley, locality of Cărand (Karand, Hungary, in the previous papers of authors), district of Arad, Romania.

### MORPHOLOGY AND STRUCTURE OF THE SILICEOUS ENDOSKELETAL DINOFLAGELLATES

The endoskeletal dinoflagellates constitute a very small group known in the literature as the family *Gymnosclerotidae* Schiller. Four genera, *Plectodinium* Biecheler, *Achradina* Lohman, *Monaster* Schütt, and *Amphitholus* Schütt, are exclusively living (Chatton, 1953, p. 334,335),

and have a mineralized skeleton of unknown composition. A single species of the genus *Actiniscus*, found in both living and fossil state, contains a skeleton consisting of opaline silica.

In the Tertiary there were many more species with siliceous endoskeletons. They belonged to at least four genera: *Actiniscus* Ehr., *Foliactiniscus* n. g., *Cinctactiniscus* n. g., *Carduifolia* Hov. A fifth genus, *Calicipedinium* n. g., might be doubtfully assigned to the same group. All these genera have a few common elements: a curved siliceous spicule consisting of a central body from which depart commonly four or five tricostrate arms. In such a spicule a convex or external surface and a concave or internal surface may be distinguished. The generic differences concern some structural and morphological characteristics such as structure of the central field, position of the median crest of the arms, and type of connection of these crests to the central field.

Most species exhibit a bilateral symmetry—all the species of *Carduifolia*, *Cinctactiniscus*, *Foliactiniscus*, one species of *Actiniscus*, and one of *Calicipedinium*. The radial symmetry is characteristic for the other species of *Actiniscus* and *Calicipedinium*.

The structure and superficial ornamentation of the spicules are quite characteristic in some genera. Their study might suggest some phylogenetic relationships between different genera or between these dinoflagellates and other flagellates.

Some spicules may have a smooth surface. This is, for example, the case with *Calicipedinium* and some *Carduifolia*, *Actiniscus*, etc. The young specimens of many species, even of those with a very complicated structure, may exhibit a smooth surface.

Most specimens and species have a wrinkled surface. Wrinkles are transverse and are developed in the furrows between the longitudinal crests. When they are more pronounced they limit circular or oval depressions. *Carduifolia* and *Cinctactiniscus* are characterized by this ornamentation. Almost all the species of *Actiniscus* and *Foliactiniscus* may have also an ornamentation of this type, either on the whole spicule or only on the median and distal part of the arms.

A similar ornamentation is exhibited by some ebridians of the genera *Hermesinum*, *Podamphora*, and *Podamphoropsis*, whose skeletons are also tricostrate. It probably reflects, on another plane, the close relationships between ebridians and dinoflagellates, demonstrated by the nuclear characters and by the two flagella.

The most complicated structure of the actiniscids is the alveolar structure. It is peculiar only to most species of *Actiniscus* and *Foliactiniscus* and may affect either only the central body of the spicule or the whole skeleton. It

gradually pervades the skeleton from the center to the distal end of the arms. Such a structure makes the spicules much lighter, and is probably much more favorable to the species than a massive structure. The species with alveolar structure are, for example, much more frequent in the Neogene than in the Oligocene.

The complications introduced by this structure greatly hampered its deciphering by previous authors. It is to be noted first that the skeleton of *Actiniscus* and *Foliactiniscus* is not finely canaliculated as Frenguelli (1940) affirmed. The canalicules he claimed to exist in the median crests and in many parts of the skeleton are the thin walls separating the alveoli. In transmitted light they darken the shell because along them light has to pass through a thicker mass and therefore diminishes.

The alveolar structure is actually rather simple (Figure 1). It is derived from the wrinkled structure. A gradual passage may be followed along an arm, from faint transverse wrinkles (ridges) at the distal end, to high transverse walls with expanded crests around the center of the spicule. The alveoli are separated from one another by thin walls and are open only at the outer end. Their opening is more or less constricted varying with the specimen or with its distance from the center. The best developed alveoli are the central or apical alveola and the first row of 4 to 6 alveoli around it. In apical view the expanded distal end of the walls limiting the central amphora-shaped alveola appears like a ring with polygonal contour and circular opening. It is the apical plate or ring of previous authors (Gemeinhardt, 1931; Hovasse, 1932a). It is not a true ring resulting from connection between the high corners of the radial crests, but just the rim of the apical alveola, as was proved above (see Plate 1, Figure 20; Plate 2, Figure 12).

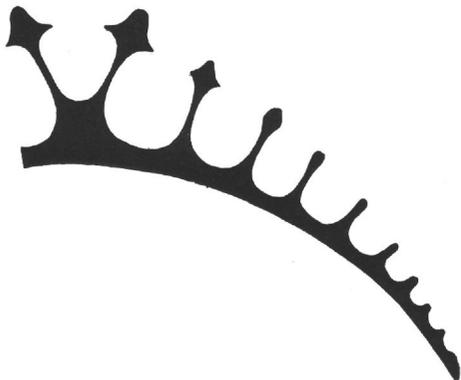


Figure 1. Axial section through a spicule of *Actiniscus* showing the passage from the alveolar structure, in the center, to the wrinkled structure on the arms.

#### ENDOSKELETAL DINOFLAGELLATES IN THE SOUTHWESTERN PACIFIC

In the Southwestern Pacific sediments cored in Leg 21, the occurrence of the endoskeletal dinoflagellates coincides

with the three groups of siliceous sequences: Early-Middle Paleocene, Middle Eocene, and Late Oligocene-Quaternary.

1) *Early-Middle Paleocene sediments* bearing siliceous microfossils have been cored at Site 208 (Cores 29-32). Only the core catcher samples have been investigated for endoskeletal dinoflagellates. They contain few specimens of *Carduifolia onopordoides* and *C. ex gr. lata*.

2) *Middle Eocene sediments* bearing siliceous microfossils have been cored at Sites 206C, 207A, and 208. The assemblage is generally as poor as the previous one. *Carduifolia ex gr. lata* and *Carduifolia sp.* were the only endoskeletal dinoflagellates recorded.

3) *Late Oligocene-Quaternary* sediments cored at Site 206 were most interesting for the subject under discussion. All the species of the genera *Actiniscus*, *Foliactiniscus*, and *Cinctactiniscus* described in this paper are based on samples from this sequence. Their distribution is given in Figure 2.

#### SYSTEMATICS

##### PYRRHOPHYTA

##### Class DINOPHYCEAE

##### Order GYMNODINIDA

##### Family ACTINISCIDAE Kützing

*Actiniscaceae* Kützing, 1849. Species Algarum (cf. Frenguelli, 1940, p. 107).

*Gymnosclerotidae* Schiller, 1935; Chatton, 1953.

*Carduifoliidae* Hovasse, 1943.

**Remarks:** All the genera under discussion in this paper appear to belong to this family. This systematic position is undoubted for *Actiniscus*, *Foliactiniscus*, and *Cinctactiniscus*, that constitute a fairly homogenous group. *Carduifolia* was placed by Hovasse (1943) in a particular family, *Carduifoliidae*. As will be demonstrated below, *Carduifolia* shows a rather close morphological resemblance to *Cinctactiniscus* and may be thus considered as an actiniscid. If *Calicipedinium* is a dinoflagellate, its place beside the four genera should be logical.

All these genera are characterized by a spicule with an apical central body from which depart four to six tricostrate arms. If only the siliceous spicules of the fossil forms are taken into account, the family Actiniscidae would appear much more homogenous than the family Gymnosclerotidae, erected especially for living species.

##### Genus ACTINISCUS Ehrenberg

*Actiniscus* Ehrenberg, 1840, Abh. Preuss. Akad. Wiss., 1839, p. 111, 149 (fide Loeblich, A. R., Jr. and Loeblich, A. R., III, 1966, p. 14); Frenguelli, 1940; Deflandre, 1953.

*Gymnaster* Schütt, 1891 (fide Loeblich, A. R., Jr. and Loeblich, A. R., III, 1966, p. 33); Hovasse, 1932a, 1932b; Deflandre, 1932; Schiller, 1935.

*Microdistephanus* Filipescu, 1943, p. 265; Filipescu, 1959.

*Lutetianella* Filipescu, 1943, p. 265; Filipescu, 1959.

?*Diaster* Meunier, 1910, p. 83, 84.

**Type species:** *Actiniscus pentasterias* Ehrenberg, 1840.

**Diagnosis:** Star-shaped siliceous skeleton with four to six curved and tricostrate radial arms; two crests are situated in the basal plate of the star; the third being on the convex side and originating in a button-like central body. With or without alveolar structure.

**Remarks:** Several observations should be made concerning the synonymy list. *Gymnaster* Schütt is illegitimate and must be rejected (cf. I.C.B.N., Art. 63; I.C.Z.N., Art. 24b). It was described on a living *Actiniscus pentasterias* Ehr.

*Microdistephanus* Filipescu (1943, 1959) with its four species (*stellatus*, *pentaradiatus*, *hexaradiatus*, *ellipticus*) is *Actiniscus* in axial view and very schematically drawn. None of these species are new. Most parts of them may be recognized in Ehrenberg's figures.

*Lutetianella* Filipescu (1943, 1959), also very schematically drawn, is also *Actiniscus* but in lateral view. Its diadem-shaped

		Age		Genus	Species	Sample
		Early	Late			
		206-5, CC				
		206-6, CC				
		206-7, CC				
		206-8, CC				
		206-9, CC				
		206-10, CC				
		206-11, CC				
		206-12, CC				
		206-13, CC				
		206-14, CC				
		206-15, CC				
		206-16, CC				
		206-17, CC				
		206-18, CC				
		206-19, CC				
		206-20, CC				
		206-21, CC				
		206-22, CC				
		206-23, CC				
		206-24, CC				
		206-25, CC				
		206-26, CC				
		206-27, CC				
		206-28, CC				
		206-29, CC				
		206-30, CC				
		206-31, CC				
		206-32, CC				
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		206-34, CC				
		206-35, CC				
		206-36, CC				
		206-37, CC				
		206-38, CC				
		206-39, CC				
		206-40, CC				
		206-41, CC				
		206-42, CC				
		206-43, CC				
		206-44, CC				
		206-45, CC				
		206C-1, CC				
		206C-2, CC				
		206C-3, CC				
		206C-4, CC				
		206C-5, CC				
		206C-6, CC				
		206C-7, CC				
		206C-8, CC				
		206C-9, CC				
		206C-10, CC				
		206C-11, CC				

Figure 2. Distribution of endoskeletal dinoflagellates in Upper Oligocene-Quaternary samples at Site 206.

skeleton represents two opposite arms. Our affirmations concerning the systematic situation of these two genera are based on study of the original thin sections.

As for *Diaster* Meunier, the five- and six-armed skeletons resemble young skeletons of *A. pentasterias*; the nuclear and cytoplasmic characteristics should also argue this synonymy (Hovasse, 1932b).

The distinctive peculiarity of this genus, a peculiarity which differentiates it from *Foliactiniscus*, is the presence of a button-like central body, from which the median crests of the arms depart. This salience is very distinct. In axial view it appears like a dark polygonal small area, sometimes with lighter center. The number of corners of this salience is equal to the number of the arms (Plate 2, Figure 6, 7, 10; Plate 3, Figures 11, 14-16), and the lighter center results from its concave top (Plate 2, Figures 8, 9; Plate 3, Figures 1, 2, 4, 5). In the specimens with alveolar structure this salience serves as support for an amphora-shaped central alveola. It is simple in *A. pentasterias* (Plate 2, Figure 9) and mostly double in *A. radícula*. In the specimens lacking an alveolar structure the central alveola is lacking as well: there is only a depressed surface (see, for example, Plate 3, Figures 11, 15-18).

In the specimens with alveolar structure the central alveola is surrounded by a row of peripheral alveoli, the number of which is equal to the number of arms. These alveoli are disposed in the interradial spaces. Their distal wall forms on the plate a large ring when seen in apical view. Beyond this ring, when the star plate is completely or almost completely alveolar, the alveoli are disposed only on the two lateral sides of the median crests of the arms. The peripheral ring results from the connection of the first proximal row of transverse ridges.

The external borders of the median crests are thickened and show a fringed contour. The highest points represent the place of origin of the transverse ridges of the arms, and may sometimes be very long or even highly ramified as in *A. radícula*.

The number of arms varies in this genus from four to six. When there are more arms, the supplementary ones originate from branching of the radial arms, the center remaining unchanged. Forms with twelve arms, as illustrated by Frenguelli (1940, p. 109, fig. 38H), do not exist. They are double skeletons such as that illustrated in Plate 5, Figure 7 of the present paper. Such skeletons are frequently found in this genus (see also Plate 3, Figure 6).

At least four species belong to this genus: *A. pentasterias* Ehr., *A. radícula* n. sp., *A. tetrasterias* Ehr., *A. elongatus* Dum., and probably *A. percurvatus* (Hov.). *A. elegans* Ehr. is probably a well-developed *A. pentasterias*. The six-armed forms known as *A. sirius* Ehr. and some of the four-armed forms are probably simple varieties of *A. pentasterias*.

**Geologic range:** Deflandre (1953) writes that *Actiniscus* is known from Cretaceous. To our knowledge this is the only mention that this genus extends that far back. We have found no specimen of *Actiniscus* in the Eocene and Paleocene sediments available for study. The oldest occurrence of it was recorded in the Late Oligocene; this refers to very rare small *A. pentasterias* and *A. tetrasterias*. Their number increases slightly in the Early Miocene, becomes exceedingly high during the Middle and Late Miocene and Early Pliocene, and decreases again in Late Pliocene and Quaternary.

#### *Actiniscus pentasterias* Ehrenberg

(Plate 2, Figures 2,3, 6-11, 14; Plate 3, Figures 13, 14; Plate 5, Figures 6-8)

*Actiniscus pentasterias* Ehrenberg, 1854, pl. 18, fig. 61; pl. 19, fig. 45; pl. 20, fig. 48; pl. 33 (XVII), fig. 1; pl. 35A (XXIII), fig. 1; pl. 36, fig. 36; Frenguelli, 1940, p. 109, fig. 38A; Frenguelli, 1941, p. 97, pl. 1, figs. 10,11; Hajós, 1968, p. 53, pl. 3, figs. 1-4. *Gymnaster pentasterias* (Ehr.), Schütt, 1895 (fide Chatton, 1953, fig. 238A, B); Wright, 1907 (fide Deflandre, 1932, fig. 40); Gemeinhardt, 1931, pl. 10, figs. 9-11; Hovasse, 1932a, p. 128, fig. 11a, b; Rampi, 1941, p. 293, fig. 13; Hovasse, 1946, p. 16, fig. 5b; Colom, 1946, pl. 2, fig. 51.

? *Actiniscus sirius* Ehrenberg, 1854, pl. 18, figs. 59,60; pl. 33 (XV), fig. 1; Frenguelli, 1940, p. 109, figs. 38 E, F.

? *Actiniscus elegans* Ehrenberg, 1854, pl. 22, fig. 51; Frenguelli, 1940, p. 109, fig. 38C, D; Dumitrică, 1968, p. 234, pl. 4, figs. 21, 23, 25.

*Actiniscus stella* Ehr., Frenguelli, 1940, p. 109, fig. 38 B.

*Stephanogonia danica* Grev., Cleve-Euler, 1941, p. 182, pl. 16, figs. 102, 103.

**Description:** Skeleton constituted of a star-shaped concave plate with five arms, rarely with six or four. Commonly with alveolar structure, except for young specimens, consisting of a central amphora-shaped alveola supported by a central massive protuberance and surrounded by five, rarely six or four peripheral alveoli. The arms are of varying length depending on specimens and age. They may also have an alveolar structure or only simple transverse wrinkles between the median and lateral crests, or may have both kinds of structure—an alveolar structure at the proximal ends gradually passing to wrinkles toward the distal ends.

**Dimensions:** Distance between two opposite arms 20 to 44 $\mu$ . Very young specimens are certainly smaller.

**Remarks:** *A. pentasterias* exhibits a wide variability in ornamentation, size, number of arms, and their curvature. It is possible that some of them should be distinguished as independent taxa of subspecific rank. The species was recorded from the Upper Oligocene to Quaternary at Site 206.

#### *Actiniscus radícula* n. sp.

(Plate 2, Figures 15-17; Plate 3, Figures 1-5; Plate 5, Figure 4)

**Description:** Skeleton strongly developed in apical and antapical direction, constituted ordinarily of five unequal arms downwardly directed. The arms are straight or slightly curved and massive. Their median crests are armed with simple or ramified long spines. The spines are very well developed on the apical part of the skeleton, where the apical alveola is surrounded by massive, long, and highly ramified apophyses. The alveolar structure is limited particularly to the central part of the skeleton. It consists of a simple or double amphora-shaped apical alveola surrounded by five peripheral alveoli, some of them with very constricted opening. Many specimens may have also a row of external alveoli located at the proximal ends of the arms on both sides of the median crests.

**Dimensions:** Height of skeleton 55 to 80 $\mu$ .

**Remarks:** This is the most aberrant species of *Actiniscus*. It was recorded between 206-23, CC and 206-18, CC, namely in Late Miocene and Early Pliocene, but the best developed and most frequent specimens occur in the late Miocene at 206-22, CC. Below and above this level the frequency of the species decreases rapidly and most specimens have less developed apophyses.

#### *Actiniscus elongatus* Dumitrică

(Plate 3, Figures 6-12; Plate 5, Figures 10, 11)

*Actiniscus elongatus* Dumitrică, 1968, p. 240, pl. 4, figs. 22, 26.

**Description:** Star-like skeleton consisting of an elongate pentagonal plate with bilateral symmetry, from the corners of which depart five curved arms situated two at one extremity of the plate, three at the other extremity. The median crests of the arms are connected apically by crests forming an elongate pentagon with concave surface. This depression may be simple or divided transversely by one or two wrinkles. No alveolar structure was observed. The arms may have a smooth surface or be covered with transverse wrinkles. The lateral and particularly the median crests of the arms commonly have a fringed contour, sometimes with knobbed spines.

**Dimensions:** Span of skeleton in longitudinal direction 20 to 48 $\mu$ .

**Remarks:** Double skeletons have sometimes been observed. The two skeletons are disposed face to face by their concave sides, in the same relation as the object and its image in a mirror (Plate 3, Figure 6).

At Site 206 this species has an occurrence generally limited to the interval Middle Miocene-Early Pliocene.

#### *Actiniscus tetrasterias* Ehrenberg

(Plate 3, Figures 15-18; Plate 5, Figure 9)

*Actiniscus tetrasterias* Ehrenberg, 1854, pl. 18, fig. 62; Dumitrică, 1968, pl. 4, fig. 24.

*Actiniscus* — Stern, Gemeinhardt, 1931, pl. 10, fig. 8.

**Description:** Star-shaped skeleton with four curved, equal arms. The apical part of the star is a squarish truncate pyramid with concave surface, sometimes with a minute central pit. From the high

corners of this pyramid depart the four median crests of the arms. They have a smooth or, more frequently, a fringed external contour. Outer surface of the arms is smooth or covered with transverse wrinkles, never with alveolar structure.

**Dimensions:** Distance between two opposite arms 17 to 23 $\mu$ .

**Remarks:** Hovasse (1932a) included the four-armed skeletons in *A. pentasterias*. However, there is nothing to prove that the four-armed and five-armed skeletons are conspecific. First, there is a difference in size, *A. tetrasterias* being generally smaller than *A. pentasterias*. There is also a structural difference. We have never found skeletons of *A. tetrasterias* with alveolar structure, which is common in *A. pentasterias* with its pentagonal and hexagonal varieties. Of course it is possible that some four-armed skeletons should be varieties of *A. pentasterias*, but most of them appear to be a distinct species.

*A. tetrasterias* was found from the base of the *Lychnocanoma elongata* Zone to Quaternary. At Site 206 it was generally a sparse species, except for a short interval in the Late Pliocene-Early Pleistocene (206-13, CC to 206-11, CC), where it is one of the most frequent actiniscids.

#### Genus FOLIACTINISCUS new genus

**Type species:** *Actiniscus folia* Hovasse, 1943.

**Diagnosis:** Star-shaped siliceous skeleton bilaterally symmetrical, with five curved and tricostrate arms. Two crests of the arms are lateral and in the plane of the plate, the third is normal to it and situated on the convex side. The median crests are connected with one another as follows—from a point situated slightly eccentrically depart three crests; one constitutes the median crest of the odd arm, the other two bifurcate rapidly, each bifurcation constituting the median crest of one of the four paired arms. The plane of bilateral symmetry passes through the odd arm. With or without alveolar structure. When there is an alveolar structure, except for other less important alveoli situated along the arms, there are five alveoli on the central plate—four equal and symmetrically disposed in the intercrestal space, and a larger odd alveola cut by the plane of symmetry and located in the angle between the two short central crests.

**Remarks:** This genus, superficially similar to *Actiniscus* in its alveolar structure and having five arms, is distinguished from it by the type of connection of the median crests to the center. In this genus there is no central protuberance supporting a central alveola, when there is an alveolar structure. This difference is very obvious by comparison of the specimens illustrated in Plate 1, Figure 20, representing a *Foliactiniscus*, and Plate 2, Figure 9, representing an *Actiniscus*.

It is possible that *Foliactiniscus* should have been the ancestral type for *Actiniscus*. The apical alveola of the latter would have derived from the larger alveola of the former by its closing on the external side, opposite to the odd arm. The specimen illustrated in Plate 1, Figure 12 would be a suggestive example of this supposition. Such a possible phylogenetic relationship would be also supported by the much higher frequency of *Foliactiniscus* in Oligocene and lower part of the Early Miocene.

**Geologic range:** At Site 206 *Foliactiniscus* was found from the Late Oligocene to Quaternary.

#### *Foliactiniscus folia* (Hovasse)

(Plate 1, Figure 11)

? *Gymnaster folia* Hovasse, 1943, p. 278, fig. 1.

*Gymnaster folia* Hovasse var. *hellenica*, Hovasse, 1943, p. 278, fig. 2.

**Description:** Palmate skeleton with five long, arcuate arms. Median crests united to the central crests as in the generic diagnosis. Without alveolar structure. The ornamentation of the convex side consists of transverse wrinkles.

**Dimensions:** Distance between two opposite arms 30 $\mu$ .

**Remarks:** A single specimen was found in sample 206-31, CC. It resembles perfectly *G. folia* var. *hellenica*.

#### *Foliactiniscus pyramis* n. sp.

(Plate 1, Figures 14-17)

**Description:** Pyramidal skeleton with smooth edges, with four better developed arms, the fifth, namely the odd arm, much shorter.

The alveolar structure limited to five central alveoli. The arms are either smooth or with a few transverse wrinkles.

**Dimensions:** Height of skeleton 24 to 30 $\mu$ , distance between two opposite arms 24 to 32 $\mu$ .

**Remarks:** This species was recorded only in 206C-3, CC and 206-45, CC.

#### *Foliactiniscus pannosus* n. sp.

(Plate 1, Figures 18, 19, 21-23; Plate 2, Figures 1, 5)

**Description:** Shell robust, with five unequal arms downwardly directed. Median crests strongly developed in the apical region, their nodal points being prolonged into long costate apophyses. Alveolar structure developed particularly in the central part of the skeleton, with five unequal alveoli. The arms may have an alveolar structure only in the proximal extremity, most of them being either smooth or with transverse wrinkles and sometimes with incipient alveoli.

**Dimensions:** Height of skeleton 40 to 56 $\mu$ , distance between two opposite arms 36 to 46 $\mu$ .

**Remarks:** By its long apical apophyses this species resembles *A. radricula*. The differences between them are of generic order as established in this paper (compare, for example, Plate 1, Figure 21 with Plate 3, Figure 1). Typical specimens of *F. pannosus* have been recorded in 206C, CC. Forms with less developed apical apophyses have been recorded from 206C-5, CC to 206-44, CC.

#### *Foliactiniscus mirabilis* n. sp.

(Plate 1, Figures 12, 13, 20; Plate 2, Figures 4, 12, 13)

**Description:** Five-armed skeleton with alveolar structure, without long apical apophyses. The arms are long and fairly curved. On each lateral furrow they bear commonly 5 to 8 incipient or mature alveoli.

**Typical forms:** Plate 2, Figures 12-13, Late Pliocene, DSDP 206-14, CC.

**Dimensions:** Distance between two opposite arms 27 to 50 $\mu$ . The Upper Oligocene forms are smaller (27-34 $\mu$ ), the Middle Miocene-Pliocene forms larger (40-50 $\mu$ ).

**Remarks:** *F. mirabilis* closely resembles *A. pentasterias*, and particularly what was considered as *A. elegans* by Frenguelli (1940). The species was recorded from Late Oligocene to Quaternary.

#### Genus CINCTACTINISCUS new genus

**Type species:** *Cinctactiniscus cinctus* (Hovasse), 1943.

**Diagnosis:** Siliceous skeletons consisting of a curved, elongate plate forked at its extremities. Concave side smooth, convex side with two parallel longitudinal ridges united with one another by transverse ridges. The extremities of the longitudinal ridges are divergent and become median crests in the four tricostrate arms. A fifth tricostrate arm departs laterally from the median zone of the plate.

**Remarks:** In its morphology this new genus is much more remote from *Actiniscus* than *Foliactiniscus*. With the latter it shows most common elements (to be compared, for example, with *C. intermedius*, Plate 1, Figure 8 with *F. folia*, Plate 1, Figure 11). Both have five arms, two paired and an odd one, and bilateral symmetry. The longitudinal furrow bordered by the two longitudinal crests (*C. robustus*, *C. intermedius*) might be regarded as the apical field of *Foliactiniscus* (the field opposite to the odd arm and having the larger alveola in *F. mirabilis*, Plate 1, Figure 12) or of *Actiniscus* (the apical pentagonal field of *A. elongatus*, for example). The difference consists in the fact that in at least two species of *Cinctactiniscus* this field is cut transversally by a median ridge, a prolongation of the median crest of the odd arm.

Several common elements appear to exist between this genus and *Carduifolia*, although at first sight these genera seem to be quite different (see Remarks to *Carduifolia*).

Three species of this genus—*C. robustus* n. sp., *C. intermedius* n. sp., and *C. cinctus* Hovasse—have been distinguished at different levels between Late Oligocene and basal Quaternary.

#### *Cinctactiniscus robustus* n. sp.

(Plate 1, Figures 1-4; Plate 5, Figures 1, 3)

**Description:** Skeleton massive, commonly slightly curved, with the convex side about twice or more as wide as the apical field. The latter is concave and bordered by two sharp longitudinal ridges and

two shorter transverse ridges. It is transversely cut in two equal concave fields by a median transverse ridge prolonged also on the lateral faces of the skeleton and, as median crests, along two median arms situated in the plane of bilateral symmetry. The point of junction of the crests is marked by sharp pyramidal elevations. Beyond the apical field the longitudinal crests diverge and extend as median crests in the four descending paired arms. Surface smooth or with slight oblique or transverse ridges.

**Dimensions:** Length of skeleton 32 to 38 $\mu$ .

**Remarks:** *C. robustus* appears to be the most primitive species of the genus. It was found in the Late Oligocene at Site 206C (Samples 11, CC, where it is common, and 8, CC).

***Cinctactiniscus intermedius* n. sp.**  
(Plate 1, Figures 5, 7, 8; Plate 5, Figure 2)

**Description:** Skeleton elongate and curved in semicircle. The apical part is much elongated and divided in two concave fields by three prominent transverse ridges. The median ridge extends on a side in an odd arm. The concave side narrower than the convex one. The arms are tricostrate and short, with the median crest on the convex side. The ornamentation consists of slight transverse wrinkles.

**Dimensions:** Distance between extremities 28 to 40 $\mu$ .

**Remarks:** This new species is morphologically intermediate between *C. robustus* and *C. cinctus*. From the former it preserves the three apical transverse ridges, but is distinguished from it by a more delicate skeleton, absence of the median transverse ridge on one side and absence of its corresponding arm, and also by a much more narrow concave side and by ornamentation. From *C. cinctus* it differs in having only three transverse ridges.

In southwestern Pacific sediments it was recorded in the Uppermost Oligocene and lower part of Early Miocene, between 206C-6, CC, where the species is common, and 206-42, CC.

***Cinctactiniscus cinctus* Hovasse**  
(Plate 1, Figures 6, 9, 10)

*Gymnaster cinctus* Hovasse, 1943, p. 279, fig. 3.

**Description:** Skeleton curved in semicircle, with two fringed longitudinal ridges. The longitudinal furrow cut by several transverse ridges generally slightly emphasized. The odd arm present on one side of the plate and rather short. The four paired arms are also short. Ornamentation consists of transverse wrinkles bordering circular or elongate cavities.

**Dimensions:** Distance between the opposite arms 33 to 48 $\mu$ .

**Remarks:** *A. cinctus* seems to be the most advanced form of this genus. In the southwestern Pacific it was encountered between Late Oligocene (206C-9, CC) to Early Pliocene (206-18, CC). It is generally a rather rare species, particularly in post-Oligocene sediments. The Pacific specimens are wholly conformable to the holotype, described from the Early Miocene

Genus **CARDUIFOLIA** Hovasse

**Type species:** *Carduifolia onopordoides* Hovasse, 1932.

**Diagnosis:** Easel-shaped siliceous skeleton with a central apical body and four tricostrate descending feet whose median crests are situated on the concave side, the convex side having a longitudinal furrow.

**Remarks:** In spite of some different opinions, this genus appears to be almost certainly an actiniscid. As will be demonstrated below, it shows many affinities with some genera of this group. Initially it was included among Ebridians (Hovasse, 1932a, b) and placed later in Carduifoliidae, a special family of this group (Hovasse, 1943). Hovasse (1932b) recognized, however, that *Carduifolia* may be related to the four-armed *Gymnaster*, that in young stages are very similar to some centers of *Carduifolia lata*. Only the curvature of the arms is different: convex in one case, concave in the other.

Deflandre (1936, p. 65, 73) recognized also some gymnodinian affinities of this genus, but he stated later (Deflandre, 1953b, p. 432, 433) that it is not possible at present to establish either its place or its flagellate or rhizopodian nature.

On the contrary, it seems that there are sufficient morphological arguments to place *Carduifolia* within the Actiniscidae. *Carduifolia apiculata*, for example, shows striking morphological affinities to an endoskeletal gymnodinian, *Monaster rete* Schütt (in Chatton, 1953,

fig. 237 D; Hovasse, 1932a, fig. 12b) having five feet and an apical spine. The difference consists not only in the different number of feet (arms), but also in the chemical composition of their skeleton. The inner skeleton of *Monaster rete* does not appear to be siliceous, since it is dissolved by acids. At any rate, the general shape of the spine of *C. gracilis*, *C. apiculata*, etc., suggests by comparison with the spine of *Monaster* a similar position in cell.

As was remarked above, between *Carduifolia* and *Cinctactiniscus* appear to exist some morphological affinities. In both genera there is an elongate central part, whose extremities bear two arms (to be compared, for example, *Carduifolia gracilis* and *Cinctactiniscus*). It might be retorted that the central part of *Cinctactiniscus* is four-edged, whereas that of *Carduifolia* is three-edged. That is not true. The central part of *Carduifolia* is also four-edged, since the concave ridge is actually formed of two joined parallel ridges (see Plate 4, Figures 19, 20, 26, and also Hovasse, 1943, fig. 5, or Loeblich et al., 1968, Pl. 49, fig. 12). The difference is only quantitative: in *Carduifolia* the distance between these two ridges is very narrow, whereas in *Cinctactiniscus* it is much wider.

It might also be stated that, whereas in *Cinctactiniscus* the median crest of the arms is situated on the convex side, in *Carduifolia* it is on the concave side. The difference is only superficial. A new comparison shows that in *Carduifolia* the concave median crest of the arms might be very easily turned into a lateral crest if the distance between the two concave edges of the central body became larger, because this extension would result in a slight turning of the arms. The resulting skeleton would be of *Cinctactiniscus* type. The resemblance would be closer if we compared, for example, *Cinctactiniscus* with *Carduifolia apiculata*, where the laterally disposed apical arm with the median crest toward the axis suggests a homology with the odd arm of *Cinctactiniscus*.

The superficial ornamentation is, on the other hand, of the same type in both genera.

Consequently, the affinities between the two genera are much more significant than the differences, and the latter are not structural.

**Geologic Range:** The species of *Carduifolia* known until present came from the interval Paleocene-Miocene, but the lower limit must be changed, since Deflandre (1953b) reported that forms fairly identical with *C. onopordoides* are found in the Cretaceous.

***Carduifolia onopordoides* Hovasse**  
(Plate 4, Figures 17, 18, 23)

*Carduifolia onopordoides* Hovasse, 1932a, p. 126, fig. 9; Frenguelli, 1940, p. 86, fig. 25d.

*Carduifolia* sp. Frenguelli, 1940, p. 87, fig. 25e.

*Carduifolia avipes* Hovasse, 1943, p. 280, fig. 5.

**Remarks:** Typical forms have been encountered in Lower Paleocene sediments cored at Site 208. No specimen was recorded in the Middle Eocene or Oligocene. However the species appears to be long ranged; *C. avipes* described by Hovasse from Early Miocene is also *C. onopordoides*. Rare specimens are also found in the Egerian (Late Oligocene) from Wallern, Austria.

***Carduifolia gracilis* Hovasse**  
(Plate 4, Figures 21, 26)

*Carduifolia gracilis* Hovasse, 1932a, p. 127, fig. 10; Frenguelli, 1940, p. 86, fig. 25b; Dumitrică, 1968, p. 236, pl. 3, fig. 15.

**Remarks:** In the southwestern Pacific this species was found particularly in the Middle Miocene. These specimens are not as well developed as those from the type locality (Cărand, Romania), or other Rumanian or Hungarian localities (Plate 4, Figure 21).

***Carduifolia lata* Hovasse**  
(Plate 4, Figures 19, 20, 24)

*Carduifolia lata* Hovasse, 1932b, p. 470, figs. 24, 25.

**Remarks:** Specimens more or less similar to topotype specimens (Plate 4, Figure 24) have been encountered in Paleocene and Middle Miocene at Sites 208, 207A, 206C.

***Carduifolia* sp.**  
(Plate 4, Figure 25)

**Remarks:** One specimen recorded in the Middle Eocene sample 208-27, CC. It is clearly distinguished from all the species of *Carduifolia* described by its apical prominence.

*Carduifolia* ? sp.

(Plate 4, Figures 15, 16)

**Remarks:** Few fragments similar to the two illustrated have been found in Late Oligocene at Site 206 (Samples 5, CC and 6, CC). Their morphology suggests arms of *Carduifolia*. The spines on the lateral crests are lamellar.

## Genus CALICIPEDINIUM new genus

**Type species:** *Calicipedinium quadripes* Dumitrică, n. sp.

**Diagnosis:** Massive siliceous spicules of candlestick shape consisting of an axial rod with a cup-like or button-like plate at the apical end and a star-like plate with commonly four to five three-bladed arms at the basal end.

**Remarks:** Two morphological types, regarded as two species, *C. quadripes* and *C. hexastylus*, have been encountered by the author in the so-called Radiolarian Schist horizon of Middle Miocene age (*Cannartus laticonus* Zone) in Romania, in an assemblage constituted of radiolarians, ebridians, silicoflagellates, dinoflagellates (*Actiniscus*), diatoms, sponge spicules and archaeomonads. Both species are a common element of this assemblage.

Although we are not sure whether these spicules are actually endoskeletal dinoflagellates, it must be recognized that their morphology has close affinities with the morphology of the spicule of *Actiniscus*. Exaggerating, the spicule of *Calicipedinium quadripes* could be regarded as an *Actiniscus tetrasterias* with the button-shaped apical protuberance very high. The four tricostrate arms are also similar except for the fact that in *Calicipedinium* they are not concave.

**Etymology:** The generic name derived from the Latin word *calix*—cup, and *pes*—foot.

*Calicipedinium quadripes* n. sp.

(Plate 3, Figures 19-26; Plate 4, Figures 1-4)

**Description:** Spicule with star-shaped basal plate consisting of four, exceptionally three or five, three-bladed arms. Two crests lie in the basal plane, the third rises medianly and in many specimens is prolonged on the axial rod, where it bears a small thorn. The axial rod is prismatic or cylindrical, and extends apically in a minute cup often with rolled rim.

**Dimensions:** Height of spicule 5 to 9 $\mu$ , length of arms of the basal plate 8 to 20 $\mu$ .

**Remarks:** Two varieties are distinguished in this species: one with longer arms and simple axial rod, the other with shorter arms and with a row of spines around the rod. Typical for the species are considered the spicules of the second type. The three-armed or five-armed spicules are very rare. The species is frequent in the Middle Miocene (*Cannartus laticonus* Zone), Radiolarian Schist horizon from the Subcarpathians and Getic Depression, Romania. The specimens illustrated come from the sample nr. 1315, Tilvici Valley, Păusesti Otăsău, district of Rîmnicu Vîlcea, and sample nr. 808, Pluta Valley, Chiojdea, district of Prahova. No similar form was seen in the southwestern Pacific sediments.

*Calicipedinium hexastylus* n. sp.

(Plate 4, Figures 5-14)

**Description:** Spicule very small, with cylindrical axial rod and five arms disposed in the horizontal plane. A sixth tricostrate arm descends from the center of the basal plate. Its three crests are connected with the inner corners of the basal star as in Plate 4, Figure 8.

**Dimensions:** Total span of the star plate 5 to 15 $\mu$ .

**Remarks:** This minute species is distinguished from *C. quadripes* by its much smaller size, and by its having five arms in the horizontal plane, and a descending arm. Frequent in the same samples as above.

## ACKNOWLEDGMENTS

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## PLATE 1

Scale bar for all figures

- Figures 1-4 *Cinctactiniscus robustus* n. g., n. sp.  
 1: Holotype, apical view. 2-4: Lateral view.  
 1-3: DSDP 206C-11, CC.  
 4: DSDP 206C-8, CC.
- Figures 5, 7, 8 *Cinctactiniscus intermedius* n. g., n. sp. All figures  
 DSDP 206C-6, CC.  
 8: Holotype.  
 5: An uncommon specimen with four apical  
 transverse ridges, lateral view.  
 7, 8: Apical view.
- Figures 6, 9, 10 *Cinctactiniscus cinctus* (Hovasse), lateral view.  
 6: DSDP 206C-8, CC.  
 9: DSDP 206C-6, CC.  
 10: DSDP 206C-9, CC.
- Figure 11 *Foliactiniscus folia* (Hovasse), apical view, DSDP  
 206-31, CC.
- Figures 12, 13,  
 20 *Foliactiniscus mirabilis* n. g., n. sp., Late Oligocene  
 specimens.  
 12, 13: Apical view.  
 20: Oblique view.  
 12: DSDP 206C-10, CC.  
 13, 20: DSDP 206C-11, CC.
- Figures 14-17 *Foliactiniscus pyramis* n. g., n. sp., lateral view.  
 14: DSDP 206C-3, CC.  
 15-17: DSDP 206-45, CC.
- Figures 18, 19,  
 21-23 *Foliactiniscus pannosus* n. g., n. sp., lateral view,  
 DSDP 206C-6, CC.  
 21: Transverse section showing one central and two  
 peripheral alveoli.

PLATE 1

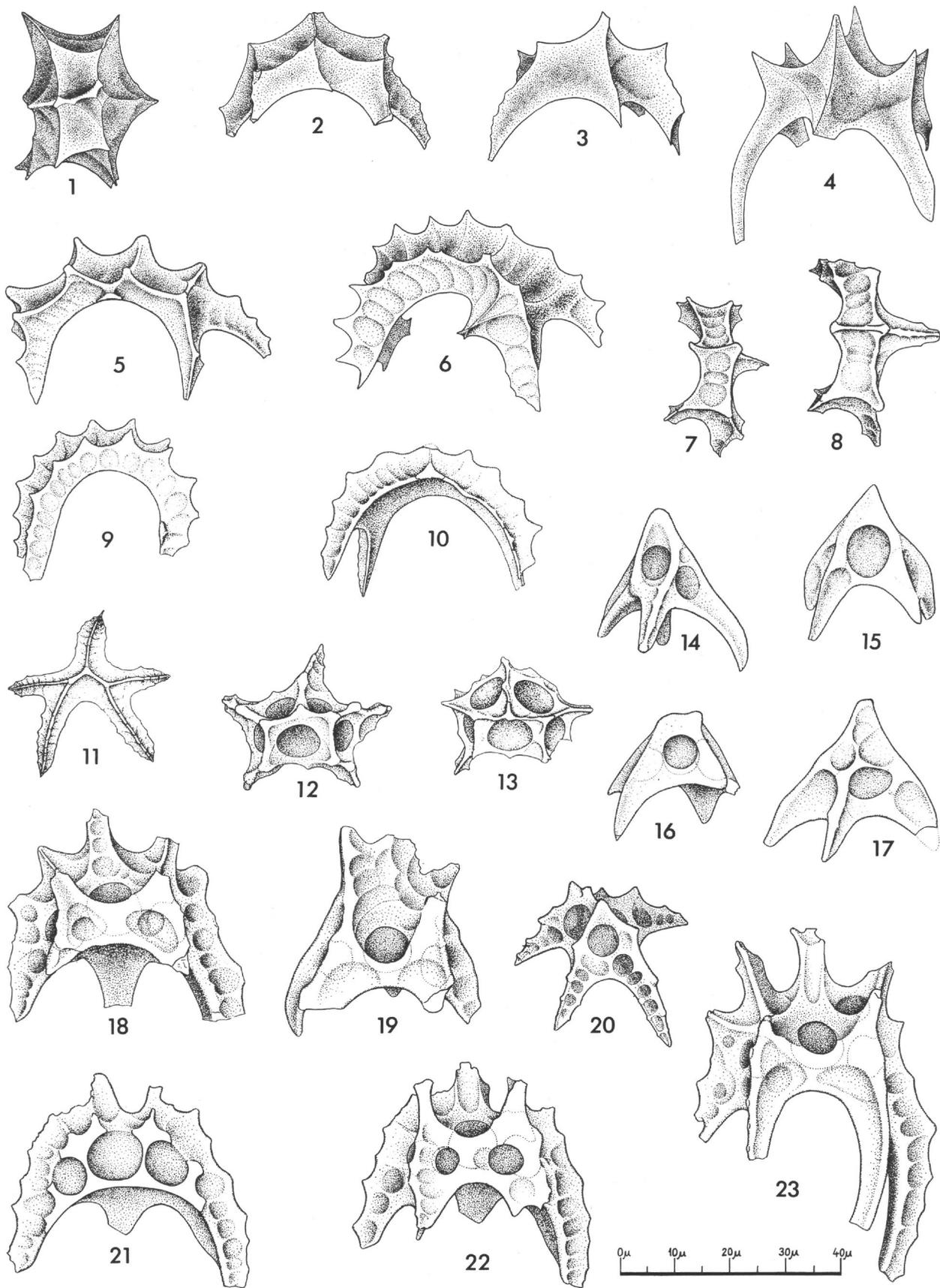


PLATE 2

Scale bar for all figures

- Figures 1, 5 *Foliactiniscus pannosus* n. g., n. sp.  
1: Lateral view, DSDP 206C-6, CC.  
5: Basal view showing by transparence the position of median crests and alveoli.
- Figures 4, 12, 13 *Foliactiniscus mirabilis* n. g., n. sp.  
4: Lateral view, a specimen with strong nodal points, DSDP 206-31, CC.  
12: Basal view.  
13: Lateral view, both figures DSDP 206-14, CC.
- Figures 2, 3, *Actiniscus pentasterias* Ehrenberg.  
6-11, 14 2: Basal view showing a slight ornamentation on the concave face, DSDP 206-31, CC.  
3: Apical view, DSDP 206-31, CC.  
6, 7, 10, 11: Pentaradial skeletons in apical view, Lower Badenian, Ameis, Austria.  
5: Section of the apical part showing the central button, supporting the apical alveola, and the five surrounding alveoli.  
8: Lateral view, DSDP 206-31, CC.  
14: Lateral view, DSDP 206-28, CC.  
9: Transverse section through the last figure showing the apical alveola and two opposite alveoli of the central field.
- Figures 15-17 *Actiniscus radricula* n. sp., lateral view, DSDP 206-22, CC.

PLATE 2

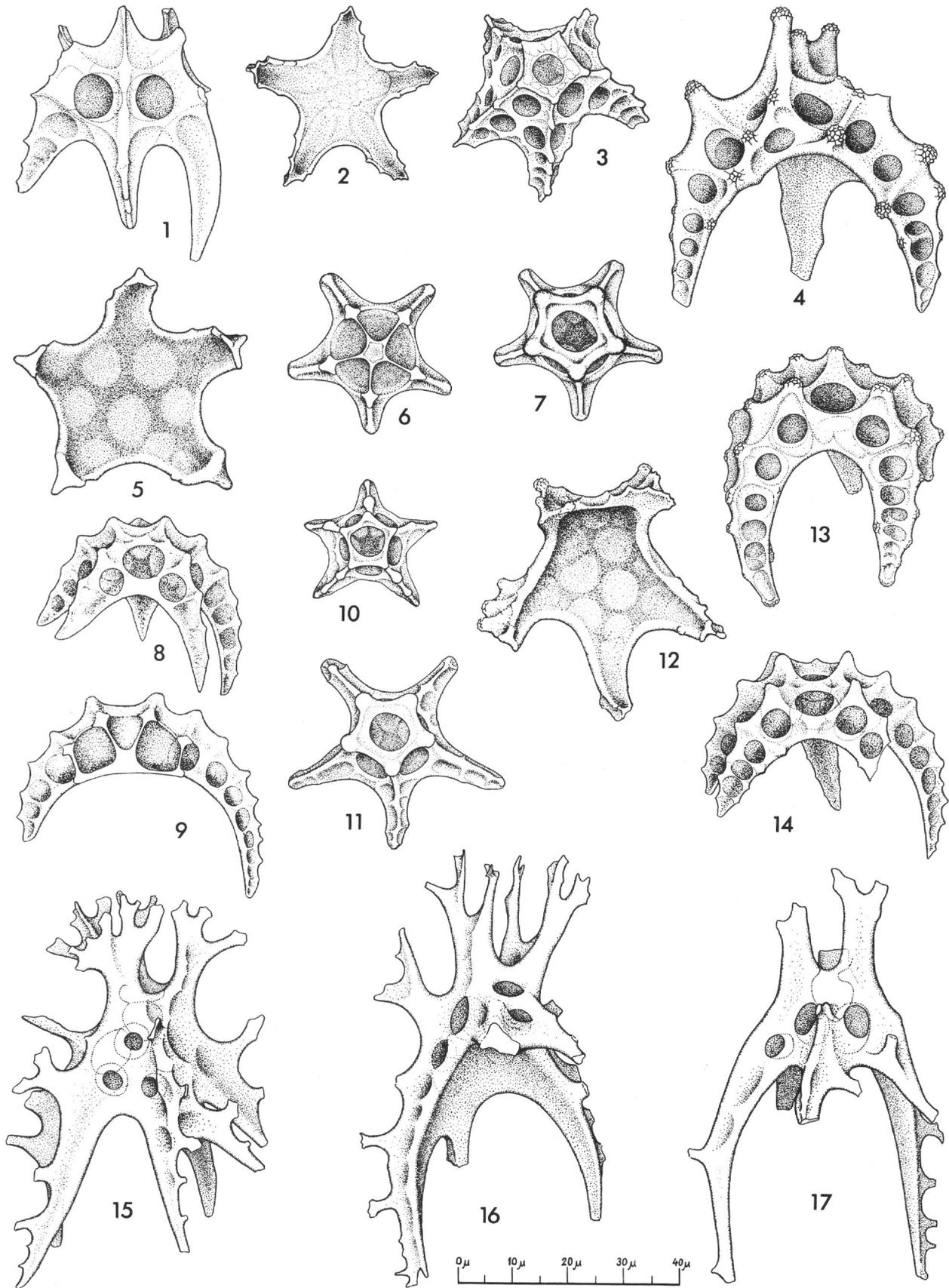


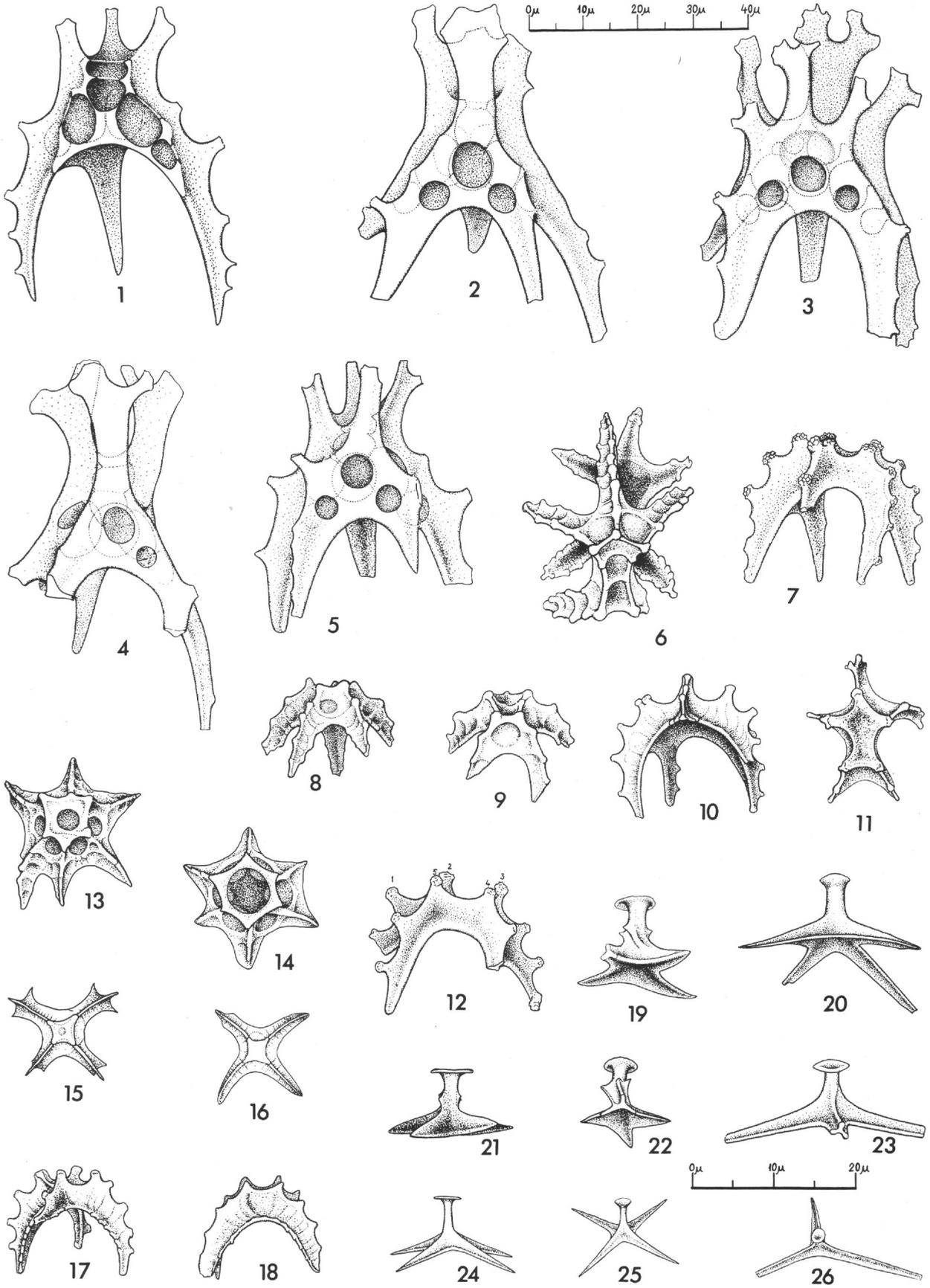
PLATE 3

Scale bar of 40 $\mu$  for Figures 1-18

Scale bar of 20 $\mu$  for Figures 19-26

- Figures 1-5 *Actiniscus radricula* n. sp., lateral view, DSDP 206-22, CC.  
1: Section through a spicule showing a double apical alveola supported by a button and surrounded by peripheral alveoli.
- Figures 6-12 *Actiniscus elongatus* Dumitrica.  
6: Double skeleton in axial view, sample nr.1315, Radiolarian Schist Horizon (Middle Miocene), Păusesti Otăsău, Romania.  
7: Lateral view, DSDP 206-18, CC.  
8, 9: Lateral view facing the end with two arms, DSDP 206-31, CC.  
10, 12: Lateral view, DSDP 206-19, CC.  
11: Apical view, DSDP 206-19, CC.
- Figures 13, 14 *Actiniscus pentasterias* Ehrenberg, hexagonal forms in apical view.  
13: Sample nr.1315, Radiolarian Schist Horizon (Middle Miocene), Păusesti Otăsău, Romania.  
14: Lower Badenian, Ameis, Austria.
- Figures 15-18 *Actiniscus tetrasterias* Ehrenberg.  
15: Apical view, DSDP 206-40, CC.  
16: Apical view, DSDP 206-13, CC.  
17: Lateral view, DSDP 206-19, CC.  
18: Lateral view, DSDP 206-12, CC.
- Figures 19-26 *Calicipedinium quadripes* n. g., n. sp.  
19: Oblique view, sample nr.1315, Radiolarian Schist Horizon (Middle Miocene), Păusesti Otăsău, Romania.  
20-25: Oblique and lateral view, sample nr.808, Radiolarian Schist Horizon (Middle Miocene), Chiojdeanca, Romania.  
26: Three-armed specimen in apical view, the same sample as for Figure 19.

PLATE 3



## PLATE 4

Scale bar of 20 $\mu$  for Figures 1-4, 6-14Scale bar of 40 $\mu$  for Figures 15-26

- Figures 1-4     *Calicipedinium quadripes* n. g., n. sp.  
 1-3: Apical view, sample nr.1315, Middle Miocene, Păusești Otășău, Romania.  
 4: Lateral view, Middle Miocene, Chiojdeanca, Romania.
- Figures 5-14     *Calicipedinium hexastylus* n. g., n. sp., in apical (10), antapical (8, 9, 13), lateral (5, 6, 11, 12, 14) and oblique (7) views.  
 5: The same specimen as in Figure 6, much magnified.  
 5, 6, 9, 10, 13: Sample nr.1315, Middle Miocene, Păusești Otășău, Romania.  
 7, 8, 11, 12, 14: Sample nr.808, Middle Miocene, Chiojdeanca, Romania.
- Figures 15, 16     *Carduifolia* ? sp., fragments.  
 15: DSDP 206C-5, CC.  
 16: DSDP 206C-6, CC.
- Figures 17, 18, 23     *Carduifolia onopordoides* Hovasse, in latero-basal view (Figures 17, 18) and apical view (Figure 23, fragment); DSDP 208-30, CC.
- Figures 19, 20, 24     *Carduifolia lata* Hovasse.  
 24: Topotypical form from Oamaru Diatomite, Cormacks, New Zealand, apical view.  
 19: Lateral view, DSDP 207A-11, CC.  
 20: Latero-basal view, DSDP 208-30, CC.
- Figures 21, 26     *Carduifolia gracilis* Hovasse.  
 21: Lateral view, sample nr.1315, Middle Miocene, Păusești Otășău, Romania.  
 26: Basal view, DSDP 206-31, CC.
- Figure 22     *Carduifolia apiculata* Hovasse, lateral view, Lower Sarmatian, Cărand, Romania.
- Figure 25     *Carduifolia* sp., lateral view, DSDP 208-27, CC.

PLATE 4

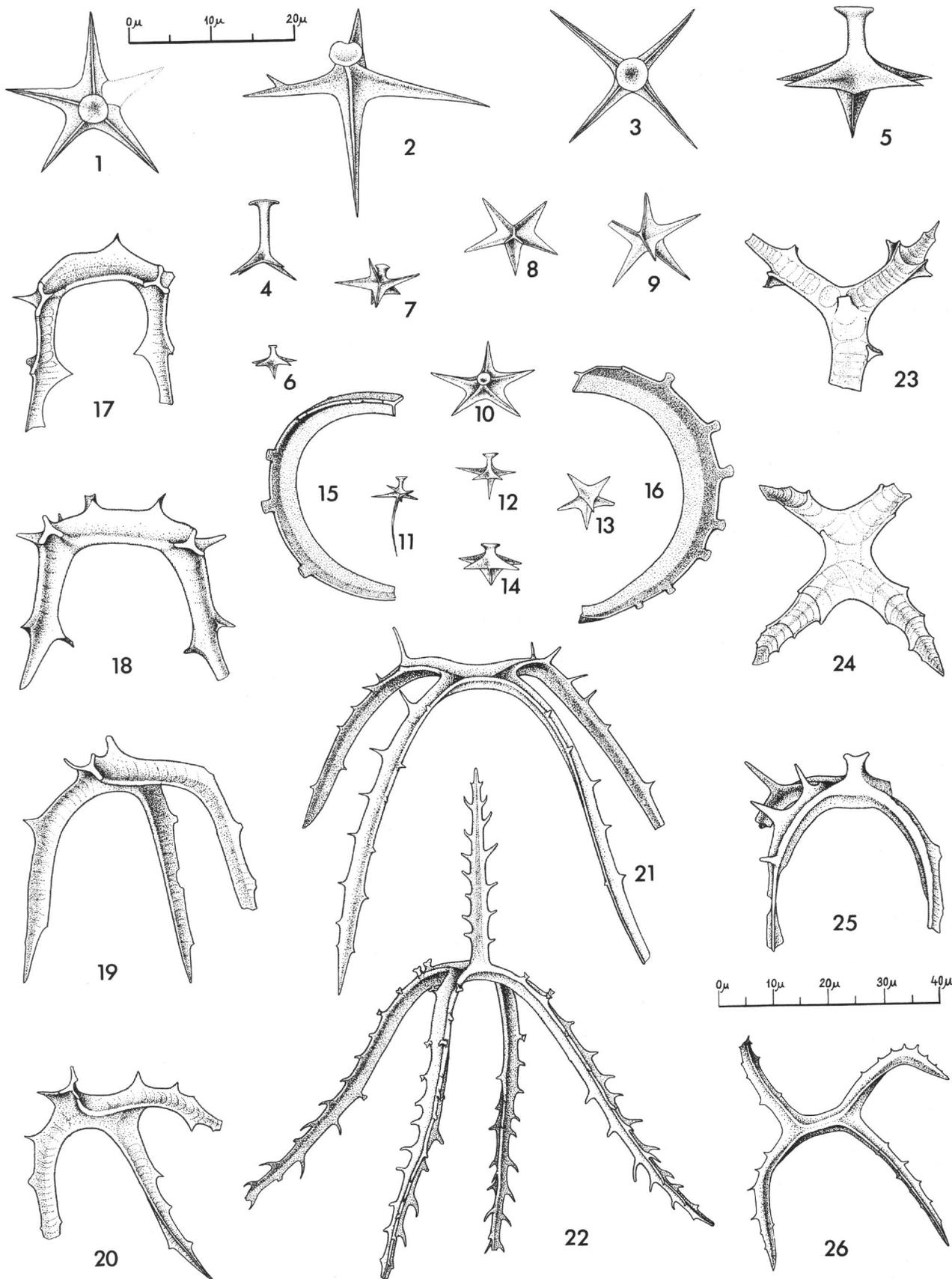
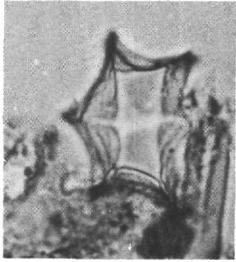


PLATE 5

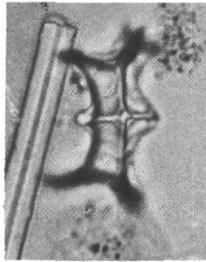
Magnification X700

- Figures 1, 3 *Cinctactiniscus robustus* n. g., n. sp.  
1: Apical view.  
3: Lateral view; both figures DSDP 206C-11, CC.
- Figure 2 *Cinctactiniscus intermedius* n. g., n. sp., apical view,  
DSDP 206C-6, CC.
- Figure 4 *Actiniscus radricula* n. sp., lateral view, DSDP 206-22,  
CC.
- Figure 5 *Foliactiniscus mirabilis* n. g., n. sp., apical view, DSDP  
206C-10, CC.
- Figures 6-8 *Actiniscus pentasterias* Ehrenberg, DSDP 206-22, CC.  
6, 8: Basal view.  
7: Double skeleton.
- Figure 9 *Actiniscus tetrasterias* Ehrenberg, lateral view, DSDP  
206-12, CC.
- Figures 10, 11 *Actiniscus elongatus* Dumitrică, DSDP 206-19, CC.  
10: Apical view.  
11: Lateral view.

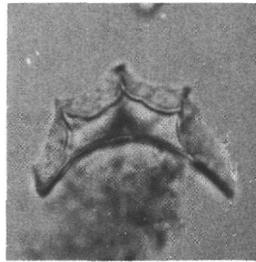
PLATE 5



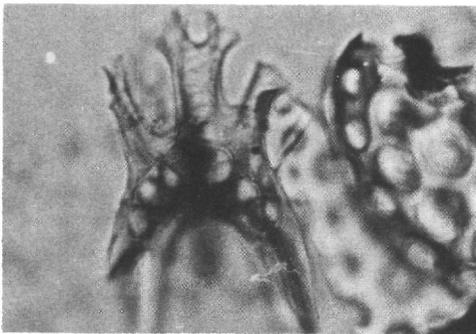
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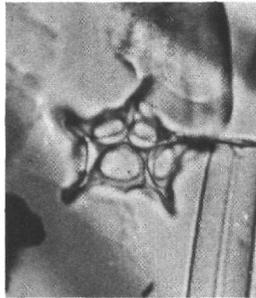
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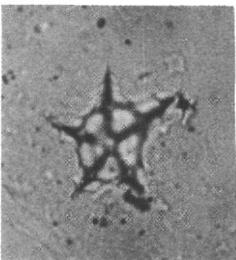
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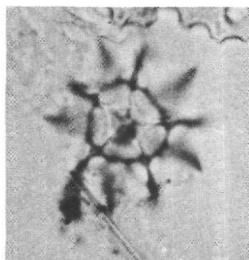
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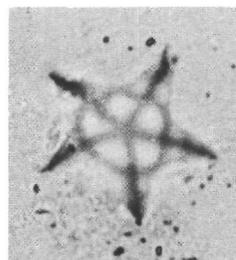
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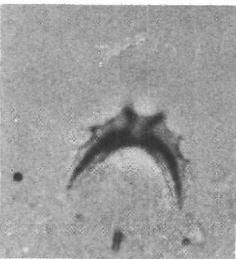
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7



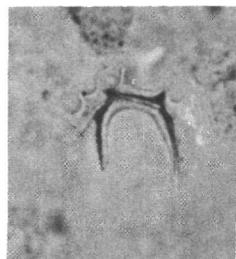
8



9



10



11