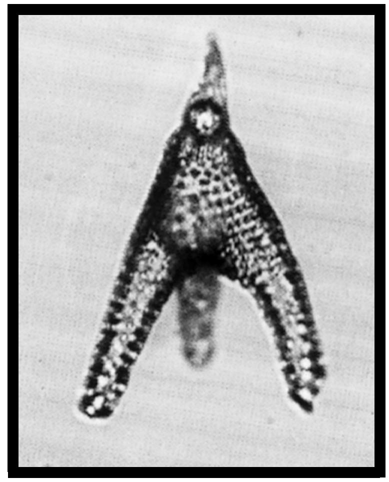
Sethochytris triconiscus Haeckel



[?] *Sethochytris triconiscus* Haeckel, 1887, p.1239, pl.57, fig.13; Riedel and Sanfilippo, 1970, p.528, pl.9, figs.5-6

DESCRIPTION

Cephalis poreless, spherical, bearing a stout conical horn. Thorax pyriform with circular pores, drawn out in its distal part into three divergent cylindrical porous tubes, which are open terminally. In some specimens, a rib terminating in a short free spine can be distinguished in the outer wall of the distal portion of these tubes (Riedel and Sanfilippo, 1970).

DIMENSIONS

Total length of skeleton 150-210 µm, its total breadth 100-170 µm (Riedel and Sanfilippo, 1970).

Total length 140-235 µm; maximum breadth 85-170 µm (Sanfilippo et al., 1985).

DISTINGUISHING CHARACTERS

This species is distinguished from its ancestor *Sethochytris babylonis* and from *Lithochytris archaea* Riedel and Sanfilippo (1970, p.528, pl.9, fig.7) and *Lithochytris vespertilio* Ehrenberg (1873, p.239) by having porous subcylindrical feet, and from the two last-mentioned also by being smaller and having only two segments. The scope of *Sethochytris triconiscus* is here modified to the extent of admitting specimens with feet closed terminally (Riedel and Sanfilippo, 1970, pl.9, fig.5), so long as they are long and subcylindrical rather than short and conical (Sanfilippo et al., 1985).

VARIABILITY

This two-segmented form has its tetrahedral thorax drawn out distally into three long, divergent, subcylindrical (not short, conical) porous tubes, which are open or closed with a spine distally. In some specimens, a rib corresponding to this spine can be distinguished in the outer wall of the tubular feet (Sanfilippo et al., 1985).

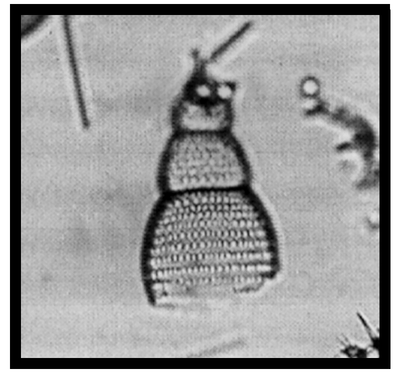
DISTRIBUTION

Sethochytris triconiscus occurs widely in tropical assemblages of late middle Eocene age. Its morphotypic first appearance lies within the *Podocyrtis mitra* Zone and its morphotypic last appearance lies within the *Podocyrtis goetheana* Zone.

PHYLOGENY

Intermediate transitional forms indicate that *Sethochytris triconiscus* arose from the *S. babylonis* group. It left no descendants.

Siphostichartus corona (Haeckel)



Cyrtophormis (Acanthocyrtis) corona Haeckel, 1887, p.1462, pl.77, fig.15

Siphostichartus corona (Haeckel), Nigrini, 1977, p.257, pl.2, figs.5-7 (with synonymy)

DESCRIPTION

Shell smooth, hyaline, conical, compressed laterally. Cephalis hemispherical with a few circular pores, well-developed three-bladed apical horn, and prominent duck-billed vertical tube; apical spine free of cephalic wall and axial rod well developed. Thorax inflated, slightly heavier than the rest of the shell; two or three transverse rows of circular pores. Abdomen inflated conical with four to seven transverse rows of circular pores. Fourth segment considerably larger than the others, usually contracting distally and without a differentiated peristome; numerous widely spaced transverse rows of small circular pores. Termination ragged or shell may terminate along a pore row, thus giving the appearance of terminal "teeth" (cf. Riedel and Sanfilippo, 1971, p.1600). Intersegmental strictures curved, not pronounced internally (Nigrini, 1977).

DIMENSIONS

Total length (excluding apical horn) 135-190 µm; length of abdomen 30-40 µm; length of fourth segment 70-105 µm; maximum breadth (across fourth segment) 70-95 µm (Nigrini, 1977).

DISTINGUISHING CHARACTERS

Four segmented, hyaline, laterally compressed artostrobiid with a prominent duck-billed vertical tube. The segmental divisions are well marked externally, and there is no peristome.

VARIABILITY

Rather constant. Early forms more porous, later forms more hyaline. There is a similar form in which the third segment appears to be divided into two segments. The relationship of this morphotype to *S. corona* has not been examined.

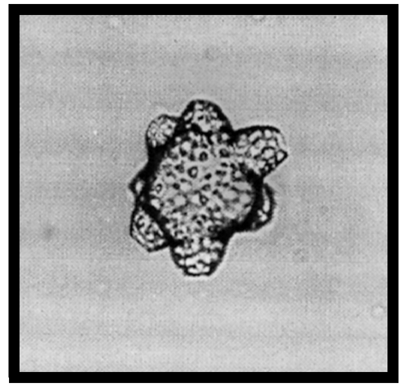
DISTRIBUTION

This low-latitude species is rare at time of first appearance in the *Stichocorys wolffii* Zone; few to common from *Dorcadospyris alata* Zone to *Didymocyrtis penultima* Zone; last rare occurrences in the *Stichocorys peregrina* Zone.

PHYLOGENY

Appears to have developed from *Siphostichartus praecorona* Nigrini (1977, p.258) in which the third segment has only two rows of pores and a less prominent apical horn and vertical tube.

Solenosphaera omnitubus omnitubus Riedel and Sanfilippo



Solenosphaera omnitubus Riedel and Sanfilippo, 1971, p.1586, pl.1A, fig.24; pl.4, figs.1-2 (*non* pl.1A, fig.23); Sanfilippo and Riedel, 1974, p.1024, pl.1, figs.1-5

DESCRIPTION

Shell small, approximately spherical, with 4 to 8 short, truncate, cylindrical tubes without differentiated termination, which occupy most of the surface of the sphere. Pores small, subcircular, not very variable in size, similar on the tubes and the sphere (Riedel and Sanfilippo, 1971).

DIMENSIONS

Based on 30 specimens. Overall diameter (including tubes) 70-120 µm. Length of tubules usually 5-10 µm, but some may be 20-70 µm (Riedel and Sanfilippo, 1971).

DISTINGUISHING CHARACTERS

Riedel and Sanfilippo (1978a) treated this subspecies and *S. omnitubus procera* together under the specific name and characterized them as having "Short or long tubes, closely spaced, occupying almost the entire spherical shell."

According to Riedel and Sanfilippo (1971), *S. omnitubus omnitubus* "differs from other members of the genus in the small number of tubes which occupy a very large proportion of the surface of the sphere."

According to Sanfilippo and Riedel (1974), the nominate subspecies includes only specimens "in which the tubular prolongations are as short as, or shorter than, those in the forms" illustrated by them in 1971 excluding fig.23.

Above and below the range of *S. omnitubus*, and co-occurring with it, is a collosphaerid that is very similar, but has a discernible spherical center from which tubes project. *S. omnitubus* must be comprised entirely of tubes.

VARIABILITY

The spherical shell surface is occupied entirely by cylindrical tubes, with a minimal amount of connecting lattice. Most specimens have 4-8, rarely 10 short tubes (5-20 µm), and some have 3-6 longer tubes (20-70 µm). Pores are small (<5 µm), subcircular, irregularly arranged (Sanfilippo et al., 1985).

DISTRIBUTION

S. omnitubus omnitubus is found in latest Miocene to early Pliocene sediments in latitudes lower than 20° in the Indian and Pacific Oceans. Its morphotypic first appearance lies within the *Didymocyrtis penultima* Zone and its morphotypic last appearance lies within the *Spongaster pentas* Zone. In the Indian Ocean, where members of the *Spongaster berminghami* -> *Spongaster pentas* lineage are rare, the last morphotypic appearance of *Solenosphaera omnitubus omnitubus* can be used as a convenient approximation for the base of the *Spongaster pentas* Zone.

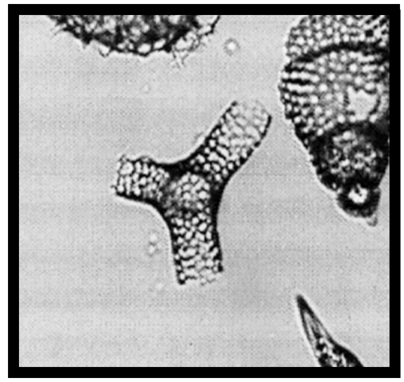
PHYLOGENY

Unknown.

REMARKS

Near both ends of its range, the tubes of *S. omnitubus* narrow distally.

Solenosphaera omnitubus procera Sanfilippo and Riedel



Solenosphaera omnitubus procera Sanfilippo and Riedel, 1974, p.1024, pl.1, figs.2-5

DESCRIPTION

This subspecies comprises specimens with three to six tubular prolongations, longer than those of the nominate subspecies, and no spherical central shell (Sanfilippo and Riedel, 1974).

DIMENSIONS

Based on 10 specimens. Maximum diameter, to ends of tubes 55-105 µm (Sanfilippo and Riedel, 1974).

DISTINGUISHING CHARACTERS

See Distinguishing Characters for *S. omnitubus omnitubus*.

DISTRIBUTION

S. omnitubus procera is found in latest Miocene and early Pliocene in latitudes lower than 20° in the Indian and Pacific Oceans. Its morphotypic first appearance lies within the *Didymocyrtis penultima* Zone and its morphotypic last appearance lies within the *Spongaster pentas* Zone.

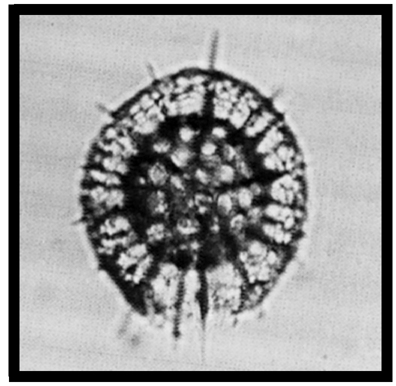
PHYLOGENY

Unknown.

REMARKS

Strictly speaking, subspecies should not occupy the same geographic region during the same time interval. Hence, the division of *S. omnitubus* into two subspecies is probably not valid, nor is it useful stratigraphically. It is likely that the two forms are variations within a single species, but they could be considered as two separate species.

Sphaeropyle langii Dreyer



Sphaeropyle langii Dreyer, 1889, p.13, pl.4, fig.54; Kling, 1973, p.634, pl.1, figs.5-10, pl.13, figs.6-8 (with synonymy); Foreman, 1975, p.618, pl.9, figs.30-31 (with synonymy)

DESCRIPTION

There are four concentric porous spheres of which the diameters are in the relative proportion of 1:3:9:14. All four spheres are perfectly round if we disregard the pylome and some undulations of the outermost shell. The spheres are thin and are connected by relatively few radial beams that continue beyond the outer sphere as thorns. These radial thorns are all approximately the same size and length and are double the length of the diameter of the innermost sphere. The innermost sphere is only recognizable as a shadow and therefore the structure cannot be recognized. The second and fourth spheres are similar in their structure, the pores are subcircular and of unequal size and somewhat smaller than the intervening bars. In contrast the pores of the third sphere are about three times wider than those of the second and fourth spheres and three to four times wider than the intervening bars. Moreover, they are subcircular and of unequal size. The spheres have a smooth surface. The pylome is large and clearly visible and its rim is covered with thorns or teeth of unequal size (translated from Dreyer, 1889).

DIMENSIONS

Based on 50 specimens. Diameter of outer shell 110-210 µm, second shell 70-114 µm, third shell 25-45 µm, innermost shell 12-15 µm. Thickness of outer shell 3-15 µm (Foreman, 1975).

DISTINGUISHING CHARACTERS

See under *Sphaeropyle robusta.*

DISTRIBUTION

The morphotypic first appearance of this species defines the base (approximately equivalent to the Miocene/Pliocene boundary) of the *Sphaeropyle langii* Zone in the North Pacific (Foreman, 1975). It is extant.

Casey and Reynolds (1980) believe it to be cosmopolitan, but is more common in high and middle latitudes.

PHYLOGENY

The evolutionary transition of this species from *Sphaeropyle robusta* occurs near the Pliocene-Pleistocene boundary. It is extant.

REMARKS

Examination of North Pacific material has led us to believe that the distinctions between *S. langii* and *S. robusta* are not at all clear and hence that *S. langii* is not a suitable zonal marker.

Sphaeropyle robusta Kling

Sphaeropyle robusta Kling, 1973, p.634, pl.1, figs.11-12, pl.6, figs.9-13, pl.13, figs.1-5

DESCRIPTION

Four concentric shells. Innermost shell robust, spherical, with circular pores of uniform size, irregularly arranged, 34 per half-circumference. Second shell (outward) robust, spherical, with circular pores of fairly uniform size, quincuncially arranged, 6-7 per half-circumference, weakly framed. Third shell, usually relatively thin-walled (particularly in later representatives), spherical to subspherical, with circular pores of variable size but conspicuously large relative to other shells, 7-9 per half-circumference, with tiny by-spines at most bar intersections. Cortical shell robust, subspherical to elongate, protruding at one end, bearing a pylome that is surrounded with a corona of stout teeth; pores circular, irregularly arranged, usually with well-developed frames, about 20 per half-circumference; bar intersections often developed into short by-spines.

Approximately 6 radial bars connect the inner three shells, many times this number between cortical and next inner shell. Stout radial main-spines are usually short in Leg 18 material, but appear broken and could be better developed (preserved) elsewhere (Kling, 1973).

DIMENSIONS

Based on 10 specimens (younger material). Diameter of innermost shell 16-18 µm, second shell 40-46 µm, third 100-110 µm, cortical (small diameter) 146-200 µm.

Based on 10 specimens (older material). Diameter of innermost shell 10-20 µm, second shell 30-44 µm, third 62-100 µm, cortical 98-15 µm (Kling, 1973)

DISTINGUISHING CHARACTERS

This species differs from *S. langii*, its apparent descendant, primarily in its more robust cortical shell with framed pores. *S. langii* is generally smaller with a thin cortical shell bearing simple, cylindrical pores (Kling, 1973).

S. robusta could not be distinguished from *S. langii* on the basis of the relative robustness of the outer shell. Instead it is distinguished from *S. langii* by its second shell, which has distinctly smaller pores, more regular in size. Using the size and regularity of the pores of the second shell as the criterial for distinguishing these two species gives a somehat longer morphological range for *S. langii* than indicated by Kling (1973) (Foreman, 1975).

VARIABILITY

Earlier populations are smaller with peristomal teeth fused into a rim. They are otherwise similar although it may eventually be possible to separate these forms as a new species (Kling, 1973).

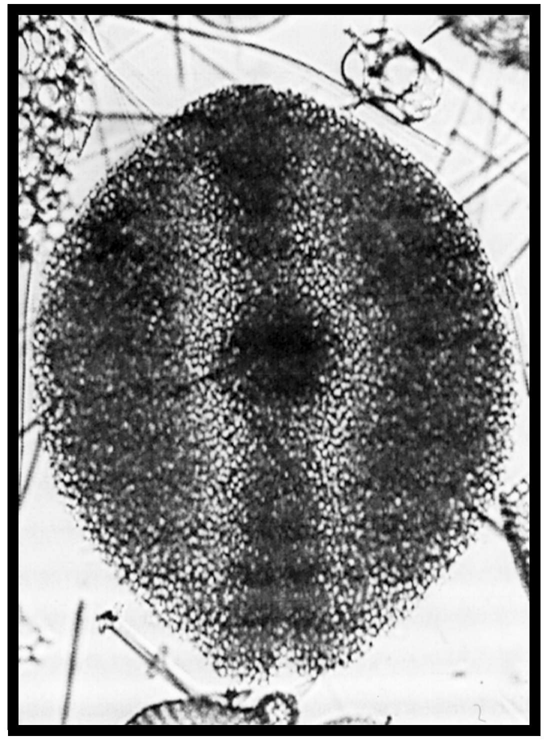
DISTRIBUTION

This species is found in high and middle-latitude sediments. Its morphotypic last appearance lies within the *Eucyrtidium matuyamai* Zone in the North Pacific. Its morphotypic first appearance is in the early Miocene.

PHYLOGENY

Ancestry unknown, but its evolutionary transition to *Sphaeropyle langii* occurs near the Pliocene-Pleistocene boundary.

Spongaster berminghami (Campbell and Clark)



Spongasteriscus berminghami Campbell and Clark, 1944, p.30, pl.5, figs.1-2

Spongaster klingi Riedel and Sanfilippo, 1971, p.1589, pl.1D, figs.8-10, pl.4, figs.7-8

Spongaster berminghami (Campbell and Clark) Sanfilippo and Riedel, 1973, p.524; Riedel and Sanfilippo, 1978a, p.73, pl.2, figs.14-16

DESCRIPTION

Shell of fair size, shaped like a Greek cross; with four arms in two opposite crossed pairs, two arms of one pair longer (vertical axis) than two arms of pair at an angle to them (transverse axis); arms squarish, wide (~0.83 length of longest arms, measured to center of shell, and about equal in length and width in transverse arms), free ends with rounded edges and subparallel sides, connected across angles made by intersection of paired arms by meshwork of similar structure and density, and not forming a patagium (quadrangular disc); meshwork made up everywhere of fine alveolelike, subhexagonal pores, very dense and frothy; framework with only a very few, short, widely scattered projecting points so that general surface is not spiny (Campbell and Clark, 1944).

Finely spongy skeleton elliptical in outline. Especially thickened are the central area, two opposite radii (and especially their distal parts), and two bluntly crescentic zones near the periphery (one on either side of the thickened diameter). One of the thickened radii includes a narrow conical pylome-tube (Riedel and Sanfilippo, 1971).

DIMENSIONS

Length of long axis, 210-240 μm, of short axis, 140-180 μm (Campbell and Clark, 1944).

Major diameter 325-405 µm; minor diameter 255-355 µm (Riedel and Sanfi1ippo, 1971).

Major diameter of disk 270-405 µm; minor diameter 211-355 µm (Sanfilippo et al., 1985).

DISTINGUISHING CHARACTERS

Elliptical spongy skeleton. Two opposite radii (especially their distal parts), and two bluntly crescentic zones near the periphery, are especially thickened and appear darker than the remainder of the skeleton (Riedel and Sanfilippo, 1978a).

The combination of thickened or denser areas on two opposite radii, and distinct crescentic areas at the periphery between those radii, distinguish *S. berminghami* from all other spongodiscids.

VARIABILITY

S. berminghami is an elliptical to sometimes circular, spongy disk with thickened or denser zones in the center and along two opposite radii, and in two crescent-shaped areas on the periphery between those radii. One of the thickened radii includes a narrow conical pylome-tube, in most specimens expressed at the margin as a small cleft. The thickened zones on opposite radii may appear as two discrete circular areas, or as a bar through the long axis, like a propeller (Sanfilippo et al., 1985).

DISTRIBUTION

S. berminghami is found in late late Miocene to early early Pliocene assemblages in latitudes lower than 40°, but it is rare in the Indian Ocean. Its morphotypic first appearance lies within the *Didymocyrtis antepenultima* Zone. Its evolutionary transition to *Spongaster pentas* defines the base of the *Spongaster pentas* Zone. However, its morphotypic last appearance is diachronous by ~0.8 m.y. (younger in the tropical Indian Ocean than in the tropical Pacific Ocean).

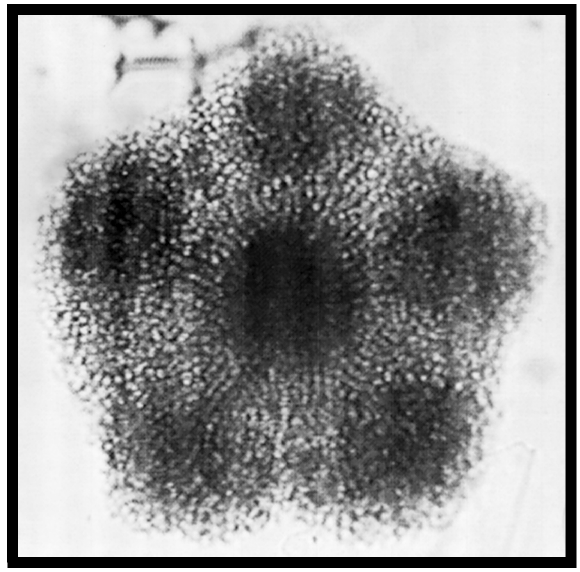
PHYLOGENY

S. berminghami originated from a circular spongodiscid, and evolved into *S. pentas*.

REMARKS

For further discussion of the evolution of this species see Riedel and Sanfilippo, 1978a, p.88 and Riedel and Sanfilippo, 1981, pp.341-344.

Spongaster pentas Riedel and Sanfilippo



Spongaster pentas Riedel and Sanfilippo, 1970, p.523, pl.15, fig.3; Riedel and Sanfilippo, 1978a, p.74, pl.2, figs.5-8

DESCRIPTION

Spongy disc usually pentagonal, occasionally hexagonal. Rays from center to marginal angles generally not markedly denser (but usually slightly thicker) than the spongy structure between them. Central area (one-half to one-third of disc diameter) more dense, or thicker, with concentric structure (Riedel and Sanfilippo, 1970).

DIMENSIONS

Diameter 170-290 µm (Riedel and Sanfilippo, 1970).
Diameter 170-360 µm (Sanfilippo et al., 1985).

DISTINGUISHING CHARACTERS

Spongy disc usually pentagonal, occasionally quadrangular or hexagonal, generally with thickened zones corresponding to the angles (Riedel and Sanfilippo, 1978a) *S. pentas* is distinguished from *S. berminghami* by its polygonal rather than bipolar symmetry. It is distinguished from *S. tetras* by the number of rays in most specimens being greater than four (Riedel and Sanfilippo, 1978a).

VARIABILITY

S. pentas is a spongy disk whose symmetry is usually pentagonal or hexagonal, occasionally quadrangular or heptagonal. It generally has thickened or denser zones (corresponding to the angles) and in the center. The most frequent form has five or six thick or dense lobes with lighter spongy material between them, the outline slightly concave between the lobes. In some specimens there are no such concavities between the lobes, and in some the entire disk appears equally dense (Sanfilippo et al., 1985).

DISTRIBUTION

S. pentas is found in middle Pliocene assemblages from latitudes lower than 40°, but it is rare in Indian Ocean sediments. Absent from DSDP Site 206, near New Zealand. Its evolutionary transition from *S. berminghami* defines the base of the *Spongaster pentas* Zone. However, its morphotypic first appearance is diachronous by ~0.8 m.y. (younger in the tropical Indian Ocean than in the tropical Pacific Ocean). Its morphotypic last appearance is also diachronous by ~0.8 m.y. (older in the tropical Indian Ocean than in the tropical Pacific Ocean).

PHYLOGENY

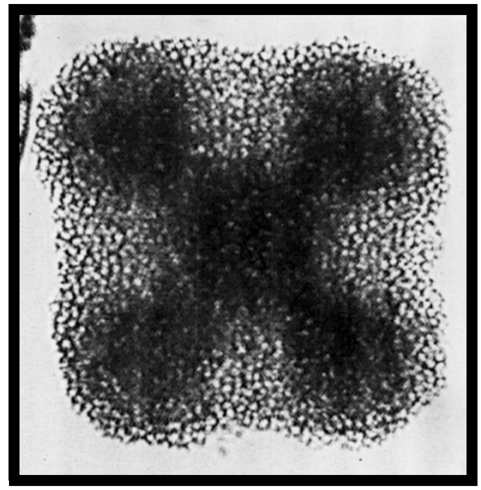
S. pentas evolved from *S. berminghami* and into *S. tetras*.

REMARKS

Additional illustrations can be found in Riedel and Sanfilippo, 1971, pl.1D, figs.5-7.

Casey et al., 1979 reported the presence of *S. pentas* in Holocene Gulf of Mexico sediments. They considered it to be part of a relict fauna isolated from pan-tropical distribution by the uplift of the Isthmus of Panama.

Spongaster tetras tetras Ehrenberg



Spongaster tetras Ehrenberg, 1860, p.833; 1872b, p.299, pl.IV(iii), fig.8

Spongaster tetras tetras Ehrenberg, Nigrini, 1967, p.41, pl.5, figs.1a-1b (with synonymy); Riedel and Sanfilippo, 1978a, p.74, pl.2, figs.2-3

DESCRIPTION

Shell is a square with rounded corners. Four spongy, pear-shaped "arms" approximately at right angles, are regularly placed in one plane around 5 concentric lattice spheres. A completely enveloping patagium usually makes the central spheres difficult to see, and, at best, 5 concentric rings can be recognized; the "arms" appear merely as dark patches.

Patagium is, for the most part, a dense irregular spongy meshwork with small subcircular pores, but around the "arms" bars become thicker and 3-bladed. In some specimens radial beams apparently form a basis for the patagium, which will then have a radially striated border. Patagium may be depressed slightly around the central structure, but at its periphery its thickness is ~0.25 the length of the sides of the square (Nigrini, 1967).

DIMENSIONS

Distance between sides 150-302 µm (usually 150-276 µm); diagonal 187-369 µm (usually 187-316 µm) (Nigrini, 1967).

Diagonal width 160-370 µm (Sanfilippo et al., 1985).

DISTINGUISHING CHARACTERS

S. tetras is distinguished from *S. pentas* by having generally four rather than five or six rays. In some core sequences, occasional assemblages within the stratigraphic range of *S. tetras* contain rare five-rayed individuals, and therefore identifications based on single specimens can be unreliable (Riedel and Sanfilippo, 1978a).

S. tetras tetras is distinguished from *S. tetras irregularis* (Nigrini, 1967, p.43, pl.5, fig.2) by its square rather than rectangular shell.

VARIABILITY

S. tetras is a quadrangular (rarely pentagonal) spongy disk, with thickened or denser zones, corresponding to the angles and in the center. The outline between the corners may be straight, resulting in a rectangular perimeter, or curved inward to produce a lobed one. Quadrangular (rarely pentagonal) specimens with density uniform throughout are also admitted (Sanfilippo et al., 1985).

DISTRIBUTION

This extant species is found in late Pliocene to Quaternary sediments from all latitudes less than 40°, except DSDP 206 near New Zealand and 362 off SW Africa. Its evolutionary transition from *Spongaster pentas* lies within the *Spongaster pentas* Zone. Its morphotypic first appearance is a reliable and easily recognizable synchronous event. In latitudes higher than about 30°, the square subspecies *S. tetras tetras* is absent, and only the rectangular subspecies *S. tetras irregularis* (Nigrini, 1967, p.43, pl.5, fig.2) occurs.

PHYLOGENY

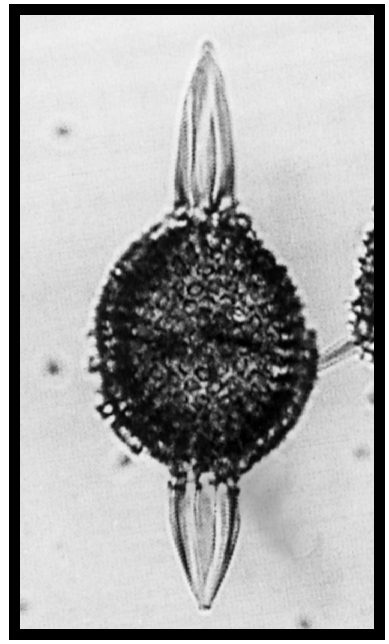
S. tetras evolved from *S. pentas*, and remains extant.

REMARKS

Additional illustrations can be found in Riedel and Sanfilippo, 1971, pl.1D, figs.2-4.

Benson's (1966) description of this species (p.238) is consistent with the above, but his dimensions are generally smaller (e.g., length of diagonal 127-196 μm), which may reflect lack of affinity for restricted water masses such as the Gulf of California.

Spongatractus balbis Sanfilippo and Riedel



Spongatractus balbis Sanfilippo and Riedel, 1973, p.518, pl.2, figs.1-3, pl.25, figs.1-2

DESCRIPTION

Cortical shell ellipsoidal, thick-walled, with subcircular pores (approximately 8-13 on the half-equator), joined to the double medullary shell by bars lying approximately in the equatorial plane, and usually two bars collinear with the polar spines. On the surface of the cortical shell are one to three layers of meshwork formed by connection of the distal ends of small superficial thorns. Two-bladed polar spines are somewhat variable in form and size, but are commonly robust, about half as long as the cortical shell, with a change in contour from parallel-sided proximally to tapered distally (Sanfilippo and Riedel, 1973).

DIMENSIONS

Based on 25 specimens. Major diameter of cortical shell (excluding external layers) 105-150 µm, its minor diameter 65-145 µm. Maximum diameter of outer medullary shell 30-50 µm (Sanfilippo and Riedel, 1973).

DISTINGUISHING CHARACTERS

S. balbis is distinguished from *S. pachystylus* by the lesser development of external meshwork, and from members of the *Axoprunum pierinae* (Clark and Campbell, 1942) group (Sanfilippo and Riedel, 1973) by the presence of meshwork on the cortical shell (Sanfilippo et al., 1985).

VARIABILITY

The thick-walled ellipsoidal cortical shell is covered by one to three layers of spongy meshwork, formed by connection of the distal ends of superficial thorns. The cortical shell has approximately 8-13 subcircular pores on the half-equator. Two bladed polar spines are variable in form and size, commonly robust, about half as long as the cortical shell, with a change in contour from parallel-sided proximally to tapered distally (Sanfilippo et al., 1985).

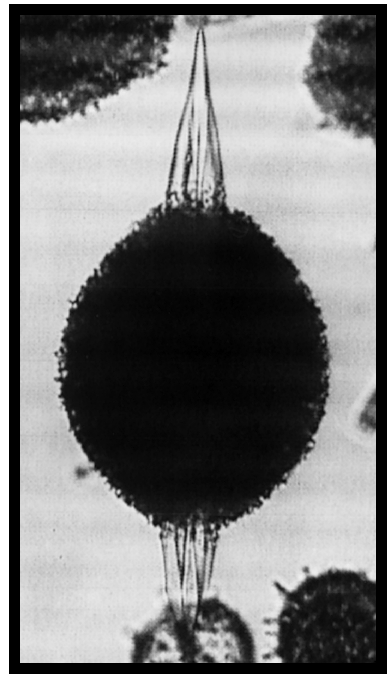
DISTRIBUTION

This species is found in localities from 30°S to 35°N, through most of the early Eocene, and earliest middle Eocene. Its morphotypic first appearance is approximately synchronous with the lower limit of the *Buryella clinata* Zone. Its evolutionary transition to *Spongatractus pachystylus* lies within the *Phormocyrtis striata striata* Zone.

PHYLOGENY

Spongatractus balbis evidently evolved from the *Axoprunum pierinae* (Clark and Campbell) group (Sanfilippo and Riedel, 1973, p.488, pl.1, figs.6-12, pl.23, fig.3) and gave rise to *S. pachystylus*.

Spongatractus pachystylus (Ehrenberg)



Spongosphaera pachystyla Ehrenberg, 1873, p.256; 1875, pl.26, fig.3

Spongatractus pachystylus (Ehrenberg), Sanfilippo and Riedel, 1973, p.519, pl.2, figs.4-6, pl.25, fig.3 (with synonymy)

DESCRIPTION

Thick-walled ellipsoidal shell, covered completely by one thick or several layers of spongy meshwork, and joined to a spherical, double medullary shell by bars approximately in the equatorial plane. Additionally, there are two bars collinear with the two robust, bladed spines, which are variable in form and size. Commonly the polar spines are as long as the major diameter of the cortical shell, with a distinct change in contour midway, from parallel proximally to tapered distally. The external spongy layer commonly obscures the medullary shell - only when this layer is thinned by dissolution can the medullary shell be observed. Small thorns may be present on the proximal part of the polar spines. These are remnants of the spongy cortical shell, indicating the extent (major diameter) of the cortical shell before dissolution. (Sanfilippo, unpubl. data)

DIMENSIONS

Based on 35 specimens. Major diameter of cortical shell 160-230 µm; minor diameter 105-180 µm. Length along major axis including the spines 270-465 µm (Sanfilippo, unpubl. data).

DISTINGUISHING CHARACTERS

S. pachystylus is distinguished from *S. balbis*, its ancestor, by greater development of the outer spongy layer, and from the *Axoprunum pierinae* (Clark and Campbell) group (Sanfilippo and Riedel, 1973, p.488) by the distinctively bladed spines and presence of the spongy layer (Sanfilippo, unpubl. data).

VARIABILITY

The spines are constantly robust, and show a characteristic change in contour from parallel-sided proximally to tapered distally. The development of the spongy layer on the cortical shell varies in thickness, but by definition is always more than three layers thick in early forms--later forms may have only one thick, unzoned layer (Sanfilippo, unpubl. data).

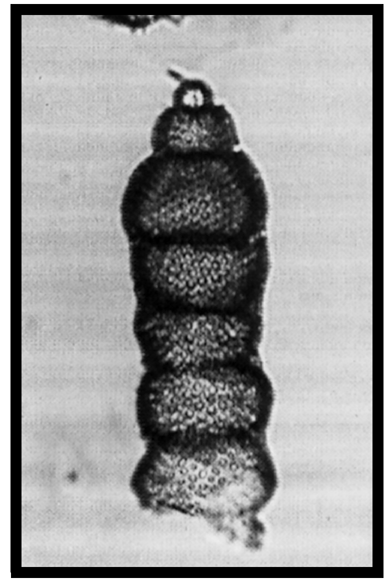
DISTRIBUTION

S. pachystylus is found at all middle Eocene localities in 30°S to 35°N. It evolved from *Spongatractus balbis* within the *Phormocyrtis striata striata* Zone. Its morphotypic last appearance lies within the *Podocyrtis goetheana* Zone.

PHYLOGENY

S. pachystylus evolved from *S. balbis* and left no known descendants. In the latest part of its range, *S. pachystylus* is accompanied by an ellipsoidal to discoidal form that may be related. It has a double medullary shell and a marginal pylome, and is covered with dense spongy meshwork obscuring the details of a phacoid shell similar in size to that of this species (Sanfilippo et al., 1985).

Stichocorys delmontensis (Campbell and Clark)



Eucyrtidium delmontense Campbell and Clark, 1944, p.56, pl.7, figs.19-20

Stichocorys delmontensis (Campbell and Clark) Sanfilippo and Riedel, 1970, p.451, pl.1, fig.9 (with synonymy)

DESCRIPTION

Shell not especially large, rather stout (1.6-2.4 diameters of cylinder in length); cephalis knoblike, distinct, with much lateral flattening, and with a short, sometimes curved, or straight, apical horn, cervix truncate and constricted; thorax distinct, truncate apically, subhemispherical, its basal diameter exceeding distal diameter, and marked by an internal transverse septum; abdominal joints three, clearly limited by lumbar constrictions and transverse septa, uppermost joint subhemispherical like thorax and more or less continued in contour with it, these two regions forming, as a whole, a cone (45°), its sides strongly bulged, its length ~0.29 total length, and its basal diameter 1.37 upper diameters, second and third joints together subcylindrical, second one about same length as first, and third one shorter, its distal end inturned with a somewhat constricted mouth with short, projecting, discrete, spinelike denticles (mouth commonly torn); wall uniformly thin, gray; pores lacking on cephalis, on thorax ~40, well scattered, in subhexagonal areas with raised corners, pores of abdomen larger than those of thorax, well-separated, scattered, all pores subcircular (Campbell and Clark, 1944).

DIMENSIONS

See under Variability

DISTINGUISHING CHARACTERS

The upper conical, generally more robust part of the shell is formed of three segments. Thorax generally has more pores than in *S. wolffii*, and the fourth segment lacks longitudinal ribs. Third segment inflated annular, rather than truncate conical as in its direct evolutionary descendant, *S. peregrina* (Riedel and Sanfilippo, 1978a).

The third segment is typically inflated annular, but specimens with conical third segments are admitted here if the fourth segment is not as wide as the third (Westberg and Riedel, 1978).

Stichocorys peregrina has the upper, conical part of the shell composed of four segments rather than three, the third segment typically truncate-conical rather than annular, and the fourth segment as wide as or wider than the third. *S. wolffii* has fewer pores on the thorax, and longitudinal ridges on the fourth segment of some specimens. There is an undescribed Eocene form, probably related to *Eucyrtidium montiparum* Ehrenberg (1873, p.230; 1875, pl.9, fig.11), in which the thorax is slightly more conical than that of *Stichocorys delmontensis*, but which is so similar that the species are difficult to distinguish unless age is taken into account (Sanfilippo et al., 1985).

VARIABILITY

The proximal conical part of the shell, formed of three segments, is generally more robust than the distal segments. The fourth segment (in some specimens as robust as the third) is narrower than the third. Thorax and subsequent segments are generally evenly perforate, with circular to subcircular pores. Total number of segments varies from four to about nine. Late specimens are commonly larger (length of first three segments (excluding horn) 105-120 µm; maximum breadth of third 85-100 µm) than earlier ones (length of first three segments 95-105 µm; maximum breadth of third 80-90 µm). In some middle-latitude assemblages, specimens almost certainly belonging to this species have the fourth and subsequent segments as wide as the third, and therefore cannot be recognized individually (Sanfilippo et al., 1985).

DISTRIBUTION

Stichocorys delmontensis is widespread and common in assemblages of middle early to late Miocene age in low and middle latitudes. Its morphotypic first appearance lies within the *Stichocorys delmontensis* Zone. Its evolutionary transition to *Stichocorys peregrina* defines the base of the *Stichocorys peregrina* Zone.

PHYLOGENY

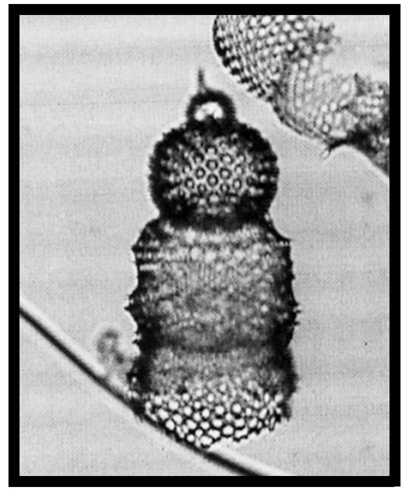
This species apparently arose from a robust many-segmented form with no distinction between an upper conical part of the shell and a lower cylindrical one, which is common in early Miocene assemblages but not yet described. It evolved into *S. peregrina*.

REMARKS

Additional illustrations can be found in Sanfilippo et al., 1973, pl.6, fig.3; Westberg and Riedel, 1978, pl.3, figs.1-5.

Reynolds (1980) defines the base of his *Theocorys redondoensis* Zone in the western North Pacific by the evolutionary transition from *S. delmontensis* to *S. peregrina*. The *S. peregrina* Zone of Riedel and Sanfilippo (1978a) is partially equivalent to this zone.

Stichocorys johnsoni Caulet



Stichocorys johnsoni Caulet, 1986, p.851, pl.6, figs.5-6

DESCRIPTION

Shell with four (or more?) segments, distinctly separated by constrictions, the first three segments together forming a conical section. Cephalis subspherical, rough, poreless, and bearing a slightly curved apical horn generally longer than the first segment. Thorax subspherical, well developed, having 20-30 irregularly arranged subcircular pores. Third segment conical, longer and broader than any other, bearing two kinds of pores: ordinary small pores on the whole surface and a single row of pores twice as large as the others just below the lumbar stricture. Fourth segment generally ragged with smaller pores irregularly arranged. Entire apertural margin never observed (Caulet, 1986).

DIMENSIONS

Length of first, second and third segments 120-130 µm. Thoracic length 40 µm. Abdominal length 50-60 µm (Caulet, 1986).

DISTINGUISHING CHARACTERS

Eucyrtidium diaphanes (Sanfilippo et al., 1973, p.221, pl.5, figs.12-14) also has a single row of large pores just below the lumbar stricture and is thus similar to this form, but its shell has a different shape and the stratigraphic range is quite different.

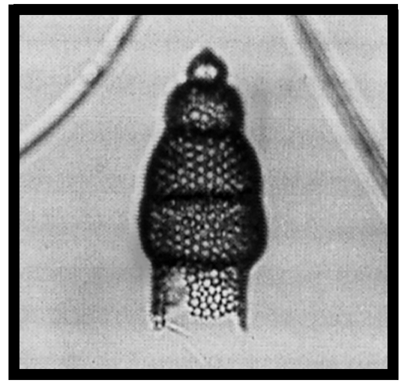
VARIABILITY

This species was first described from Indian Ocean material. Pacific Ocean forms of this species generally lack an indentation on the third segment.

DISTRIBUTION

First occurrence has not been recognized, but is at least as old as the *Didymocyrtis antepenultima* Zone. Its morphotypic last appearance lies within the *Stichocorys peregrina* Zone.

Stichocorys peregrina (Riedel)



Eucyrtidium elongatum peregrinum Riedel, 1953, p.812, pl.85, fig.2; Riedel, 1957, p.94

Stichocorys peregrina (Riedel), Sanfilippo and Riedel, 1970, p.451, pl.1, fig.10; Westberg and Riedel, 1978, p.22, pl.3, figs.6-9

DESCRIPTION

Shell with seven (or more) segments distinctly separated by constrictions, the first four segments together forming a conical section, the subsequent segments an approximately cylindrical section. Cephalis subspherical, rough, poreless, and bearing, usually eccentrically, a straight or curved conical horn of the same length. Thorax hemispherical with rough surface, having some 40 subcircular pores, which are irregularly arranged and 1.5-3 times as broad as the intervening bars. Third segment conical, usually longer than any other, and fourth segment a cylinder bulged laterally to a greater or less degree; these two segments with a rough surface, and circular pores 2-4 times as broad as the bars, often regularly arranged in indistinct vertical series, 7-9 in a vertical row on each segment, 14-20 on a half equator. Segments subsequent to the fourth are generally shorter and narrower than the third and fourth, subcylindrical and laterally bulged: their surfaces are smooth, with irregularly disposed subcircular pores, 2-5 times as broad as the bars. The entire apertural margin of the shell was not observed, though it might be expected to be not greatly constricted, without radial apophyses (Riedel, 1953).

DIMENSIONS

Length of the first four segments 125-135 μm; greatest breadth (in the lower part of the third segment, or the middle of the fourth) 70-80 μm. Breadth of cephalis 20 μm; of thorax 35-40 μm; of fifth segment 60-65 μm. Length of cephalis 12-15 μm; of thorax 20-25 μm; of third segment 35-50 μm; of fourth segment 30-40 μm; of subsequent segments 20-45 μm (Riedel, 1953).

DISTINGUISHING CHARACTERS

The upper conical part of the shell consists of three segments, and the fourth is equally robust. The third segment is long, truncate conical, and the thorax short (Riedel and Sanfilippo, 1978a).

Westberg and Riedel (1978) placed an additional restriction on the identification of this species, i.e. "that the width of the top quarter of the fourth segment must be at least as great as the maximum width of the third segment."

In *Stichocorys delmontensis*, the cylindrical part of the shell begins below the third segment, rather than below the fourth. In *Eucyrtidium calvertense* Martin (1904, p.450, pl.130, fig.5) and *E. inflatum* Kling (1973, p.636, pl.11, fig.7, pl.15, figs.7-10) the pores of the third and the fourth segments show a pronounced longitudinal alignment, which is lacking in *Stichocorys peregrina* (Sanfilippo et al., 1985).

VARIABILITY AND DISTRIBUTION

In typical, low-latitude forms, the third segment is long and pronouncedly conical, the fourth is wider than the third, and the subsequent segments are narrower and constitute a cylindrical lower part of the shell. In latitudes higher than about 20°, and in areas of cold boundary currents, the skeleton tends to be more robust, the third segment is shorter and less obviously conical, and the fourth segment is rarely pronouncedly wider than the third (DSDP Sites 223, 303, 310, 173, 84, 157, 362). In its extreme development, this tendency leads to forms in which the segments uniformly increase in width distally. The specific name has only been used for forms in which the width of the top quarter of the fourth segment is at least as great as the maximum width of the third, though this may be an artificial delimitation in view of the tendency described above. Nevertheless, we perpetuate it here because it is not certain that the forms becoming pronouncedly narrower after the fourth segment are conspecific with those expanding uniformly, and the definition applied until now has served to delimit a stratigraphically useful early to middle Pliocene species in low latitudes (Sanfilippo et al., 1985).

The evolutionary transition of *Stichocorys peregrina* from *Stichocorys delmontensis* defines the base of the *Stichocorys peregrina* Zone. Its morphotypic last appearance defines the base of the *Pterocanium prismatium* Zone and is a synchronous event, at least, in low latitudes.

PHYLOGENY

This species evolved from *Stichocorys delmontensis*, and became extinct without leaving any descendants.

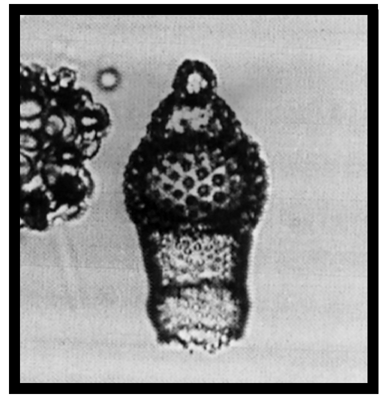
REMARKS

See Holdsworth (1975) for discussion of some difficulties with regard to the identification of *S. peregrina* and *S. delmontensis* at DSDP Site 289.

Reynolds (1980) defines the base of his *Theocorys redondoensis* Zone (late Miocene) in the western North Pacific by the evolutionary transition from *Stichocorys delmontensis* to *S. peregrina*.

The *Lamprocyclas heteroporos* Zone of Hays (1970) and emended by Kling (1973) in the North Pacific is defined by the last occurrence of *Stichocorys peregrina*. This zone is uppermost Pliocene and falls within the *Pterocanium prismatium* Zone in the equatorial Pacific.

Stichocorys wolffii Haeckel



Stichocorys wolffii Haeckel, 1887, p.1479, pl.80, fig.10; Riedel, 1957, p.92, pl.4, figs.6-7

Stichocorys baerii Haeckel, 1887, p.1479, pl.80, fig.8

Stichocorys mulleri Haeckel, 1887, p.1480

DESCRIPTION

Shell with four or more segments (usually 5 or 6), of which the cephalis, thorax and abdomen form an upper conical portion sharply differentiated from the subcylindrical lower portion. Shell surface usually rough or thorny in upper portion, smooth post-abdominally. Cephalis spherical, usually poreless, bearing a sharp conical apical horn of approximately the same length or shorter. Thorax hemispherical, with most of the pores (irregularly or approximately hexagonally arranged) secondarily closed with siliceous lamellae; pores rarely with a tendency toward longitudinal alignment, with rows separated by longitudinal ridges. Abdomen inflated annular, with round pores (sometimes double-contoured) approximately hexagonally arranged, often with apparent longitudinal alignment, of approximately the same width as the intervening bars. Fourth and subsequent segments narrower than widest part of abdomen, thinner-walled than first three segments, with pores of proximal one or two segments often tending to longitudinal alignment with intervening longitudinal ridges, and pores of distal segments irregular in size, shape and arrangement (Riedel, 1957).

DIMENSIONS

Length of first three segments 85-110 µm; breadth of abdomen 65-100 µm, of fourth segment 55-75 µm (Riedel, 1957).

DISTINGUISHING CHARACTERS

Under this name we record all specimens of *Stichocorys* in which the thorax is practically poreless (with no more than half a dozen pores on the visible half of that segment). In many specimens the fourth segment has rather irregular longitudinal ridges, but this is not a required characteristic for the species (Riedel and Sanfilippo, 1978a).

S. wolffii is distinguished from the co-occurring *S. delmontensis* by its practically poreless thorax - only specimens with a total of twelve or less thoracic pores are admitted. A commonly occurring feature, but not required for identification, is the presence of rather irregular longitudinal ridges on the fourth segment.

In the later part of its range, where the skeletons are small and sparsely porous, some co-occurring forms do not have a wider, conical upper part of the shell and a narrower, terminal cylindrical part. Such specimens are not included in this species.

We suspect that *S. wolffii* is not a good "biological" species, but might rather be simply a morphological variant of *S. delmontensis*. However, it is retained because of its stratigraphic utility (Sanfilippo et al., 1985).

VARIABILITY

Through the greatest part of its range, the most variable features are the breadth of the third segment (ranging from 65 to 100 µm), and the degree of distinctness of the segments forming the narrower, post-abdominal part of the skeleton. In the latest part of its range, the test is generally smaller (breadth of third segment 50-80 µm; length of first three segments (excluding horn) 75-100 µm), and its wall tends to become almost completely poreless.

One complication in the stratigraphic use of this species is the fact that, at least once or twice during its range, it declined in abundance by about two orders of magnitude (Westberg and Riedel, 1978, p.13, text-fig.9) (Sanfilippo et al., 1985).

DISTRIBUTION

S. wolffii is found in tropical late early to middle Miocene assemblages, and a few specimens have been recorded in the Mediterranean. Its morphotypic first appearance defines the base of the *Stichocorys wolffii*. Its morphotypic last appearance is approximately synchronous with the base of the *Diartus petterssoni* Zone.

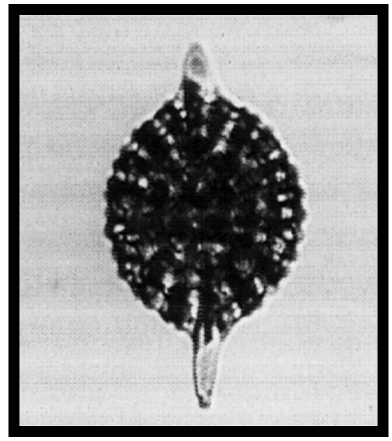
REMARKS

Additional illustrations can be found in Riedel and Sanfilippo, 1971, pl.2E, figs.8-9; Riedel and Sanfilippo, 1978a, pl.1, fig.3, pl.9, fig.12.

For a long period during the early part of its range, this species is accompanied by specimens of *Stichocorys delmontensis* identical in all respects in possessing a more porous thorax. Only toward the end of its range does it diverge substantially from the accompanying *S. delmontensis*; it is smaller, and other segments in addition to the thorax tend to be poreless... In many of the specimens of *S. wolffii* near the top of its range, segmental divisions beyond the third tend to be lost (Riedel and Sanfilippo, 1978a).

DSDP Site 289 contains a segment throughout which *S. wolffii* predominates numerically over *S. delmontensis*, this segment being preceded and succeeded by segments in which *S. delmontensis* is predominant. The most characteristic *S. wolffii* morphotype is restricted to the *S. wolffii* dominated segment. The levels of population change are comparatively easily recognizable datums at Site 289. However, the observed morphologic gradation between *S. wolffii* and *S. delmontensis* morphotypes, and the reversible dominance of the former might suggest that "*S. wolffii*" is no more than a dimorph of *S. delmontensis*, its abundance being determined by local environmental factors (Holdsworth, 1975, p.531).

Stylacontarium acquilonium (Hays)



Druppatractus acquilonius Hays, 1970, p.214, pl.1, figs.4-5; Ling, 1975, p.717, pl.1, figs.17-18

Stylacontarium acquilonium (Hays) Kling, 1973, p.634, pl.1, figs.17-20, pl.14, figs.1-4; Ling, 1973, p.777, pl.1, figs.6-7

DESCRIPTION

Cortical shell, ellipsoidal, usually thick-walled, but showing considerable variation in thickness, pores evenly spaced, circular to oval, with raised hexagonal borders, 6-7 across minor axis, short thorn-like projections arising from nodes. In some thick-walled individuals, the distal ends of these projections are connected. Shell bears two polar spines unequal in length, circular in cross section, distally sharpened, weakly three-bladed at base. Medullary shell single, ellipsoidal, composed of loose meshwork, pores large, irregular in shape, supported by 8-10 stout beams, 6-8 approximately in the equatorial plane, two along main axis being internal extensions of polar spines (Hays, 1970).

DIMENSIONS

Based on 25 specimens. Length of major axis cortical shell 164-185 µm, width 132-162 µm, pore diameter 6-21 µm (usually about 17 µm), thickness 10-29 µm, median 21 µm, length of polar spines 35-79 µm. Length of medullary shell 47-57 µm, width 44-47 µm (Hays, 1970).

DISTRIBUTION

S. acquilonium is apparently restricted to the North Pacific. It is absent from the equatorial Pacific and from the Antarctic. Its morphotypic last appearance is just above the base of the *Eucyrtidium matuyamai* Zone in the North Pacific.

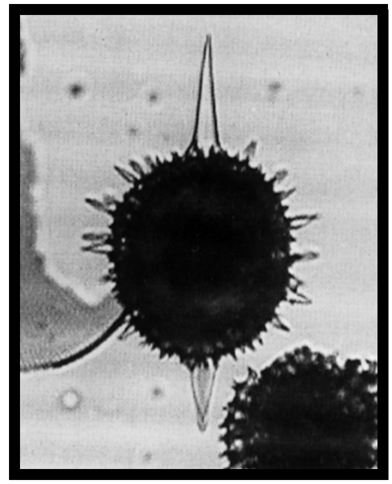
PHYLOGENY

According to Reynolds (1980), this species evolved from *S*. sp. cf. *S. acquilonium* (= *S*. sp. aff. *S. bispiculum* of Kling, 1973, p.634) at or near the Miocene/Pliocene boundary.

REMARKS

According to Robertson (1975) heavy shelled specimens of *Axoprunum stauraxonium* (see Nigrini and Moore, 1979, p.S57) are similar to *S. acquilonium*, but *A. stauraxonium* is smaller in size (<165 µm, along the major axis).

Stylatractus universus Hays [= *Axoprunum angelinum* (Campbell and Clark)]



Stylatractus sp. Hays, 1965, p.167, pl.1, fig.6

Stylatractus universus Hays, 1970, p.215, pl.1, figs.1-2

DESCRIPTION

Skeleton consists of 1 cortical and 2 medullary shells, medullary shells spherical, cortical shell prolate. Innermost shell thin-walled, pores circular with hexagonal borders. Second shell thin-walled, pores regular to irregular in size and shape. Cortical shell wall very thick. Pores circular to oval, 11-14 across equatorial diameter, surface varying from smooth to rough. Medullary shells connected to cortical shell by numerous stout radial beams, two lying along the major axis project through cortical shell as stout polar spines; other beams radiate out in all directions from bases attached to inner medullary shell. Some beams penetrate through cortical shell and form short primary spines. Shell bears two large, nearly equal, polar spines as long to half as long as major axis of cortical shell (Hays, 1965).

DIMENSIONS

Diameter of innermost shell 15-20 µm, of 2nd shell 40-50 µm, of cortical shell (minor axis) 106-115 µm (major axis) 109-123 µm, length of spines 40-120 µm (Hays, 1965).

DISTINGUISHING CHARACTERS

S. universus is distinguished from *Stylacontarium acquilonium* (Hays) (Kling, 1973, p.634. pl.1, figs.17-20, pl.14, figs.1-4) by its smaller size and smaller pores and the presence of two medullary shells.

There is an unnamed, sometimes co-occurring actinommid, which is very similar to *S. universus* in shell surface and pore size, but which is somewhat larger (cortical shell 120-140 µm) and has a spherical cortical shell, and no medullary shell (Sanfilippo et al., 1985).

VARIABILITY

A prolate cortical shell, containing two spherical medullary shells, bears stout polar spines, which are circular in cross section and nearly as long as the major axis of the cortical shell (100-125 µm). The only substantial morphological variation is in the beams (not restricted to the equatorial plane), which connect the cortical and medullary shells. In some cases these project through the cortical shell as short spines in addition to the two, longer polar spines (Sanfilippo et al., 1985).

DISTRIBUTION

S. universus is practically cosmopolitan. In middle Quaternary sediments, its upper limit constituting an important stratigraphic datum in the middle of the Brunhes magnetic epoch. The lower limit of its range is not known, but may be as old as Paleocene. Its morphotypic last appearance lies within the *Collosphaera tuberosa* Zone.

In the tropical Indian Ocean, Johnson et al. (1989) used the upper limit of *Stylatractus universus* to divide the *Collosphaera tuberosa* Zone into two zones.

PHYLOGENY

Unknown.

REMARKS

There is a difficult and convoluted problem as to whether this form should be called *Stylatractus universus* Hays or *Axoprunum angelinum* (Campbell and Clark) (see Nigrini and Lombari, 1984). Usage seems to favor *S. universus*. The taxonomy of *A. angelinum* can be found in Kling, 1973, p.634.

Additional illustrations can be found in Kling, 1971, pl.1, figs.7 and Kling, 1973, pl.1, figs.13-16, pl.6, figs.14-18.