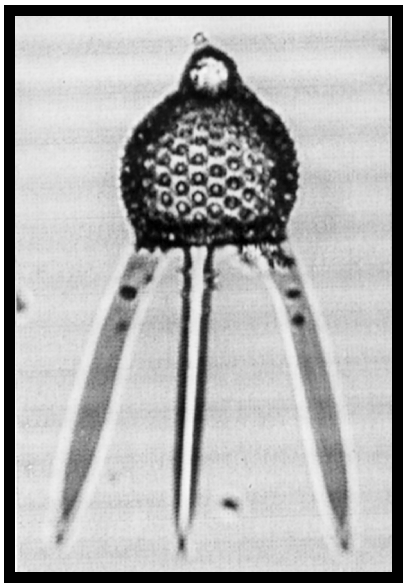
# *Calocyclas bandyca* (Mato and Theyer)



*Lychnocanoma bandyca* Mato and Theyer, 1980, p.225, pl.1, figs.1-6

*Calocyclas bandyca* (Mato and Theyer), Sanfilippo and Riedel in Saunders et al., 1985, p.411, pl.5, figs.1,5-6

## DESCRIPTION

Cephalis subhemispherical with a few, randomly arranged, small, irregular pores; apical spine lacking. Thorax campanulate with relatively large, longitudinally arranged hexagonal frames. Irregular, laminar lattice extends from distal thorax on well-preserved specimens. Very fine, randomly arranged distal pores. Three sturdy, prominent, cylindrical to conical, straight to slightly curved feet extend from thorax (Mato and Theyer, 1980).

## DIMENSIONS

Based on 15 specimens. Overall length 310-470 µm; of cephalis 20-30 µm, of thorax 100-120 µm, of feet 190-340 µm; greatest width of cephalis 20-40 µm, of thorax 120-140 µm (Mato and Theyer, 1980).

Length (excluding horn) 290-470 µm; of thorax 100-120 µm; maximum width of thorax 105-140 µm, width of aperture 50-70 µm (*Lychnocanoma bandyca* in Sanfilippo et al., 1985).

## DISTINGUISHING CHARACTERS

*C. bandyca* is distinguished from other species by its three (rarely four to five) subcylindrical, sturdy feet, and distinctive inflated thorax with longitudinally arranged pores in hexagonal frames. Occurring stratigraphically earlier (*Podocyrtis mitra* Zone) and through the *Thyrsocyrtis bromia* Zone together with *Calocyclas bandyca* are forms (of the *Sethochytris babylonis* group) with rather similar morphology. *S. babylonis* does not have an inflated thorax, the aperture is very restricted

and the conical feet are long, very slender, never sturdy as those of *Calocyclas bandyca* (*Lychnocanoma bandyca* in Sanfilippo et al., 1985).

## VARIABILITY

This two-segmented form varies little during its short stratigraphic range. The three, sturdy, cylindrical to conical feet vary somewhat in length, and in being straight or slightly curved. In some specimens, remnants of a delicate lattice extend from the distal margin of the thorax. Rare specimens with four or five feet are found near the beginning of its range (*Lychnocanoma bandyca* in Sanfilippo et al., 1985).

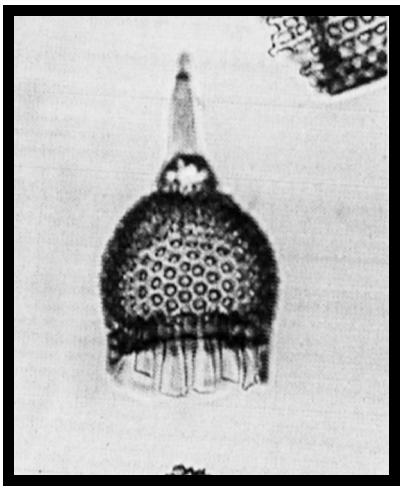
## DISTRIBUTION

*C. bandyca* is found in moderate abundance in tropical localities of late late Eocene age. Its morphotypic first appearance marks the base of the *Calocyclas bandyca* Zone and it becomes extinct approximately at the upper limit of the same zone.

## PHYLOGENY

*C. bandyca* evolved from *Calocyclas turris* via intermediate morphotypes in which the lamellar feet are fewer in number, long, and tending to be cylindrical proximally, joined about mid-length by a band of irregular lattice-work, which in some specimens extends upwards to join the thorax (Sanfilippo and Riedel in Saunders et al., 1985).

# *Calocyclas hispida* (Ehrenberg)



*Anthocyrtis hispida* Ehrenberg, 1873, p.216; 1875, pl.8, fig.2

*Cycladophora hispida* (Ehrenberg), Riedel and Sanfilippo, 1970, p.529, pl.10, fig.9; 1971, p.1593, pl.3B, figs.10-11; Moore, 1971, p.741, pl.4, figs.6-7

## DESCRIPTION

Two segmented theoperid with 15-25 lamellar feet or teeth surrounding the thoracic aperture. Cephalis spherical, poreless or with a few small pores, bearing a slender conical horn of variable length. The tip of the horn sometimes appears roughened. Thorax subhemispherical with small subcircular pores, quincuncially arranged with the longitudinal axis of the quincunx horizontal, giving the pores the appearance of being longitudinally arranged. In later forms the thoracic pores become more regularly longitudinally arranged. In some specimens the surface can be quite thorny, and in thick-walled specimens the pore frames are commonly hexagonal. The distal part of the thorax is surrounded by 15-25 subparallel lamellar feet or teeth. Early forms have narrower more widely spaced lamellar teeth around the apertural margin (Sanfilippo, unpublished).

## DIMENSIONS

Based on 35 specimens throughout its long stratigraphic range, from the Pacific, Indian and Atlantic Oceans. Total length (excluding horn): 115-215 µm; length of cephalothorax 90-150 µm. Thoracic width 90-140 µm. Horn usually broken, but when observed complete its length is 10-115 µm (Sanfilippo, unpublished).

## DISTINGUISHING CHARACTERS

*C. hispida* is distinguished from its descendant *C. turris* by its lamellar feet not being joined by bars to form an abdomen, and from other similar theoperids by the lamellar feet being subparallel, not diverging distally (Sanfilippo, unpublished).

## VARIABILITY

This long ranging species varies in thoracic size and in the thoracic pores becoming more regularly longitudinally arranged in later forms. Early forms are within the smaller size-range, and have narrower more widely spaced lamellar feet. In thick-walled specimens the pore frames are commonly hexagonal, and the surface may be thorny. This species is rare in the early part of its stratigraphic range, becoming more common in the later part (Sanfilippo, unpublished)

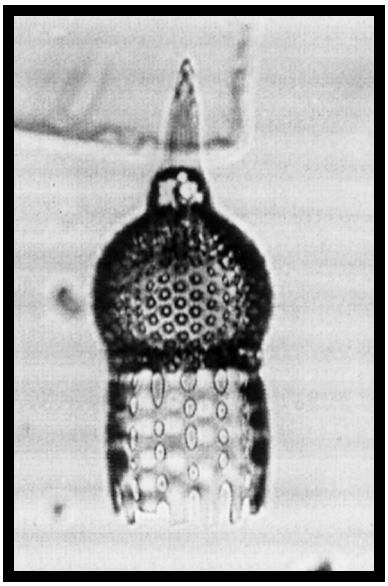
## DISTRIBUTION

Middle to low paleolatitudes from the early Eocene *Buryella clinata* Zone through the late Eocene *Calocyclas bandyca* Zone.

## PHYLOGENY

The ancestry of *Calocyclas hispida* is yet unknown. In the late Eocene it gave rise to *C. turris*.

# *Calocyclas turris* Ehrenberg



*Calocyclas turris* Ehrenberg, 1873, p.218; 1875, pl.18, fig.7; Foreman, 1973, p.434

## DESCRIPTION

Shell of three segments, with the collar and lumbar strictures expressed externally. Cephalis subspherical, poreless or with a pitted surface, bearing a conical horn twice to three times the length of the cephalis. In late, robust forms, the cephalis is enclosed in the base of the horn, which terminates in a knob-like or roughened thickening. Thorax inflated-hemispherical with circular pores arranged quincuncially (long axis of the quincunx horizontal). Thick-walled specimens have deep-set pores surrounded by hexagonal poreframes. At the junction of these pore-frames small thorns may develop. The cylindrical abdomen consists of ~20 lamellar feet joined by bars to form the third segment with longitudinal rows of pores. This abdomen is commonly five pores long. The elongated abdominal pores are up to four times as long as the thoracic ones. In late forms the number of longitudinal lamellae is reduced, and they become thickened, rib-like. The distal portion of the abdomen, when preserved, consists of tapering, unjoined, prolongations of the lamellae (Sanfilippo, unpublished).

## DIMENSIONS

Based on 40 specimens. Total length (excluding horn) usually 170-220 μm (but may be up to 505 μm). Length of cephalothorax 105-160 μm; maximum breadth 100-145 μm (but may be up to 165 μm) (Sanfilippo, unpublished).

## DISTINGUISHING CHARACTERS

The lamellar feet are joined by bars to form an abdomen with longitudinal rows of pores (Riedel and Sanfilippo, 1978a).

*C. turris* is distinguished from its ancestor *C. hispida* (Ehrenberg, 1873) by its lamellar feet being joined by bars to form an abdomen with

longitudinal rows of pores, and from its descendant *C. bandyca* by not having the lamellar feet reduced in number and developed into strong, divergent, conical legs.

## VARIABILITY

This short ranged species varies in thoracic size, length and robustness of the abdomen, and in the thoracic pores becoming more regularly longitudinally arranged in later forms. Prior to the speciation of *C. bandyca* the number of longitudinal abdominal longitudinal lamellae is reduced, and they become substantially thickened, while the transverse bars become fewer and much thinner (Sanfilippo, unpublished).

## DISTRIBUTION

*C. turris* is found in moderate abundance in tropical samples of late Eocene age. It evolved from *Calocyclas hispida* within the *Cryptocarpium azyx* Zone and became extinct within the *Cryptocarpium ornatum* Zone.

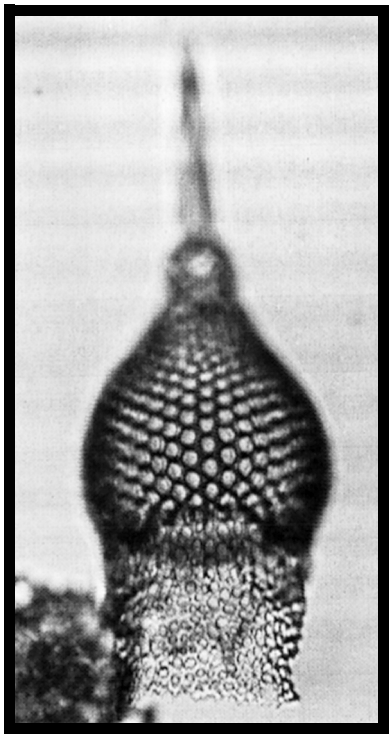
## PHYLOGENY

This species evolved from *C. hispida* by the feet becoming joined to form an abdomen, and gave rise to *C. bandyca*. All three species may co-occur.

## REMARKS

Additional illustrations can be found in Riedel and Sanfilippo, 1978a, pl.3, figs.7-8.

# *Calocycletta (Calocyclior) caepa* Moore



*Calocycletta caepa* Moore, 1972, p.150, pl.2, figs.4-7

## DESCRIPTION

Cephalis ovate, lobed, with sparse circular to subcircular pores and bearing a conical (early forms) to slightly bladed (late forms) apical horn. Thorax subspherical to campanulate, with circular pores hexagonally arranged and longitudinally aligned. External lumbar stricture absent in early forms but distinct in late forms. Abdomen lighter and more delicate than thorax, cylindrical in shape, containing subcircular to circular pores that may show longitudinal alignment and hexagonal arrangement (early forms). Late forms may have a very light, very irregularly pored abdomen that appears almost spongy. Abdomen terminates in five to fourteen triangular or spike-shaped feet that are usually very short and irregularly spaced (Moore, 1972).

## DIMENSIONS

Based on 30 specimens. Length of apical horn 62-130 µm, of cephalis 34-43 µm, of thorax 62-110 µm, of abdomen 43-158 µm, of feet 5-14 µm. Breadth of cephalis 34-43 µm, of thorax 101-134 µm, of abdomen (distally) 58-101 µm (Moore, 1972).

## DISTINGUISHING CHARACTERS

Only if the abdomen and terminal feet are preserved can early forms of *C. caepa* be distinguished from *C. virginis* and *C. serrata*. The bladed apical horn, campanulate thorax and very delicate abdomen of later forms aid in their distinction (Moore, 1972).

## VARIABILITY

See Description above.

## DISTRIBUTION

This species is present in middle to late Miocene sediments from the tropical Pacific Ocean, but is essentially absent from Indian Ocean sediments. Its morphotypic first appearance is within the *Stichocorys wolffii* Zone and it became extinct within the *Stichocorys peregrina* Zone.

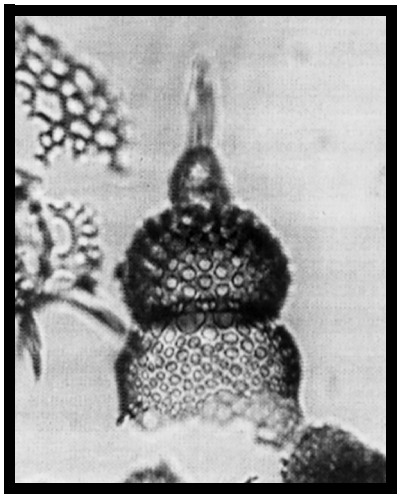
## PHYLOGENY

*C. caepa* evolved from *Calocycletta virginis* near the early to middle Miocene boundary and continued on into the late Miocene. It left no descendants.

## REMARKS

For generic level phylogeny see Sanfilippo and Riedel, 1992, p.31.

# *Calocycletta (Calocycletta) cladara* Sanfilippo and Riedel



*Calocycletta (Calocycletta) cladara* Sanfilippo and Riedel, 1992, p.30, l.2, figs.12-16

## DESCRIPTION

Three-segmented pterocorythid with the cephalis distinctly pored, bearing a rather strong, slightly bladed horn. Generally, the lateral lobes of the cephalis are indistinct, and do not cause a distinct break in its contour. Thorax inflated-conical to subspherical, with pores irregular in size and arrangement, which in late forms tend to be larger near the collar stricture and with their bars joining the cephalis above the level of the collar pores. The thoracic wall is a thin, porous lamella proximally, becoming much thicker distally where the pore frames are high. Abdomen distinctly more delicate than the thorax, irregularly subcylindrical, often constricted medially; when observed complete, which is rarely, terminated with a thin poreless peristome bearing small teeth. In late forms the row of pores just below the lumbar stricture increase in size to two or three times the size of the surrounding pores (Sanfilippo and Riedel, 1992).

## DIMENSIONS

Based on 50 specimens. Length (excluding horn) 110-215 µm (usually about 156 µm), length of cephalothorax 75-110 µm; width of thorax 80-105 µm, width of abdomen 85-135 µm (usually about 110 µm) (Sanfilippo and Riedel, 1992).

## DISTINGUISHING CHARACTERS

This species differs most markedly from others of the genus by the lack of regular pore arrangement. It bears a superficial resemblance to some species of *Albastrossidium* and *Lamprocyclas*, but tracing its evolution revealed its true relationship to *Calocycletta virginis*. In the latest members of the latter species the thoracic pores lose their strict regular arrangement the horn tends to become bladed and some specimens have a delicate abdomen lacking teeth. It differs from *Pterocorys minythorax*

(Nigrini) (Caulet and Nigrini, 1988, p.231, pl.2, fig.6) by its larger thorax (*P. minythorax* thoracic width 63-72 µm; length of cephalothorax 63-81 µm), its irregular pore arrangement and the tendency in later forms to develop larger pores at the collar and lumbar strictures. The theoperid *Stichocorys johnsoni* Caulet is confusingly similar. It also displays the larger pores just below the lumbar stricture and the same sinuous abdomen, but it has a simple cephalis (Sanfilippo and Riedel, 1992).

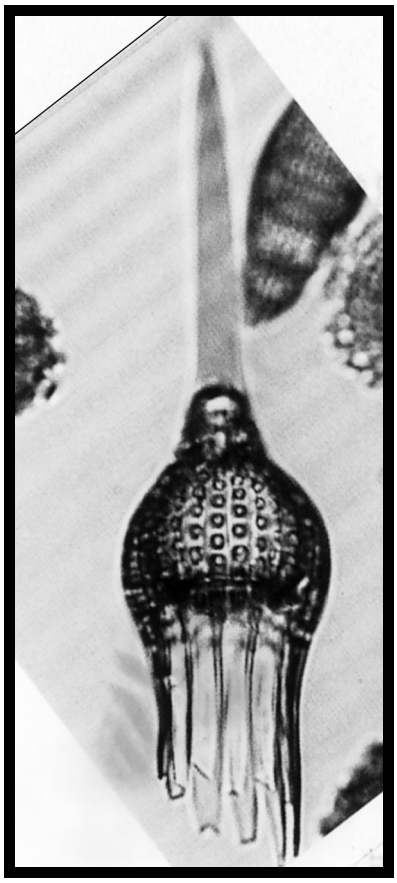
## DISTRIBUTION

The transition from *C. virginis* to *C. cladara* occurs near the boundary between the *Dorcadospyris alata* Zone and the *Diartus petterssoni* Zone (middle Miocene), and *C. cladara* becomes extinct in the lower part of the *Stichocorys peregrina* Zone (near the Miocene/Pliocene boundary). *C. cladara* occurs in low abundances in all of the Miocene assemblages of the appropriate age from latitudes lower than 40°. It reaches its highest abundances (up to 5% of the total assemblage) in the late Miocene Indian Ocean assemblages (Sanfilippo and Riedel, 1992).

## PHYLOGENY

*C. cladara* arose from *C. virginis* and left no descendants. It terminates the subgenus *Calocycletta (Calocycletta)*.

# *Calocycletta (Calocyclissima) costata* (Riedel)



*Calocyclas virginis* Haeckel, Riedel, 1957, p.90, pl.4, fig.5 (*partim*.)

*Calocyclas costata* Riedel, 1959, p.296, pl.2, fig.9

*Calocycletta costata* (Riedel), Riedel and Sanfilippo, 1970, p.535, pl.14, fig.12

## DESCRIPTION

Cephalis ovate, lobed, with sparse subcircular to circular pores and bearing a stout, conical apical horn. Thorax subspherical, with pores circular, hexagonally arranged and with a pronounced tendency to longitudinal alignment, the longitudinal rows separated by pronounced costae. No lumbar stricture externally. Abdomen subcylindrical or tapering distally, narrower than the widest part of the thorax. Abdominal pores subcircular or circular, arranged hexagonally with apparent longitudinal alignment (these longitudinal lines are continuous with those of the thorax) and often with longitudinal ridges separating pore rows. Terminal feet eleven to eighteen in number, lamellar, usually truncate, parallel or slightly convergent, broader than the spaces between them, usually situated opposite alternate rows of abdominal pores. This species is distinguished from *Calocyclas virginis* by the pronouncedly costate thorax and otherwise smooth shell surface (Riedel, 1959).

## DIMENSIONS

Based on 30 specimens. Length of apical horn 115-230 µm; of cephalis 30-45 µm; of thorax 70-100 µm; of abdomen 10-33 µm; of feet 12-70 µm. Breadth of cephalis 38-53 µm; of thorax 103-135 µm; of abdomen (distally) 75-108 µm (Riedel, 1959).

## DISTINGUISHING CHARACTERS

Horn robust, conical. Thoracic pores in longitudinal rows, separated by ridges. Abdomen with a very short latticed part, and numerous parallel lamellar feet (Riedel and Sanfilippo, 1978a).

This species is distinguished from all others of the genus by the longitudinal ribs between the rows of thoracic pores, and the consequently very smooth contour. In addition to this, it differs from co-occurring specimens of *C. virginis* in that the latter usually have a distinct change in contour where the horn leaves the cephalis, and a more abrupt collar stricture. It differs from *C. caepa* Moore (1972; a member of the *C. robusta* group of Riedel and Sanfilippo, 1978a, p.66) in that the latter has a bladed horn, and a more delicate abdomen with smaller, more numerous pores, terminating in short, triangular teeth. There is a superficial resemblance also to *Calocyclas turris* Ehrenberg (1873), but that is an Eocene species with the simple cephalis characteristic of the theoperids (Sanfilippo et al., 1985).

## VARIABILITY

The form of this species is remarkably constant over its entire geographic and stratigraphic range. The only variable character is the length of the lamellar feet, which depends principally on preservation - the feet are usually abruptly truncate as if broken, but in rare, well preserved specimens they taper to a point, and tend to diverge a little, after initial slight convergence (Sanfilippo et al., 1985).

## DISTRIBUTION

This species occurs in samples of latest early to early middle Miocene age between 15°S and 30°N. It is absent at DSDP Site 173, at 40°N in the California Current region. It is present in sediments on Mallorca, at 39-40°N. Its morphotypic first appearance marks the base of the *Calocycletta costata* Zone and it becomes extinct within the *Dorcadospyris alata* Zone.

## PHYLOGENY

*Calocycletta costata* evolved directly from *C. virginis* by the development of longitudinal ribs on the thorax. In both species the thoracic pores are quincuncially arranged, but (at the time of their co-occurrence) in the former species the quincunxes are about 10% wider

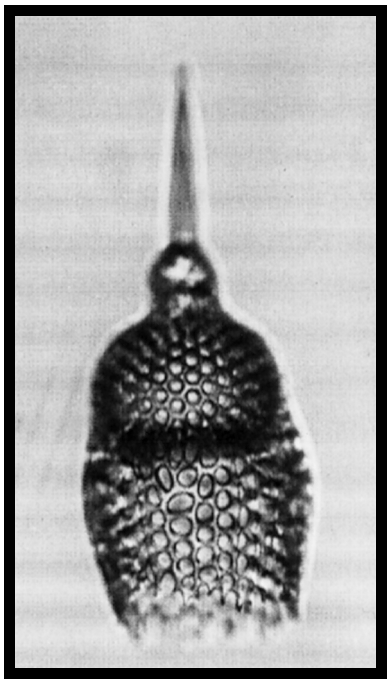
transversely than in the latter, because the bars between the pores are wider. Just before the origin of *C. costata*, specimens of *C. virginis* have somewhat larger pores (about 10 µm in diameter as compared to about 8 subsequently), and wider thorax (about 140-145 µm as compared to about 110-120 µm later) (Sanfilippo et al., 1985).

## REMARKS

Additional illustrations can be found in Riedel and Sanfilippo, 1971, pl.2H, figs.12-14; Moore, 1972, pl.1, fig.8.

For generic level phylogeny see Sanfilippo and Riedel, 1992, p.30.

# *Calocycletta (Calocycletta) robusta* Moore



*Calocycletta robusta* Moore, 1971, p.743, p.10, figs.5-6

## DESCRIPTION

Stout conical apical horn that envelopes or nearly envelopes an ovate, lobed cephalis. Cephalis has very sparse subcircular pores. Thorax robust and hemispherical to subspherical in shape. Rough surface of the thorax contains circular, hexagonally arranged pores with a tendency towards longitudinal alignment. Lumbar stricture usually not marked externally (except in early forms). Abdomen tapers distally and contains subcircular pores that are strongly longitudinally aligned. Abdominal termination usually ragged, but may end in irregular lamellar and tapering feet in the later forms (Moore, 1971).

## DIMENSIONS

Based on 30 specimens. Length of apical horn 80-185 µm; of cephalis 34-48 µm; of thorax 73-144 µm; of abdomen 64-120 µm; of feet (when present) 16-48 µm. Breadth of cephalis 40-56 µm; of thorax 120-178 µm; of abdomen (distal) 64-96 µm (Moore, 1971).

## DISTINGUISHING CHARACTERS

This species is distinguished from *Calocycletta parva* by the heavier shell of *C. robusta* (particularly the abdomen), the more regular shape and arrangements of the abdominal pores and the long, conical apical horn (Moore, 1972).

Later forms of *C. robusta* are distinguished from *C. virginis* by the presence in *C. virginis* of regularly spaced terminal feet that generally begin at the same level on the abdomen and are of approximately equal width and length. Hence, it is necessary to have complete specimens to distinguish between the two species. Similarly *C. robusta* can only be

distinguished from *C. serrata* by the presence on the latter species of triangular terminal feet.

## VARIABILITY

Early forms of *C. robusta* have a nearly hemispherical thorax, a cylindrical shape in the region of the lumbar stricture, and an abdomen that tapers distally. Later forms have a subspherical thorax that gives rise smoothly to the uniform taper of the abdomen at or slightly above the lumbar stricture (Moore, 1971).

## DISTRIBUTION

This species is a prominent constituent of assemblages from latitudes lower than 40° and ranges from the upper part of the *Dorcadospyris ateuchus* Zone to the *Lychnocanoma elongata* Zone.

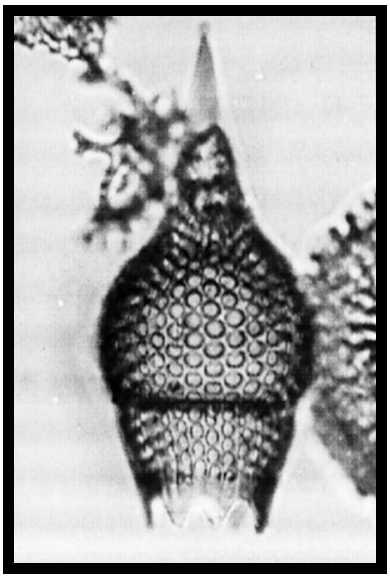
## PHYLOGENY

Descendant of *Calocycletta parva* and ancestor of *Calocycletta virginis* and *Calocycletta serrata*.

## REMARKS

For generic level phylogeny see Sanfilippo and Riedel, 1992, p.28.

# *Calocycletta (Calocyclopsis) serrata* Moore



*Calocycletta* cf. *virginis* Haeckel, Riedel and Sanfilippo, 1970, p.568, pl.14, fig.11

*Calocycletta serrata* Moore, 1972, p.148, pl.2, figs.1-3

## DESCRIPTION

Cephalis ovate, lobed, with sparse circular to subcircular pores. Some pores extend from the cephalis up into the region of a stout, conical apical horn. Thorax subspherical to campanulate, with circular pores hexagonally arranged and tending toward longitudinal alignment. Slight lumbar stricture externally. Abdomen tapering distally and terminating in three to twelve triangular terminal feet. Feet varying greatly in length and may be irregularly spaced. Abdominal pores circular to subcircular, hexagonally arranged and longitudinally aligned. Longitudinal lines continuous with those of thorax (Moore, 1972).

## DIMENSIONS

Based on 30 specimens. Length of apical horn 72-110 µm, of cephalis 38-48 µm, of thorax 96-125 µm, of abdomen 43-96 µm, of feet 5-29 µm (Moore, 1972).

## DISTINGUISHING CHARACTERS

Similar to *Calocycletta robusta*, but with terminal feet fewer and obtusely rounded (Riedel and Sanfilippo, 1978a).

The broad, shovel-shaped feet distinguish *Calocycletta serrata* from *C. robusta*, *C. virginis* and *C. caepa*. Superficially similar members of the genus *Podocyrtis* are more spindle-shaped, with ridges separating longitudinal rows of pores (Sanfilippo et al., 1985).

## VARIABILITY

The sparse pores on the cephalis vary in number, and in some specimens penetrate the base of the robust, cylindro-conical apical horn. The thorax is inflated-campanulate to subspherical, separated by the lumbar stricture (only slightly, if at all, expressed externally) from the short, tapering abdomen. Feet are shovel-shaped, 3-12 in number (Sanfilippo et al., 1985).

## DISTRIBUTION

This short ranging species occurs sparsely in early early Miocene assemblages from the tropical parts of the ocean basins. Its morphotypic first appearance is approximately synchronous with the lower limit of the *Cyrtocapsella tetrapera* Zone and it becomes extinct within the same zone.

Because its range is so short, it is not present in the ODP shipboard set of radiolarian zonal slides.

## PHYLOGENY

This species apparently evolved from *C. robusta* at about the same time as the much commoner, longer ranging *C. virginis*.

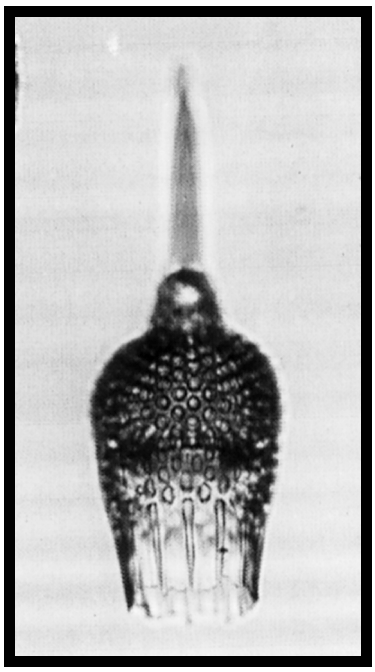
## REMARKS

For further taxonomic notes see Moore (1972).

Additional illustrations can be found in Dinkelman, 1973, pl.7, fig.5.

For generic level phylogeny see Sanfilippo and Riedel, 1992, p.30.

# *Calocycletta (Calocycletta) virginis* Haeckel



*Calocyclas (Calocycletta) virginis* Haeckel, 1887, p.1381, pl.74, fig.4; Riedel, 1959, p.295, pl.2, fig.8

*Calocycletta virginis* Haeckel, Riedel and Sanfilippo, 1970, p.535, pl.14, fig.10

## DESCRIPTION

Cephalis ovate, lobed, with usually sparse subcircular to circular pores, and bearing a stout apical horn that is usually conical but rarely weakly three-bladed. Thorax subspherical, with roughened surface. Thoracic pores circular, usually regularly hexagonally arranged, often with a tendency toward apparent longitudinal alignment, rarely with the longitudinal rows separated by long ridges. Usually no lumbar stricture externally. Abdomen subcylindrical or tapering distally, narrower than the widest part of the thorax. Abdominal pores subcircular or circular, usually smaller than those of the thorax, in most specimens longitudinally aligned. Terminal feet eleven to sixteen, lamellar, usually truncate, parallel, broader than the spaces between them, usually situated opposite alternate rows of abdominal pores (Riedel, 1959).

## DIMENSIONS

Length of apical horn 30-140 μm; of cephalis 35-40 μm; of thorax 65-130 μm; of abdomen 20-90 μm; of feet 10-45 μm. Breadth of cephalis 33-43 μm; of thorax 98-175 μm; of abdomen (distally) 78-100 μm (Riedel, 1959).

## DISTINGUISHING CHARACTERS

Thorax campanulate to hemispherical, without longitudinal ribs. Abdomen with a longer latticed part than *C. costata* and with numerous regular well developed lamellar feet originating at the same level (Riedel and Sanfilippo, 1978a).

This species differs from *Calocycletta robusta* Moore (1971, p.743, pl.10, figs.5-6) by the terminal structures being elongate, lamellar feet rather than triangular teeth. Thus the species can be unambiguously

recognized only when assemblages are well preserved (Sanfilippo et al., 1985).

## VARIABILITY

The stratigraphic range of this species spans most of the early Miocene. Early forms are transitional with *C. robusta* and have a heavy apical horn, hemispherical thorax and a strongly tapering abdomen. These early forms are distinguished from *C. robusta* by their regularly spaced terminal feet that generally begin at the same level on the abdomen and are of approximately equal width and length. Later forms may in some cases have a bladed apical horn, the thorax is less spherical and the abdomen has only a slight taper (Moore, 1972).

The cephalis is elongate-hemispherical, bearing a stout cylindro-conical horn, and the thorax is campanulate, inflated to a varying degree, with a slightly rough surface. The abdomen, with pores longitudinally aligned, is cylindrical or tapering distally, and from it depend 11-16 parallel, lamellar feet (Sanfilippo et al., 1985).

## DISTRIBUTION

*C. virginis* is common in assemblages of late early Miocene to early middle Miocene age from low and middle latitudes in all oceans, including the Mediterranean region. Its morphotypic first appearance is approximately synchronous with the lower limit of the *Cyrtocapsella tetrapera* Zone and it becomes extinct within the *Dorcadospyris alata* Zone.

## PHYLOGENY

*C. virginis* apparently branched off from *C. robusta*, which persisted to evolve into *C. caepa* Moore (1972, p.150, pl.2, figs.4-7).

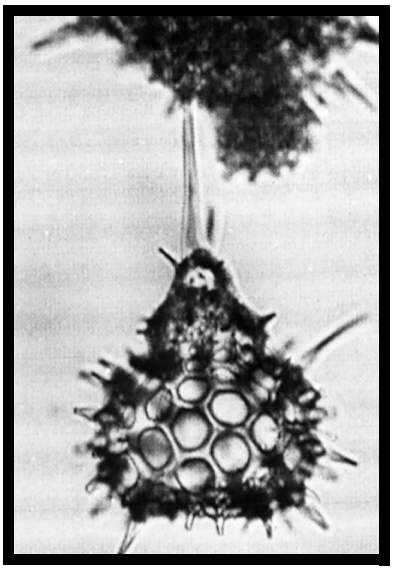
## REMARKS

See Nigrini (1974, p.1096) for further taxonomic discussion.

Additional illustrations can be found in Moore, 1972, pl.1, fig.7; Goll, 1972, pl.14, figs.1-3.

For generic level phylogeny see Sanfilippo and Riedel, 1992, p.28.

# *Calocycloma castum* (Haeckel)



*Calocyclas casta* Haeckel, 1887, p.1384, pl.73, fig.10

*Calocycloma castum* (Haeckel), Foreman, 1973, p.434, pl.1, figs.7, 9, 10

## DESCRIPTION

Shell generally of two segments, subpyriform. Cephalis subspherical, poreless, or with a very few small pores; occasionally spiny; bearing a cylindro-conical horn. Collar stricture well defined externally and with four collar pores internally. Thorax proximally conical with small circular pores sometimes arranged in vague longitudinal rows, remainder inflated with very large circular to subangular pores, surface generally with large, slender, conical spines at the junctions of the intervening pore bars. Aperture surrounded by a rounded rim, which may be smooth or bear irregularly developed, small, downwardly directed spines or thorns. Some similar early forms with a wider aperture, sometimes with attached fragments of lattice rather than thorns, are not included (Foreman, 1973).

## DIMENSIONS

Based on 20 specimens. Length overall, exclusive of horn, 150-220 μm (majority 150-185 μm); greatest width 100-185 μm; greatest diameter of pores 20-37 μm, of aperture 35-75 μm (Foreman, 1973).

## DISTINGUISHING CHARACTERS

Two-segmented, with small subspherical cephalis, and large thorax with its proximal part conical and small-pored, and its dominant distal part inflated and with very large pores. Surface generally spiny (Riedel and Sanfilippo, 1978a).

*C. castum* is distinguished from *C. ampulla* (Ehrenberg) (1854), with which it co-occurs, in having larger pores and more distinct change in contour between the conical and inflated parts of the thorax (Sanfilippo et al., 1985).

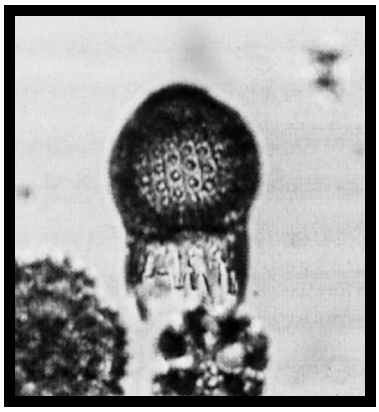
## VARIABILITY

Subpyriform shell of two segments. Cephalis poreless, occasionally spiny, with a long slender cylindro-conical horn (up to 250 μm). Thorax proximally conical with small irregular pores, distally inflated with very large subcircular pores. The abrupt change in external contour between the proximal and the distal parts of the thorax, at the level where the pores change in size, is not associated with an internal segmental division. Slender spines arise from the junctions of the intervening pore bars. Aperture restricted, surrounded by a rim that is smooth or spiny (Sanfilippo et al., 1985).

## DISTRIBUTION

*C. castum* is found between about 30°N and a locality that was at more than 45°S at the time of its deposition (DSDP Site 248), and ranges through most of the early and early middle Eocene. Its morphotypic first appearance is within the *Bekoma bidartensis* Zone and its morphotypic last appearance is approximately synchronous with the lower limit of the *Dictyoprora mongolfieri* Zone.

# *Carpocanopsis bramlettei* Riedel and Sanfilippo



*Cycladophora favosa* Haeckel in Riedel, 1954, pl.1, fig.3 (*non* fig.2)

*Carpocanopsis bramlettei* Riedel and Sanfilippo, 1971, p.1597, pl.2G, figs.8-14, pl.8, fig.7

## DESCRIPTION

Cephalis externally obtusely cap-shaped, generally separated from the thorax by a slight change in contour. Thorax barrel-shaped, with smooth surface and circular pores longitudinally aligned. Lumbar stricture expressed externally by a distinct change in contour. Abdomen subcylindrical, hyaline, usually with one row of pores proximally and a row of teeth terminally (Riedel and Sanfilippo, 1971).

## DIMENSIONS

Based on 25 specimens. Total length 115-190 µm. Maximum breadth 80-105 µm (Riedel and Sanfilippo, 1971).

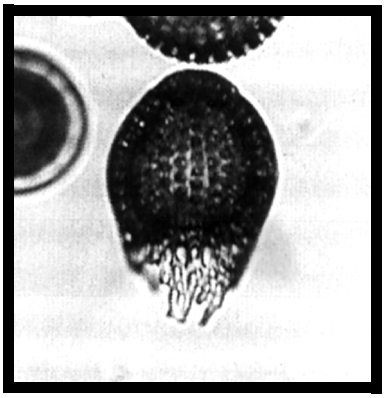
## DISTINGUISHING CHARACTERS

Lumbar stricture distinct externally. Abdomen subcylindrical, hyaline, usually with one row of pores proximally and a row of teeth terminally (Riedel and Sanfilippo, 1978a).

## DISTRIBUTION

This species occurs in low latitudes and ranges from the boundary between the *Cyrtocapsella tetrapera* and *Stichocorys delmontensis* Zones to the upper part of the *Dorcadospyris alata* Zone.

# *Carpocanopsis cingulata* Riedel and Sanfilippo



*Carpocanopsis cingulatum* Riedel and Sanfilippo, 1971, p.1597, pl.2G, figs.17-21, pl.8, fig.8

*Carpocanopsis cingulata* Riedel and Sanfilippo, Sanfilippo and Riedel, 1973, p.531

## DESCRIPTION

Cephalis obtusely cap-shaped, not separated from the thorax by an external collar structure. Thorax barrel-shaped, thick-walled (smaller and somewhat thinner in early specimens), with smooth surface and circular pores longitudinally aligned. Abdomen inverted truncate-conical, not distinguished in external contour from distal part of thorax, with rounded pores irregular in shape and arrangement. The termination of the abdomen is corroded in most specimens, but in a few is observed to consist of short, irregular, lamellar teeth (Riedel and Sanfilippo, 1971).

## DIMENSIONS

Based on 25 specimens. Length of cephalis plus thorax 95-115 μm. Maximum breadth 85-115 μm (Riedel and Sanfilippo, 1971).

## DISTINGUISHING CHARACTERS

Cephalothorax large and thick-walled, with pores longitudinally aligned. Abdomen inverted truncate-conical, not distinguished in external contour from distal part of thorax, with rounded pores irregular in shape and arrangement (Riedel and Sanfilippo, 1978a).

## DISTRIBUTION

The morphotypic first appearance of this species is approximately synchronous with the boundary between the *Dorcadospyris ateuchus* and *Lychnocanoma elongata* Zones. It becomes extinct within the *Calocycletta costata* Zone. It is confined to low latitudes.

# *Carpocanopsis cristata* (Carnevale)

? *Sethocorys cristata* Carnevale, 1908, p.31, pl.4, fig.18

? *Sethocorys cristata* var. α Carnevale, 1908, p.32, pl.4, fig.19

*Carpocanopsis cristatum* (Carnevale) ?, Riedel and Sanfilippo, 1971, p.1597, pl.1G, fig.16, pl.2G, figs.1-7

*Carpocanopsis cristata* (Carnevale) ?, Sanfilippo and Riedel, 1973, p.531

## DESCRIPTION

Cephalis hemispherical, in rare specimens bearing a short apical spine, usually separated from the thorax by a change in external contour. Thorax inflated barrel-shaped, with very thick wall and rough surface, and with fewer pores than *C. cingulata* and *C. bramlettei*, not longitudinally aligned. Abdomen usually represented by only a few corroded protuberances on the distal part of the thorax, but to judge from portions preserved on rare specimens it appears not to be separated from the thorax by an externally expressed stricture, and to have irregular pores similar to those of *C. cingulata* (Riedel and Sanfilippo, 1971).

## DIMENSIONS

Dimensions and other features are generally similar to those given by Carnevale for specimens from the Italian Miocene, but we cannot be confident of the identity of our species with his until there is an opportunity to examine additional Italian material (Riedel and Sanfilippo, 1971).

The dimensions given for *Sethocorys cristata* in Carnevale (1908) are as follows: Height of cephalis 24 μm, height of thorax 73 μm. Maximum breadth 98 μm. Length of horn 9 μm. Breadth of distal opening 34 μm. Length of "abdomen" 9 μm.

The dimensions given for *Sethocorys cristata* var. α in Carnevale (1908) are as follows: Height of cephalis 24 μm, height of thorax 78 μm.

Maximum breadth 98 µm. Breadth of cephalis 39 µm. Breadth of distal opening 31 µm. Length of "abdomen" 9 µm. Length of thorns 9 µm.

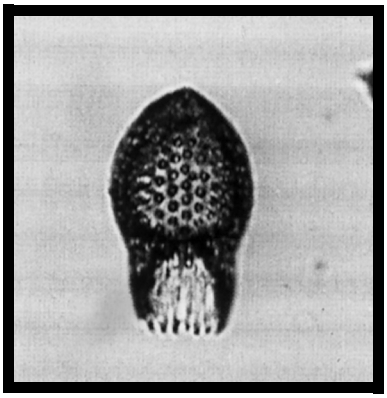
## DISTINGUISHING CHARACTERS

This species is distinguished from *C. favosa* by the abdomen being porous rather than hyaline, and evidently inverted truncate-conical (narrowing distally). It differs from *C. cingulata* [in having fewer pores, not longitudinally aligned, on the thorax, and a rough surface.] (Riedel and Sanfilippo, 1971).

## DISTRIBUTION

This low-latitude species has its morphotypic first appearance in the *Calocycletta costata* Zone and its morphotypic last appearance in the *Diartus petterssoni* Zone.

# *Carpocanopsis favosa* (Haeckel)



*Cycladophora favosa* Haeckel, 1887, p.1380, pl.62, figs.5-6; Riedel, 1954, p.172, pl.1, fig.2 (*non* fig.3)

*Carpocanopsis favosum* (Haeckel), Riedel and Sanfilippo, 1971, p.1597, pl.2G, figs.15-16, pl.8, figs.9-10

*Carpocanopsis favosa* (Haeckel) Sanfilippo and Riedel, 1973, p.531

## DESCRIPTION

Cephalis obtusely cap-like, commonly marked off externally from the thorax by a slight change in contour. Thorax barrel-shaped, with smooth or slightly rough surface and circular pores usually not showing marked longitudinal alignment. Lumbar stricture usually pronounced externally; in rare specimens the shell wall is very thick, even to the extent of filling the external lumbar stricture. Abdomen usually truncate-conical, widening distally, hyaline and commonly longitudinally ribbed, terminating in a row of irregular teeth; but in rare specimens similar to that of *C. bramlettei* (Riedel and Sanfilippo, 1971).

## DIMENSIONS

Based on 15 specimens. Total length 105-155 μm. Maximum breadth of thorax 70-95 μm (Riedel and Sanfilippo, 1971).

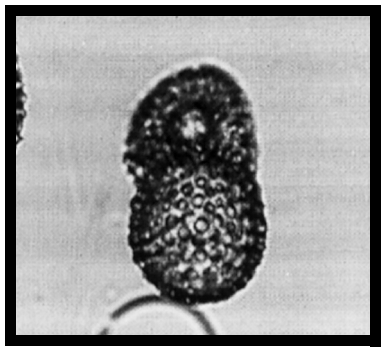
## DISTINGUISHING CHARACTERS

This species is distinguished from *C. cingulata* and *C. cristata* by the abdomen being hyaline, and widening distally. It differs from *C. bramlettei* by not showing marked longitudinal alignment of the thoracic pores (Sanfilippo, unpubl. data)

## DISTRIBUTION

This species occurs in low latitudes and ranges from within the *Cyrtocapsella tetrapera* Zone to within the *Calocycletta costata* Zone.

# *Centrobotrys gravida* Moore



*Centrobotrys gravida* Moore, 1971, p.744, pl.5, fig.8

## DESCRIPTION

Internal [eucephalic] lobe heavy, spherical with no observable pores. The arrangement of the internal spines and axial rod appears to be as illustrated by Nigrini (1967, p.50) for *C. thermophila*. However, only the ventral spine forms a pronounced opening in the outer cephalic wall. Outer shell, heavy and rough with irregularly arranged subcircular pores. Pores vary in size but are generally largest in the equatorial region of the spherical to subspherical thorax. [Collar] stricture marked; thorax closed (Moore, 1971).

## DIMENSIONS

Maximum length 128-166 μm. Maximum breadth 75-113 μm (Moore, 1971).

## DISTINGUISHING CHARACTERS

Thick-walled form with closed inflated thorax (Riedel and Sanfilippo, 1978a).

*C. gravida* is more coarsely porous than other species of the genus, and differs in having a thicker shell (Sanfilippo et al., 1985).

## VARIABILITY

The eucephalic chamber is located equidistantly from either side of the integrated ante- and post-cephalic chambers; the outline of the latter is generally semicircular, but in occasional specimens it tends to be bluntly pointed apically. The closed, globular thorax may be of the same size as the total cephalic structure, but is usually larger (Sanfilippo et al., 1985).

## DISTRIBUTION

This species is found in middle early Oligocene assemblages from the tropical Pacific Ocean and the Caribbean region. The morphotypic

first appearance of this species lies within the *Theocyrtis tuberosa* Zone and it evolves into *Centrobotrys petrushevskayae* within the same zone.

## PHYLOGENY

The ancestry of this species is not yet known, but *C. petrushevskayae* is clearly its descendant.

## REMARKS

Definiton of the terms eucephalic and ante- and post-cephalic can be found in Petrushevskaya, 1965 (pp.82-83, fig.5).

Additional illustrations can be found in Riedel and Sanfilippo, 1978a, pl.4, fig.8.

Although there are similar forms with a lighter, more elongate thorax in the Upper Eocene and Oligocene, the heavy shell and nearly spherical thorax of this species make it distinctive. Its heavy shell, short stratigraphic range and general abundance in samples make it particularly useful in stratigraphic studies (Moore, 1971).

# *Centrobotrys petrushevskayae* Sanfilippo and Riedel

*Centrobotrys*(?) sp. A Riedel and Sanfilippo, 1971, p.1602, pl.3F, figs.15-16

*Centrobotrys petrushevskayae* Sanfilippo and Riedel, 1973, p.532, pl.36, figs.12-13

## DESCRIPTION

Prominent eucephalic lobe surrounded by a large, irregularly pored chamber that is not subdivided into ante- and post-cephalic parts. Cephalic outline generally smoothly rounded, but in late forms its apex tends to be pointed though to a lesser degree than in *C. thermophila*. Thorax subcylindrical, its wall irregularly porous, tending to be closed distally in some late specimens (Sanfilippo and Riedel, 1973).

## DIMENSIONS

Based on 20 specimens. Maximum breadth of cephalis 45-65 µm (Sanfilippo and Riedel, 1973).

## DISTINGUISHING CHARACTERS

This species differs from *Centrobotrys thermophila* in having a more porous shell and rounded apex, and from *C. gravida* in not having the thorax closed and inflated, and in somewhat thinner shell wall. *C. petrushevskayae* appears to represent an evolutionary link between *C. gravida* and *C. thermophila* (Sanfilippo and Riedel, 1973).

## VARIABILITY

The merged ante- and post-cephalic chambers, which surround the eucephalic chamber, have an outline that usually comes to a rounded point apically, though in some specimens it is semicircular or (rarely) multi-lobed. Subcircular pores of unequal sizes are almost uniformly distributed over the shell wall. The subcylindrical thorax is of the same size as the cephalis, or smaller, and is rarely closed terminally (Sanfilippo et al., 1985).

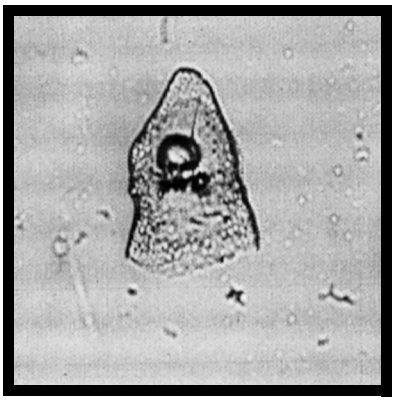
## DISTRIBUTION

This species occurs in small numbers, but is found in low-latitude assemblages of middle Oligocene age in all major ocean basins. It evolves within the *Theocyrtis tuberosa* Zone and its evolution to *Centrobotrys thermophila* is approximately synchronous with the lower limit of the *Dorcadospyris ateuchus* Zone.

## PHYLOGENY

*C. petrushevskayae* is the intermediate form in the lineage from *C. gravida* to *C. thermophila*.

# *Centrobotrys thermophila* Petrushevskaya



*Centrobotrys thermophila* Petrushevskaya, 1965, p.115, text- fig.20; Nigrini, 1967, p.49, text-fig.26, pl.5, fig.7

## DESCRIPTION

Internal [eucephalic] lobe heavy, spherical with small, closely spaced, subcircular pores, surface rough. This lobe is supported above the collar stricture by 3 stout rods or spines, 2 of which are attached to the primary laterals. The third is part of the apical spine, and originates at one end of the median bar. As it passes through the wall of the [eucephalic] lobe, it is flanked by 2 pairs of pores; it leaves the lobe as a cylindrical, needle-like spine that may or may not pierce the outer [eucephalic] wall. Vertical spine ends as a small thorn in one of the pores of the internal [eucephalic] lobe. Slender, cylindrical primary lateral, dorsal, and ventral spines extend outwards, and usually a little downwards, from the collar structure, often piercing the outer shell. The ventral spine originates near the upper end of the vertical spine. Short secondary laterals and an axial rod are also present. A pair of stout rods extend from either side of the vertical spine to the wall of the outer [eucephalic] shell. Outer shell approximately triangular in outline, often with a slight collar stricture; elliptical in transverse section. It is thin-walled, hyaline, and smooth with many, irregularly scattered, small circular pores. Termination invariably ragged (Nigrini, 1967).

## DIMENSIONS

Maximum length 90-128 µm. Maximum breadth 63-81 µm (Nigrini, 1967).

Total length 80-130 µm, maximum breadth 50-85 µm (Sanfilippo et al., 1985).

## DISTINGUISHING CHARACTERS

This species differs from *C. petrushevskayae* by the shell being more pointed apically, and having a poreless area around the eucephalic lobe (Sanfilippo et al., 1985).

## VARIABILITY

This species varies little in form. The merged ante- and post-cephalic lobes have an outline that is usually pointed apically, irregularly wavy in rare specimens, and there is no distinct change in contour between the cephalis and the broad thorax. Thoracic length is similar to that of thorax, or less. Pores in the shell wall are small and unevenly distributed, quite lacking near the eucephalic lobe (Sanfilippo et al., 1985).

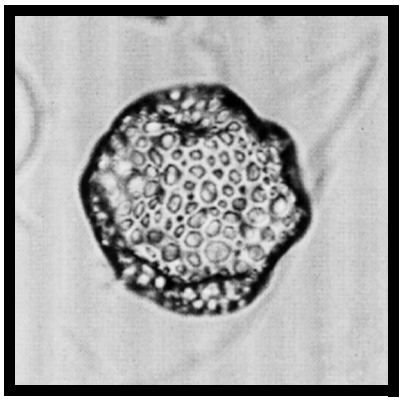
## DISTRIBUTION

*C. thermophila* occurs widely in late Oligocene to Holocene sediments from all oceans, in latitudes lower than 30°, but in small numbers. Its morphotypic first appearance is within the *Dorcadospyris ateuchus* Zone.

## PHYLOGENY

*C. thermophila* is the extant member of the lineage that commenced in the early Oligocene with *C. gravida*, and evolved through *C. petrushevskayae*.

# *Collosphaera tuberosa* Haeckel



*Collosphaera tuberosa* Haeckel, 1887, p.97; Nigrini, 1971, p.445, pl.34.1, fig.1 (with synonymy)

## DESCRIPTION

Shell is a smooth-surfaced, lumpy sphere, having numerous subcircular pores, irregular in size and distribution (10 to 30 pores on a half-equator). Usually there is a rather larger pore where the shell indents (Nigrini, 1971).

## DIMENSIONS

Maximum shell diameter 103-159 µm (Nigrini, 1971).

## DISTINGUISHING CHARACTERS

*C. tuberosa* differs from *Collosphaera orthoconus* (= *Collosphaera* sp. A Knoll and Johnson (1975, p.63, pl.1, figs.1-2,7, pl.2, figs.4-8) by having the shell surface indented, whereas the latter form has numerous outward protruberances. It is distinguished from *Buccinosphaera invaginata* by lacking invaginations of the shell wall.

## DISTRIBUTION

This species is found in late Quaternary tropical and temperate assemblages in the Pacific, Atlantic and Indian Oceans. Its morphotypic first appearance is probably synchronous and marks the lower limit of the *Collosphaera tuberosa* Zone. It is extant.

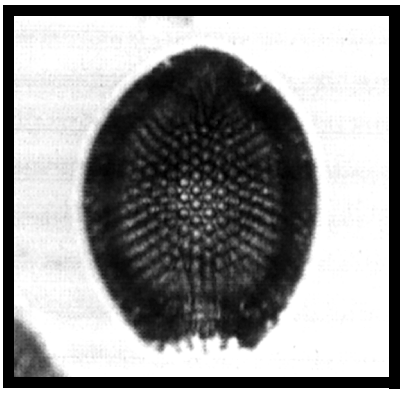
## PHYLOGENY

Unknown.

## REMARKS

Additional illustrations can be found in Nigrini and Moore, 1979, pl.1, fig.1; Knoll and Johnson, 1975, pl.2, figs.1-3.

# *Cryptocarpium azyx* (Sanfilippo and Riedel)



*Carpocanistrum azyx* Sanfilippo and Riedel, 1973, p.530, pl.35, fig.9; Riedel and Sanfilippo, 1978a, p.67, pl.4, fig.5

*Cryptocarpium azyx* (Sanfilippo and Riedel) Sanfilippo and Riedel, 1992, p.6, pl.2, fig.21

## DESCRIPTION

Cephalis within upper part of thoracic wall, and its structure consequently obscure - it is not a small sphere, but a large structure (at least distally) of widely separated, narrow bars forming a loose "basket". Thorax regularly ellipsoidal, with smooth surface, a somewhat constricted peristome, and thick wall perforated by small, closely spaced, circular pores longitudinally aligned. Peristome narrow, probably with an inwardly directed shelf, terminating in small thorns connected by ridges with the bars between distalmost thoracic pores, and perhaps the remnant of a previously existing abdomen (Sanfilippo and Riedel, 1973).

In Saunders et al., 1985 (p.412) specimens with abdominal lattice are excluded.

## DIMENSIONS

Based on 30 specimens. Total length 105-140 µm, maximum breadth 85-120 µm (Sanfilippo and Riedel, 1973).

## DISTINGUISHING CHARACTERS

Cephalis within upper part of thoracic wall. Thorax with thick wall, pores small, closely spaced and longitudinally aligned, and peristome inwardly directed (Riedel and Sanfilippo, 1978a).

This species is distinguished from *Cryptocarpium ornatum*, which co-occurs and ranges lower, by the lack of a third segment and thicker wall. Superficially similar Neogene species of *Carpocanistrum* are smaller (Sanfilippo et al., 1985).

## VARIABILITY

The variable features of this densely pored, two-segmented, ovoid form are the breadth and length of the thorax, and the thickness of the wall, which is sometimes greater than in the illustrated specimens (Sanfilippo et al., 1985).

## DISTRIBUTION

*C. azyx* is found in most tropical late Eocene localities. Absent in DSDP Site 140 Africa). Its morphotypic first appearance defines the base of the *Cryptocarpium azyx* Zone and it becomes extinct within the *Cryptocarpium ornatum* Zone.

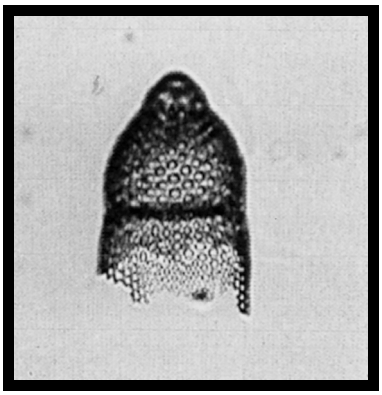
## PHYLOGENY

This species appears to have evolved from a non-tuberose precursor of *Theocyrtis tuberosa* or from *Cryptocarpium ornatum* as suggested by Sanfilippo and Riedel (1973, p.530). It seems to have left no descendants. Because of the apparent relationships of this species, its present placement in the family Carpocaniidae is not very satisfactory (see also discussion of *Cryptocarpium ornatum*).

## REMARKS

For generic level taxonomy see Sanfilippo and Riedel, 1992.

# *Cryptocarpium ornatum* (Ehrenberg)



*Cryptoprora ornata* Ehrenberg, 1873, p.222; 1875, pl.5, fig.8

*Cryptocarpium ornatum* (Ehrenberg) Sanfilippo and Riedel, 1992, p.6, pl.2, figs.18-20

## DESCRIPTION

Three-segmented pterocorythid with a cephalis that, in early forms, is as prominent as in a typical pterocorythid to as indistinct as in a typical carpocaniid in late forms. Thorax hemispherical, sometimes with a thickened wall apically. In these specimens the cephalis appears flattened, and the collar stricture is indistinct. Abdomen usually cylindrical or slightly expanded distally. The abdominal lattice is similar to that of the thorax, with pores closely spaced in longitudinal rows, not separated by ridges. The termination is undifferentiated. Longitudinal ridges between abdominal pore rows have been observed in well developed late forms (Sanfilippo, unpubl. data).

## DIMENSIONS

Total length 90-175 μm; of cephalothorax 70-105 μm; maximum width of thorax 65-100 μm (Sanfilippo et al., 1985).

## DISTINGUISHING CHARACTERS

*C. ornatum* is distinguished from *Cryptocarpium azyx* as indicated under that species. It is distinguished from *Carpocanopsis cingulata*, from which it is far separated stratigraphically, by the thinner thoracic wall and subcylindrical or distally expanding abdomen. Near the top of its range, *Cryptocarpium ornatum* is accompanied by an apparently related form which differs in having longitudinal ridges between rows of thoracic pores, and the thorax tending to become narrower distally. *C. ornatum* grades from a narrow, non-tuberose precursor of *Theocyrtis tuberosa*, the line of demarcation being drawn at the point at which the apical horn is lost (Sanfilippo et al., 1985).

See also Sanfilippo and Riedel, 1992, pl.2, fig. 17 (non-tuberose precursor of *T. tuberosa*) and pl.2, fig.21 (*Cryptocarpium azyx*).

## VARIABILITY

This three-segmented form has abdominal lattice similar to that of the thorax, with pores closely spaced in longitudinal rows, not separated by ridges. The most variable characters are the overall lengths and the degree of prominence of the cephalis. In early forms the cephalis is as prominent as in a typical pterocorythid, and in late forms it is as distinct as in a typical carpocaniid. In some specimens the abdomen slightly expands distally, and there is never a differentiated termination (Sanfilippo et al., 1985).

## DISTRIBUTION

*C. ornatum* is found in late middle Eocene to earliest Oligocene assemblages from tropical localities in all three oceans, and as far south as DSDP Site 283, near Tasmania. Its morphotypic first appearance is within the *Podocyrtis mitra* Zone and its morphotypic last appearance is approximately synchronous with the lower limit of the *Theocyrtis tuberosa* Zone.

## PHYLOGENY

This species originated from *Cryptocarpium* sp., an ancestor in common with that of the genus *Albatrossidium*. The distinct three-lobed cephalic structure originates in the genus *Cryptocarpium* in the middle Paleocene from simple three-segmented theoperids with an apical bar that gives off a pair of mitral arches near its junction with the shell wall. In the transition from *Cryptocarpium* sp. not only was the horn lost, but the cephalis eventually became flatter and the collar stricture indistinct. The late forms thus have a reduced cephalis similar to that of the carpocaniids. However, the carpocaniids of the *Theocyrtis tuberosa* Zone are not forms with pores pronouncedly aligned longitudinally and possessing post-thoracic structure (as in *Carpocanopsis cingulata* and *Cryptocarpium ornatum*), but instead are simple *Carpocanistrum* spp. with pores not pronouncedly aligned except near the top of the zone, and having the thorax terminated by a plain peristome (as illustrated by Riedel and Sanfilippo, 1971, pl.3D, figs.6-8). *Cryptocarpium ornatum* gave

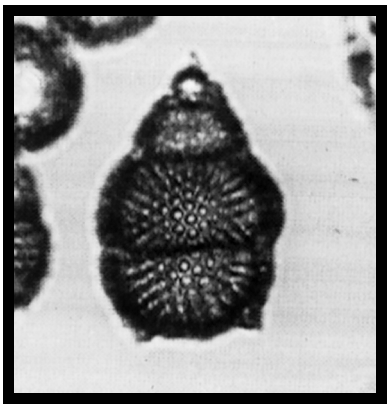
rise to *C. azyx* in the late Eocene and became extinct at the bottom of the *Theocyrtis tuberosa* Zone.

## REMARKS

Additional illustrations can be found in Sanfilippo and Riedel, 1973, pl.35, figs.3-4.

For generic level taxonomy see Sanfilippo and Riedel, 1992.

# *Cyrtocapsella cornuta* Haeckel



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

*Cyrtocapsella cornuta* Haeckel, Sanfilippo and Riedel, 1970, p.453, pl.1, figs.19-20 (with synonymy)

## DESCRIPTION

Four-segmented, pyriform skeleton. Cephalis spherical, poreless or with a few small pores, in most specimens with a short apical horn. Collar stricture pronounced. Thorax small, inflated-conical, separated from the much wider third segment by a very pronounced change in contour. Third segment truncate-hemispherical and fourth segment inverted-hemispherical with practically no external stricture between them. Mouth strongly constricted, about twice as wide as a pore. Pores subcircular to circular, not arranged in a regular pattern (Sanfilippo and Riedel, 1970).

## DIMENSIONS

Based on 30 specimens. Total length (excluding horn) 145-205 µm (usually 165-190 µm). Length of second segment 30-55 µm (usually about 45 µm), of third segment 45-70 µm (usually 50-60 µm), of fourth segment 50-80 µm. Maximum breadth 125 (rarely 115)-145 µm (Sanfilippo and Riedel, 1970).

## DISTINGUISHING CHARACTERS

A large species with generally pyriform outline, the cephalis and thorax separated from the two subsequent segments by a pronounced change in contour (at least internally). Post-lumbar stricture scarcely expressed externally (Riedel and Sanfilippo, 1978a).

See also discussion of *Cyrtocapsella tetrapera*.

## VARIABILITY

The pyriform shell of four robust segments has an abrupt change in contour between the second and third segments, which is less pronounced externally than internally in very thick-walled specimens.

Following the fourth, inverted-hemispherical segment with very restricted mouth, some specimens have a delicate, cap-like, inverted-conical closing fifth segment (Sanfilippo et al., 1985).

## DISTRIBUTION

*Cyrtocapsella cornuta* occurs in substantial numbers in assemblages of late early to middle Miocene age from low and middle latitudes of all oceans, including the Mediterranean region. Its morphotypic first appearance lies within the *Cyrtocapsella tetrapera* Zone, and it becomes extinct within the *Diartus petterssoni* Zone.

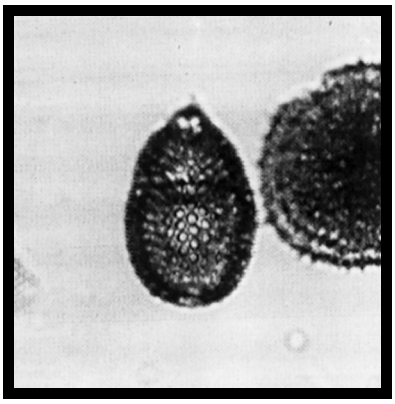
## PHYLOGENY

This species probably developed from *C. tetrapera*, which accompanies *C. cornuta* throughout its stratigraphic range.

## REMARKS

Additional illustrations can be found in Sanfilippo et al., 1973, pl.5, figs.1-2; Holdsworth, 1975, pl.2, figs.1-3, 5-8, 10.

# *Cyrtocapsella japonica* (Nakaseko)



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

*Cyrtocapsella japonica* (Nakaseko) Sanfilippo and Riedel, 1970, p.452, pl.1, figs.13-15 (with synonymy)

## DESCRIPTION

Shell consisting of three segments increasing uniformly in width, with a very constricted mouth. Cephalis spherical, poreless or with a few small circular pores, bearing a thornlike horn of the same length or shorter. Collar stricture not very distinct in contour because base of cephalis is generally enclosed in the thoracic wall. Thorax approximately hemispherical; abdomen swollen, rounded, with a mouth not much larger than a pore. Pores of thorax and abdomen generally similar, circular, usually closely spaced but occasionally sparser, rather regular in size and arrangement. Wall of thorax and abdomen thick, with rough surface. The lumbar stricture is not deep but is marked by a corresponding change in contour. Some specimens have a variable, inverted, caplike fourth segment with a thinner wall and less regular pores than in thorax and abdomen (Sanfilippo and Riedel, 1970).

## DIMENSIONS

Based on 30 specimens. Total length (excluding horn and fourth segment) 110-135 μm. Maximum breadth 55-100 μm (usually 75-90 μm). Ratio of length of abdomen to length of thorax (1.2-3.4):1, usually (1.8-2.4):1 (Sanfilippo and Riedel, 1970).

## DISTINGUISHING CHARACTERS

This species is distinguished from *C. tetrapera* by having the aperture of the third segment constricted, rather than that of the fourth. It is distinguished from *C. elongata* by having a more pronounced lumbar stricture, a rougher shell surface, and a larger skeleton (Sanfilippo and Riedel, 1970).

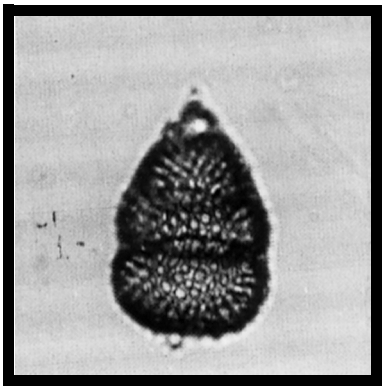
## DISTRIBUTION

This species is cosmopolitan. Its morphotypic first and last appearances both lie within the *Diartus petterssoni* Zone.

## REMARKS

For further taxonomic remarks see Sanfilippo and Riedel (1970).

# *Cyrtocapsella tetrapera* Haeckel



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

*Cyrtocapsella tetrapera* Haeckel, Sanfilippo and Riedel, 1970, p.453, pl.1, figs.16-18 (with synonymy)

## DESCRIPTION

Shell of four segments, with rounded termination. Cephalis spherical, poreless or with a few small pores in some specimens with a short apical horn. Collar stricture moderately pronounced. Thorax conical to hemispherical; third segment annular or inflated; fourth segment hemispherical with a strongly constricted mouth about twice as wide as a pore. Second to fourth segments rather thick-walled with their pores subcircular to circular and rather regular in size and arrangement. Strictures in some specimens rather pronounced, in others not expressed externally. Some specimens have a variable, inverted caplike segment with a thinner wall and less regular pores than in the second to fourth segments (Sanfilippo and Riedel, 1970).

## DIMENSIONS

Based on 35 specimens. Total length (excluding horn and fifth segment) 100-140 µm (usually 115-130 µm). Length of second segment 25-45 µm (usually about 35 µm), of third segment 25-40 µm, of fourth segment 30-55 µm. Maximum breadth 75-105 µm (Sanfilippo and Riedel, 1970).

## DISTINGUISHING CHARACTERS

Absence of a more pronounced change in contour between the second and third segments than between the other segments, and the terminal aperture is no wider than about 2 1/2 distal pore diameters. In some specimens a more delicate fifth (and occasionally sixth) segment is present (Riedel and Sanfilippo, 1978a).

*Cyrtocapsella tetrapera* is generally smaller than *C. cornuta*, and lacks the pronounced change in contour between the second and third segments that characterizes that species. It differs from four-segmented

specimens of *Stichocorys delmontensis* in having a more robust fourth segment with narrower aperture (Sanfilippo et al., 1985).

## VARIABILITY

The ovoid skeleton of four robust segments is sometimes terminated by a fifth (and rarely even a sixth), more delicate, inverted cap-like closing segment. Cephalis poreless or with a few small pores and in some specimens a short apical horn; thorax conical to hemispherical; third segment annular or inflated; fourth segment inverted hemispherical. Aperture of fourth segment constricted, of varying size but no wider than 2 1/2 times diameter of pores of that segment. External strictures vary from indistinct to pronounced (Sanfilippo et al., 1985).

## DISTRIBUTION

This species is common in assemblages of late early to middle Miocene age from low and middle latitudes in all oceans, including the Mediterranean region. The last occurrence of *C. tetrapera* is later in high-latitude N. Atlantic and Antarctic cores than in tropical cores. The morphotypic first appearance of *Cyrtocapsella tetrapera* defines the lower limit of the *Cyrtocapsella tetrapera* Zone. The morphotypic last appearance of this species lies within the *Diartus petterssoni* Zone.

## PHYLOGENY

The ancestry of this species has not been traced in detail, but it probably evolved from a form of *Eucyrtidium* close to *Stichocorys delmontensis*, by the top four (rather than the top three) segments becoming more robust than the subsequent ones.

## REMARKS

Additional illustrations can be found in Sanfilippo et al., 1973, pl.5, figs.4-6; Holdsworth, 1975, pl.2, figs.9, 13-15.

For further taxonomic discussion see Holdsworth (1975).