# *Bekoma bidartensis* Riedel and Sanfilippo

*Bekoma bidarfensis* Riedel and Sanfilippo, 1971, p.1592, pl.7, figs.1-7; Foreman, 1973, p.432, pl.3, figs.20- 21, pl.10, fig.6

#### DESCRIPTION

Cephalis and thorax together campanulate, with three robust feet. Cephalis approximately hemispherical, with very thick wall, not marked off from the thorax externally. Cephalis seems



generally poreless, but with numerous depressions resembling infilled pores. In some specimens the apical and vertical spines extend beyond the cephalic surface as two weak, oblique spines. Thorax campanulate, with somewhat rough surface, proximally narrow and forming a type of "neck" merging with the cephalis with no change in contour. Thoracic pores subcircular, smaller and sparser proximally. From (and slightly above) the distinct distal rim of the thorax arise three long, thick, subparallel cylindrical feet with an outwardly-directed thorn in the distal half. In many specimens, the feet are irregularly hollow distally. Fragments of latticed abdomen are commonly present (Riedel and Sanfilippo, 1971).

#### DIMENSIONS

Based on 9 specimens. Length of cephalis plus thorax 145-165  $\mu$ m; maximum breadth of thorax 130-170  $\mu$ m (Riedel and Sanfilippo, 1971).

#### DISTINGUISHING CHARACTERS

Feet straight, not divergent, with an internal projection but not joined by a ring (Riedel and Sanfilippo, 1978a).

*B. bidartensis* differs from *B. campechensis* Foreman (1973) in not having the three feet joined by a triangular ring supported by inwardly directed thorns, and from *B. divaricata* Foreman (1973) in having less widely divergent, more robust feet (Sanfilippo et al., 1985).

#### VARIABILITY

The relatively large, thick-walled cephalis is usually provided with one or two small horns representing the apical and vertical spines. The outwardly directed thorn from each foot is approximately median or in the distal half of the foot, depending on the total length of the feet. Later forms have shorter feet. Weak abdominal meshwork is variably developed (Sanfilippo et al., 1985).

#### DISTRIBUTION

Few assemblages of late Paleocene to early early Eocene age are available, but this species has been found in the northern tropical Pacific, the northern Atlantic (~35°N), the Caribbean region, and in France. Its morphotypic first appearance marks the base of the *Bekoma bidartensis* Zone and it becomes extinct within the *Buryella clinata* Zone.

#### PHYLOGENY

This species appears to have evolved from *B. campechensis* by degeneration of the ring joining the feet, but this is uncertain because of the unavailability of complete successions. It is the last representative of its genus.

### *Bekoma campechensis* Foreman

*Bekoma campechensis* Foreman, 1973, p.432, pl.3, fig.24, pl.10, figs.1-2

#### DESCRIPTION

Shell of two segments with three feet joined by branches that form a triangular ring. Cephalis cone-shaped to rectangular in outline, bearing a conical or cylindrical apical horn and vertical horns. Apex of cephalis flattened, causing the angular appearance when viewed dorsally or ventrally. Cephalis



and proximal thorax poreless with a thick hyaline wall, surface roughened with minute irregular papillae, occasionally with tiny spines or nodes apically. Collar stricture not defined externally as contour of cephalis merges with that of thorax. Internally six collar pores, the vertical spine rising very sharply so that the cervical pores tend to be almost in a vertical plane. Thorax proximally narrow, necklike, distally expanded, tending to have straight sides. Expanded portion with pores generally subcircular and subregular in size and arrangement, and surface roughened with small, generally pointed nodes. Fragments of thin lamellar lattice extend below the wide, open aperture. Three sturdy, proximally ridged, straight, divergent feet depend from the shell immediately above the smooth apertural rim. They are joined distally by a triangular ring, which is formed by a single inward directed branch of each foot bifurcating and curving slightly downward to join the similar branch of each adjacent foot (Foreman, 1973).

#### DIMENSIONS

Based on 20 specimens. Length of cephalis and thorax together 100-140  $\mu$ m (majority 120-135  $\mu$ m); width of thorax 105-130  $\mu$ m; length of feet 65-300  $\mu$ m (generally 120-200  $\mu$ m) (Foreman, 1973).

#### DISTINGUISHING CHARACTERS

This species is distinguished from other members of the genus by the cephalis and proximal, neck-like part of the thorax being thick-walled and hyaline, and by its three, long, circular in cross section, divergent feet that are joined distally by a triangular ring formed by a single inwardly directed branch of each foot (Sanfilippo, unpubl. data).

#### VARIABILITY

*Bekoma campechensis* is one of the most commonly found Paleocene radiolarians. It includes forms varying not only in shell size, but also in length, width and angle of divergence of the three feet. The cylindrical apical horn is quite variable in size, from long and robust to short (Sanfilippo, unpubl. data).

#### DISTRIBUTION

The morphotypic first appearance of this species defines the base of the *Bekoma campechensis* Zone. It evolved into *Bekoma bidartensis* in the late Paleocene and its morphotypic last appearance lies within the *Bekoma bidartensis* Zone.

#### PHYLOGENY

The origin of this species is not known, but it is the ancestor of *Bekoma bidartensis*.

# *Botryostrobus aquilonaris* (Bailey)

- *Eucyrtidium aquilonaris* Bailey, 1856, p.4, pl.1, fig.9
- Artostrobium miralestensis (Campbell and Clark), Riedel and Sanfilippo, 1971, p.1599, pl.1H, figs.9-13 (*partim.*); Kling, 1973, p.639, pl.5, figs.31-34 (*partim.*)



*Botryostrobus aquilonaris* (Bailey), Nigrini, 1977, p.246, pl.1, fig.1 (with synonymy)

#### DESCRIPTION

Shell typically heavy, thick-walled, but early forms are not so robust. Constrictions (other than collar and lumbar strictures) unevenly spaced and all strictures usually obscure externally. Shell spindle-shaped with four or five post-cephalic segments, the fourth being widest. Cephalis hemispherical with small irregular pores; vertical tube robust, cylindrical, directed obliquely upwards at ~45°. Apical horn very small, needle-like. Thorax inflated with two or three transverse rows of large subcircular pores. Subsequent segments with three to six (usually four) transverse rows of very closely spaced circular pores. Thickness of shell makes each pore appear to have a ring around it. Shell narrows distally, terminating in smooth peristome of variable width; peristome may have single row of pores. Termination smooth or with an undulating margin (Nigrini, 1977).

#### DIMENSIONS

Based on 20 specimens. Total length 110-155  $\mu$ m; maximum breadth 60-90  $\mu$ m (Nigrini, 1977).

#### DISTINGUISHING CHARACTERS

This name is used only for very heavy, thick-walled Artostrobiids having multiple segments. It is generally smaller than *Botryostrobus miralestensis* and has fewer segments and smaller, more closely spaced pores.

#### DISTRIBUTION

Rare to few from the *Stichocorys peregrina* Zone to the Holocene. More abundant in middle- and high-latitude sediments. The occurrence of this species subsequent to the extinction of *Stylatractus universus* defines the uppermost Quaternary zone in middle latitudes. Using Indian Ocean surface sediment samples, Johnson and Nigrini (1980) found a bimodal distribution in which the species is consistently present between 35° and 46°S and occurs sporadically between 0° and 20°S.

#### PHYLOGENY

Descendant of Botryostrobus miralestensis.

### **Botryostrobus miralestensis** (Campbell and Clark)

*Dictyocephalus miralestensis* Campbell and Clark, 1944, p.45, pl.6, figs.12-14

*Botryostrobus miralestensis* (Campbell and Clark), Nigrini, 1977, p.249, pl.1, fig.9 (with synonymy)



#### DESCRIPTION

Shell spindle-shaped with thick wall, surface rough with irregular longitudinal ridges. Intersegmental constrictions (other than collar and lumbar strictures) unevenly spaced and externally obscure, but internally pronounced; five to seven segments, fourth and fifth being widest. Cephalis small, hemispherical, with small irregular pores; vertical tube short, cylindrical, directed obliquely upward at about 45°; no apical horn. Thorax and subsequent segments each bearing two to three transverse rows of large circular pores. Shell narrowing distally to generally welldeveloped poreless peristome; last segment cylindrical. Termination smooth (Nigrini, 1977).

#### DIMENSIONS

Based on 15 specimens. Total length 155-190  $\mu$ m; maximum breadth 60-90  $\mu$ m (usually 75-90  $\mu$ m) (Nigrini, 1977).

#### DISTINGUISHING CHARACTERS

See Botryostrobus aquilonaris

#### DISTRIBUTION

This species is found in both low and middle latitudes, but is rare in the latter. It is present in DSDP Site 594 (off New Zealand) material. Rare to few from the *Cyrtocapsella tetrapera* Zone to the *Diartus petterssoni* Zone.

#### PHYLOGENY

Precursor of Botryostrobus aquilonaris.

### *Buccinosphaera invaginata* Haeckel

*Buccinosphaera invaginata* Haeckel 1887, p.99, pl.5, fig.11; Nigrini, 1971, p.445, pl.34.1, fig.2 (with synonymy)

#### DESCRIPTION

Similar to Collosphaera tuberosa, but with

short (8-16  $\mu$ m), inwardly directed spines projecting from the larger pores found where the shell indents. Pores generally smaller and shell with a thinner wall than *C. tuberosa* (Nigrini, 1971).

#### DIMENSIONS

Based on 20 specimens. Maximum shell diameter 88-119  $\mu m$  (Nigrini, 1971).

#### DISTINGUISHING CHARACTERISTICS

This species is distinguished by having inwardly directed spines in the depressions of the shell wall.

This species is superficially similar to a Miocene species, *Collosphaera brattstroemi* Bjørklund and Goll, 1979, p. 1315, pl.3, figs.10-26, pl.4, figs.13-16. However, the Miocene form is much larger (diameter =  $112-192 \mu m$ ), has pores that tend to be more polyconal in shape and has closed latticed invaginations rather than open apertures.

#### DISTRIBUTION

This is a relatively rare and delicate species found in latitudes lower than 30°. Its morphotypic first appearance marks the base of the youngest Quaternary zone (*Buccinosphaera invaginata* Zone) and the event is probably synchronous. It is extant.

#### PHYLOGENY

*B. invaginata* arose from *Collosphaera orthoconus* (Haeckel) (= *Collosphaera* sp. A in Knoll and Johnson, 1975) by the development of wall invaginations.



#### REMARKS

For further taxonomic discussion, see *Collosphaera invaginata* in Bjørklund and Goll, 1979.

Additional illustrations can be found in Knoll and Johnson, 1975, pl.1, figs.3-7.

Recognition of this species requires a well-preserved assemblage and reliable core-top recovery; drilled cores may not be adequate.

### Buryella clinata Foreman

*Buryella clinata* Foreman, 1973, p.433, pl.8, figs.1-3, pl.9, fig.19; Foreman, 1975, p.620, pl.9, figs.35-36

#### DESCRIPTION

Shell of four segments, with none of the strictures expressed externally. Cephalis subspherical with a few very small circular pores,



bearing a broad-based, sharp, bladed, apical horn, its length up to twice that of the cephalis. Ridges from the horn diverge and extend to the collar stricture except ventrally where two ridges rejoin to enclose a vertical pore and form an upwardly directed tube. Collar stricture internally with four collar pores. Thorax truncate-conical with circular pores randomly or quincuncially arranged. Third segment largest, inflated, its greatest dimension medianly or in the distal half, with circular to subcircular pores, quincuncially arranged in transverse and diagonal rows. Fourth segment inversely truncate-conical proximally, cylindrical distally with thinner wall, and pores subcircular to elliptical in transverse rows, termination ragged (Foreman, 1973).

#### DIMENSIONS

Based on 15 specimens. Length overall 140-195  $\mu$ m, length of cephalis and thorax 40-45  $\mu$ m, of third segment 50-75  $\mu$ m; greatest width 65-85  $\mu$ m (Foreman, 1973).

#### DISTINGUISHING CHARACTERS

The third segment is the largest, and its pores are prominently aligned diagonally and transversely (Riedel and Sanfilippo, 1978a).

The short, well developed apical horn has pronounced blades sufficiently wide to enclose the cephalis, and extending to the collar stricture. The third segment is the largest, with pores characteristically aligned transversely and diagonally (Sanfilippo et al., 1985).

Distinguished from its ancestor, *Pterocodon ? anteclinata*, by having a bladed rather than a conical apical horn.

#### VARIABILITY

Although the pores of the third segment typically are strictly aligned transversely and diagonally, very rare specimens have the pores of that segment irregularly arranged. The development of the fourth segment, and the degree of concavity of its outline, vary greatly (Sanfilippo et al., 1985)

#### DISTRIBUTION

This species is found in late early to earliest middle Eocene assemblages from a few tropical localities, and to about 30°S (DSDP Site 248) and about 35°N (DSDP Site 10). Its evolutionary transition from *Pterocodon ? anteclinata* marks the base of the *Buryella clinata* Zone and it becomes extinct at approximately the lower limit of the *Theocotyle cryptocephala* Zone.

#### PHYLOGENY

The limit between *B. clinata* and its ancestor *Pterocodon(?) anteclinata* Foreman (1975, p.621) is drawn where the base of the horn becomes as wide as the cephalis. Co-occurring forms with which *Buryella clinata* might be confused are *B. tetradica*, in which the abdominal pores are aligned both longitudinally and transversely, commonly with longitudinal ridges separating the rows; and an undescribed form with less prominent horn, conical thorax with rough surface, distinct lumbar stricture, and thick-walled, inflated abdomen with regularly arranged pores (Sanfilippo et al., 1985).

### Buryella pentadica Foreman

*Buryella pentadica* Foreman, 1973, p.433, pl.8, fig.8, pl.9, figs.15-16

#### DESCRIPTION

Shell of five segments, subovate, smooth, with none of the strictures expressed externally. Cephalis subspherical with a few circular pores,



bearing a short, bladed or smooth conical horn. Collar stricture with four collar pores internally and a vertical pore expressed as a short, horizontally directed tube. Thorax and third segment conical, with circular pores in approximately transverse rows. Fourth segment largest, inflated, with greatest dimension medianly or in the distal half. Uniform circular pores are arranged in longitudinal and four to six, generally five, transverse rows. Area between longitudinal rows raised. Last segment truncate, inverted-conical, with thinner wall and three to five transverse rows of circular to elliptical pores. Distal margin scalloped or even, without a differentiated rim (Foreman, 1973).

#### DIMENSIONS

Based on 15 specimens. Length overall, exclusive of horn, 130-150  $\mu$ m, length of cephalis and thorax together 20-25  $\mu$ m, of third segment 20-25  $\mu$ m, of fourth segment 45-60  $\mu$ m, of last segment 30-50  $\mu$ m; greatest width 65-90  $\mu$ m (Foreman, 1973).

### DISTINGUISHING CHARACTERS

See Buryella tetradica.

#### DISTRIBUTION

This species is found as far north as 40°N (DSDP Site 384) in the North Atlantic, in the tropical Indian Ocean (DSDP Site 237) and in the Caribbean. Its morphotypic first appearance lies below the oldest defined Paleocene zone, the *Bekoma campechensis* Zone. Its morphotypic last appearance lies within the *Bekoma campechensis* Zone.

PHYLOGENY Ancestor of *B. tetradica* 

### Buryella tetradica Foreman

*Buryella tetradica* Foreman, 1973, p.433, pl.8, figs.4-5, pl.9, figs.13-14

#### DESCRIPTION

Shell of four segments subovate, smooth, with none of the strictures expressed externally. Cephalis subspherical, with a few circular pores, bearing a short, sharp horn or thorn. Collar stricture with four collar pores internally, and



vertical pore expressed as a short horizontally directed tube. Thorax conical, with circular pores arranged in approximately three vague transverse rows or more irregular. Third segment largest, inflated, with greatest dimension medianly or in the distal half. Uniform circular pores are arranged in longitudinal and four to five transverse rows. Area between the longitudinal rows raised. Last segment inverted truncate-conical, with a smooth thinner wall and two to seven transverse rows of circular to elliptical pores. Distal margin scalloped or even, without a differentiated rim (Foreman, 1973).

#### DIMENSIONS

Based on 20 specimens. Length overall, exclusive of horn, 120-185  $\mu$ m, length of cephalis and thorax 35-45  $\mu$ m, of third segment 40-65  $\mu$ m, of last segment 70-95  $\mu$ m; greatest width 70-95  $\mu$ m (Foreman, 1973).

#### DISTINGUISHING CHARACTERS

The third segment is the largest, and its pores are aligned longitudinally and transversely (Riedel and Sanfilippo, 1978a).

*B. tetradica* is distinguished from *B. pentadica* Foreman (1973, p.433), its ancestor, by having only one post-cephalic segment above the widest segment, instead of two. The difference from *B. clinata* is indicated under that species (Sanfilippo et al., 1985).

#### VARIABILITY

The four-segmented, subovate shell usually shows no external expression of the strictures, though rare early specimens have a lumbar

stricture. Also in early specimens, the fourth, more delicate segment is transversely subdivided. The pores are uniform, circular, and rectangularly arranged in longitudinal and transverse rows. The area between the longitudinal rows of pores is usually raised (Sanfilippo et al., 1985).

#### DISTRIBUTION

This species is found in Paleocene to early early Eocene assemblages from tropical localities in all three major oceans. It has been found in Subantarctic sediments from the Pacific (ODP Site 700) and the Atlantic (DSDP Sites 327 and 329). It is found in the oldest Paleocene material presently available and becomes extinct within the *Buryella clinata* Zone.

#### PHYLOGENY

This species evidently developed from *B. pentadica*, and no descendants have been recognized.