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# PALEONTOLOGICAL NOTES

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## GIANT *BATHYSIPHON* (ASTRORRHIZINA: FORAMINIFERA) FROM THE LATE CRETACEOUS HUNTERS COVE FORMATION, SOUTHWESTERN OREGON

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FORAMINIFERANS BELONGING to the genus *Bathysiphon* G. O. and M. Sars in G. O. Sars, 1872 are among the largest fossil protists ever described, some species having tubular tests exceeding 100 mm in length (Miller, 1995). One species, *Bathysiphon aaltoii* Miller, 1986, from mid-Cretaceous fine-grained turbidites within the Franciscan Complex of northern California, may be the largest fossil foraminiferan ever collected with an estimated test length of approximately 150 mm (Miller, 1991, 1997). Species of comparable size are known from the modern deep-ocean floor (where they often rival or surpass the size of co-occurring metazoans) and are an important component of deep-sea benthic ecosystems (Gooday, 1983; Gage and Tyler, 1991; Gooday et al., 1992).

In the tectonically active parts of the Pacific Rim, these giant protists are commonly found in flysch successions in association with typical deepwater trace fossils such as graphoglyptids. These remarkable tubular fossils often are the only body fossils found in abundance in Mesozoic to Cenozoic turbidite deposits in these regions, and the association appears to be indicative of deep sea-floor settings strongly influenced by sedimentation and nutrient cycling from adjacent landmasses. In the regional geologic literature, however, bathysiphonids have been misidentified as body fossils of “worms” or as tubular trace fossils.

In this report, I describe a new species of *Bathysiphon* from the Hunters Cove Formation, a thick sequence of Campanian–Maastrichtian turbidites in southwestern Oregon (Figs. 1, 2). This new taxon joins the pantheon of largest foraminiferans on record, having glassy, tubular tests up to 100 mm long and 5 mm wide. It differs from other large, Cretaceous *Bathysiphon* in having straight, thin-walled tests featuring vague axial striae on the outer surface. The taphonomy and paleoecology of this giant foraminiferan are briefly evaluated based on comparison with modern examples of *Bathysiphon* and with other Cretaceous examples from the same region.

### GEOLOGIC SETTING

Sea cliffs in the Cape Sebastian area of southwestern Oregon reveal a series of four late Mesozoic stratigraphic units, all within the Gold Beach terrane of Blake et al. (1985). These include, in ascending order, the Upper Jurassic Otter Point Formation and a series of three Cretaceous units: the Houstonaden Creek Formation, Cape Sebastian Sandstone, and the Hunters Cove Formations. The youngest unit, the Hunters Cove Formation, consists of a 300 m-thick succession of mostly fine-grained turbidites (Dott, 1971; Bourgeois, 1980; Bourgeois and Dott, 1985; Hunter and Clifton, 1987). The specimens described here were collected from coastal cliff exposures at the type locality of this unit at the northern edge of Hunters Cove, situated 5 km north-northwest of the mouth of the Pistol River and 9 km south of the town of Gold Beach.

The Hunters Cove Formation contains two major lithologic divisions of member rank (Fig. 2). The lower 200 m consist of

medium gray, laterally continuous, thin-bedded sandstone and shale beds featuring mostly Bouma  $T_{c-e}$  divisions and abundant trace fossils, including *Paleodictyon* Savi and Meneghini, 1850, *Cosmorhaphé* Fuchs, 1895, and *Helminthorhaphé* Seilacher, 1977—some of the classic features of “distal” turbidites (Middleton and Bouma, 1973; Mutti and Ricci Lucchi, 1978; Nelson and Nilsen, 1984; Stow, 1986; Pickering et al., 1989). This lower division also contains a major submarine slump structure and several thick sandstone beds, described in detail by Bourgeois (1980). The upper division, approximately 100 m thick, consists mostly of mudstone and siltstone containing a few thin sandstone beds. Hunter and Clifton (1987) interpreted the formation as an outer fan or possibly a more proximal fan succession dominated by low-density or small turbidity currents. Bourgeois (1980, p. 296) originally made the case that the Hunters Cove represents “submarine-slope and base-of-slope sedimentation in a tectonically active environment, concomitant with a relative, possibly eustatic, sea-level rise.”

Dott (1971, p. 41) reviewed the age-diagnostic fossils found in the Late Cretaceous Formations in the Cape Sebastian area, including the ammonoids *Anapachydiscus* Yabe and Shimizu, 1926, *Metaplacenticerans* Spath, 1926, and *Baculites* Lamarck, 1799 from the Hunters Cove Formation—which point to a Campanian–Maastrichtian age for this unit. The age relationships and tectonic development of lithologic units within the Gold Beach terrane were described by Blake et al. (1985) and Bourgeois and Dott (1985).

### MATERIALS AND METHODS

Bathysiphonid tests were found in the lower division of the Hunters Cove Formation on the soles of turbidite sandstone beds in localized clusters, the largest tests oriented with long axes parallel to sedimentary layering. Both large specimens and small fragments make up the clusters. Sandstone slabs containing the specimens were float blocks derived from a zone 5–10 m below a series of thick sandstone beds (Fig. 2). The slabs were simply cleaned off and photographed in reflected light. One especially large specimen was ground and polished to reveal internal structures of the test. Approximately 75 specimens were collected for use in this study.

Miller (1995, fig. 2) proposed a standard terminology for description of the anatomically simple tests of bathysiphonids. The same terminology is used in this paper (Fig. 3). Classification generally follows that of Loeblich and Tappan (1988), incorporating their suprageneric modifications (Loeblich and Tappan, 1989), but retaining *Bathysiphonidae* Avnimelech, 1952 for these distinctive foraminiferans. The type specimens are deposited in the U.S. National Museum of Natural History, Smithsonian Institution (USNM).

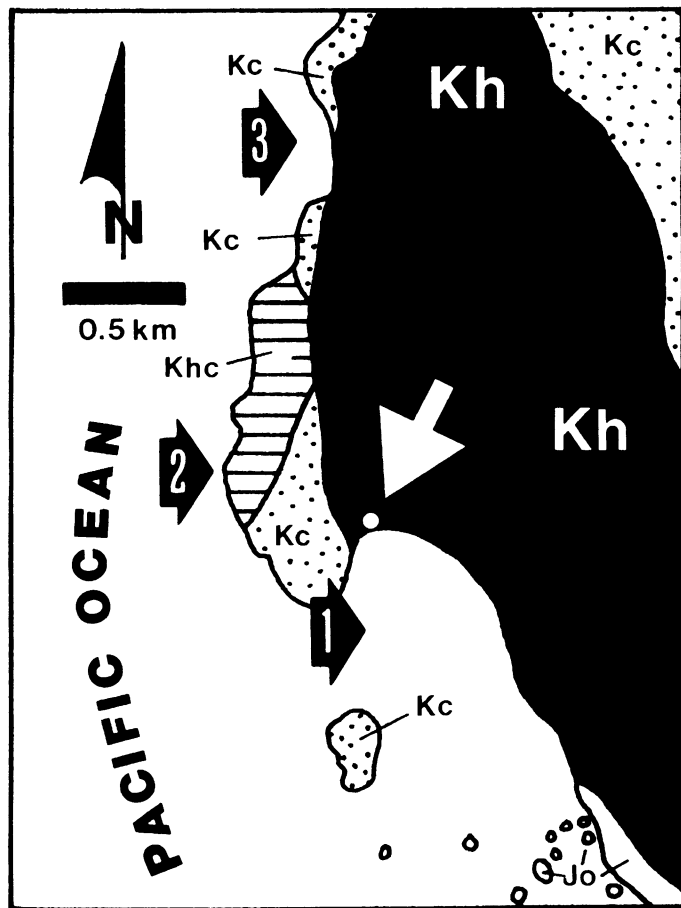


FIGURE 1—Map showing the formations making up the Gold Beach terrane and location of the collecting site. Formations include, in ascending order: *Jo* = Upper Jurassic Otter Point Formation; *Khc* = Upper Cretaceous Houstenaden Creek Formation; *Kc* = Upper Cretaceous Cape Sebastian Sandstone; *Kh* = Upper Cretaceous Hunters Cove Formation. The major geographic features include: 1 = Hunters Cove; 2 = Cape Sebastian; 3 = Salal Cove. (Based on Hunter and Clifton, 1987, fig. 2.)

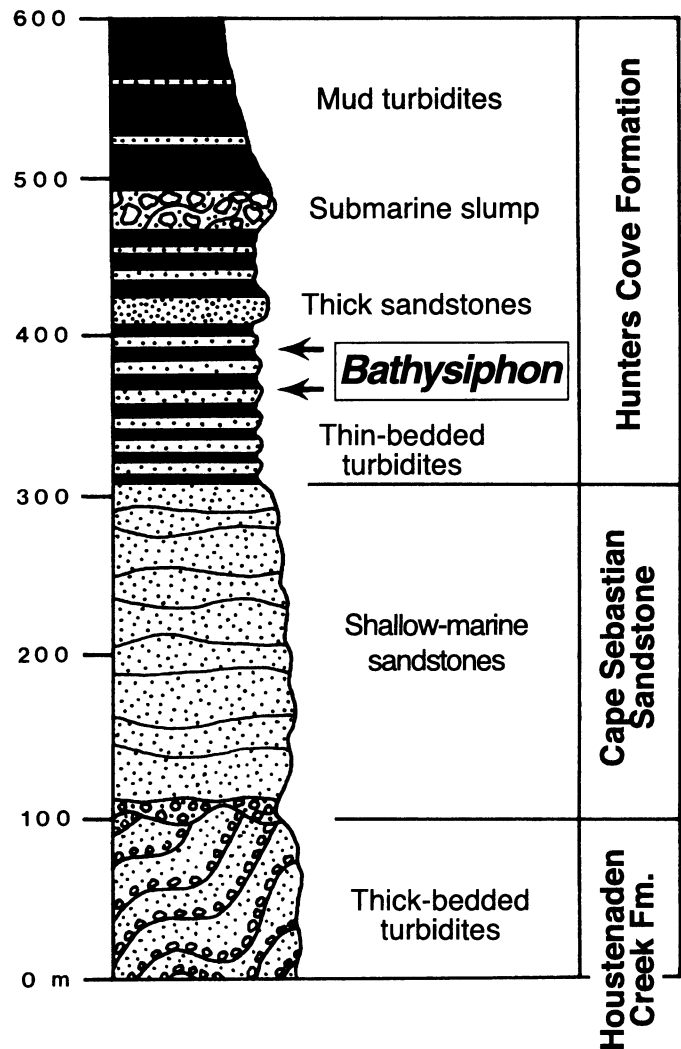


FIGURE 2—Generalized stratigraphic succession in the Cape Sebastian area, showing occurrence of *Bathysiphon* G. O. and M. Sars in G. O. Sars, 1872 tests in the lower part of the Hunters Cove Formation. (Based in part on Hunter and Clifton, 1987, fig. 3.)

#### SYSTEMATIC PALEONTOLOGY

Suborder ASTORRHIZINA Jírovec, 1953

Superfamily ASTORRHIZACEA Brady, 1881

Family BATHYSIPHONIDAE Avnimelech, 1952

Genus BATHYSIPHON G. O. and M. Sars in G. O. Sars, 1872

*Bathysiphon* G. O. and M. Sars in G. O. Sars, 1872, p. 251.

*Terebellina* ULRICH in EMERSON, PALACHE, DALL, ULRICH, AND KNOWLTON, 1904 (reprinted 1910), p. 132.

*Flagrina* VYALOV, 1968, p. 3.

*Yokoia* HATAI AND NODA, 1975, p. 211.

*Type species.*—*Bathysiphon filiformis* G. O. and M. Sars in G. O. Sars, 1872, p. 251; by monotypy. (Redescription of the species, review of authorship, and designation of a neotype were provided by Gooday, 1988b, p. 95–101.)

A more comprehensive synonymy is found in Loeblich and Tappan (1988, p. 22). Miller (1995) reviewed the various Pacific Rim fossils that are generic junior synonyms of this genus. Gooday (1983, 1988a, 1988b) has provided thorough taxonomic evaluations of the more common Recent species of *Bathysiphon*.

*Diagnosis.*—Mostly large, monothalamous foraminiferans having tests that are straight to curved, narrow, unbranched elongate

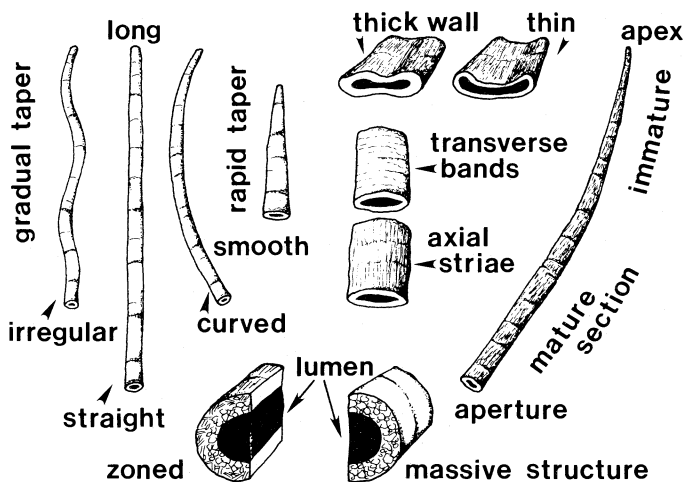


FIGURE 3—Descriptive terminology for the morphologic characters of *Bathysiphon* tests proposed by Miller (1995, fig. 2, p. 626–628).

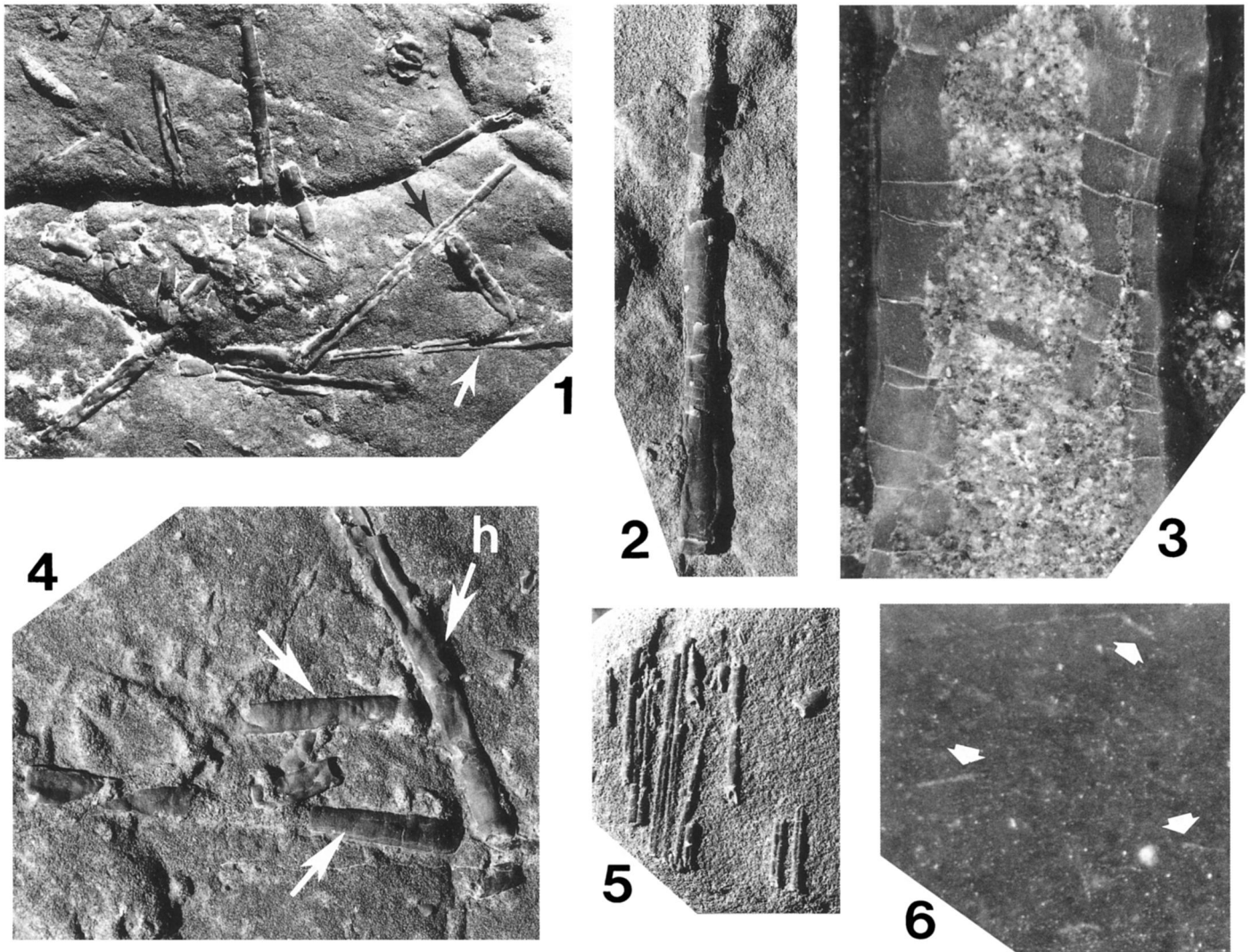


FIGURE 4—1–6, *Bathysiphon boucoti* n. sp. 1, Cluster of large specimens and small fragments on turbidite sandstone sole, including paratypes USNM 523866 (indicated with black arrow) and 523867 (white arrow) (field of view is 12 cm wide); 2, paratype USNM 523868 (test is 76 mm long); 3, same specimen shown in 2, ground and polished to reveal the wall structure and central lumen (test is 5 mm wide); 4, cluster of large tests including the holotype (*h*) USNM 523862 (53 mm long), and two of the paratypes 523863 (lower unlabeled arrow) and 523864 (upper unlabeled arrow); 5, the only example of unimodal orientation of tests found in this study (tests are 1 mm wide); 6, close view of the test wall of specimen shown in 2 and 3, revealing remnants of sponge spicules (arrows) (field of view is approximately 3 mm wide).

tubes, usually open at both ends, but may feature transverse constrictions or internal partitions; wall agglutinated, often thick relative to diameter of a central lumen, and composed of sponge spicules, sand or silt grains, other skeletal material, or some combination of these bound together with organic cement; aperture located at broader end of test (modified from Miller, 1995, p. 630).

**Discussion.**—*Bathysiphon* is a common component of the modern deep-ocean benthic biota, and appears to be especially abundant in regions receiving sediments and nutrient input from adjacent landmasses (Gooday et al., 1997). The biology of this genus has been reviewed by Le Calvez (1938), Loeblich and Tappan (1964), Christiansen (1971), Gooday (1983), Gooday and Claugher (1989), and Gooday et al. (1992, 2002). Fossil examples are common in the Mesozoic–Cenozoic flysch successions of the Pacific Rim, often co-occurring with assemblages of deep-marine trace fossils (Miller, 1988, 1991, 1993, 1995).

#### BATHYSIPHON BOUCOTI new species

##### Figure 4

**Diagnosis.**—Tests large, straight, gradually tapering; wall composed of a mixture of quartz grains and sponge spicules, and relatively thin, resulting in flattened mature sections having broad axial creases and deep, U-shaped cross sections. Exteriors feature vague axial striae and subtle transverse bulges.

**Description.**—Tests medium to light gray and translucent to almost transparent (Fig. 4.1, 4.2, 4.6). Although compressed and broken, rough estimates of test dimensions include: average maximum specimen length = 63.1 mm ( $n = 8$ ); average maximum exterior width = 4.0 mm ( $n = 15$ ); average wall thickness = approximately 0.3 mm ( $n = 7$ ); and average maximum lumen width = approximately 3.0 mm ( $n = 7$ ). In the largest specimens, the lumen occupies ~90% of the exterior width of the test. Test walls appear to lack compositional zonation, consisting mostly of small quartz grains with some incorporated sponge spicules (Fig.

4.6). The largest compressed specimens featuring the broad, U-shaped cross sections have more or less empty lumens (Fig. 4.1). Some specimens, however, are nearly completely filled with silt- and sand-sized turbidite sediments (Fig. 4.3).

*Etymology.*—Named for Dr. Arthur J. Boucot, Professor of Zoology and Geology at Oregon State University, patron of the Paleontological Society and of taxonomic paleontology in general, and preeminent figure in the growth of modern invertebrate paleobiology.

*Types.*—Holotype, USNM 523862; paratypes USNM 523863–523868.

*Occurrence.*—All specimens are from fine-grained, thin-bedded turbidites within the lower division of the Hunters Cove Formation (Fig. 2), exposed in the sea cliff at the northern edge of Hunters Cove, 700 m north of Hunters Island and 600 m southeast of Cape Sebastian (NW1/4, NW1/4, NE1/4, sec. 1, T38S, R15W; Gold Beach 15' quadrangle, Oregon).

*Discussion.*—*Bathysiphon boucoti* resembles superficially several other large Cretaceous species from the eastern Pacific borderlands, reviewed by Miller (1995, table 1). In terms of test size, it is similar to *B. aaltoi* Miller, 1986 from the mid-Cretaceous of northwestern California, and to *B. palachei* (Ulrich, 1904) from the Late Cretaceous of southern Alaska, both of which may have lengths exceeding 100 mm. *Bathysiphon aaltoi*, however, exhibits much stronger axial striae on the outer surface of tests and the test walls are thicker. *Bathysiphon palachei* is also a thick-walled form, but lacks axial striae entirely and is occasionally curved. A smaller species from the Early Cretaceous of southwestern Oregon, *B. harperi* Miller, 1995, resembles *B. boucoti* in having a straight test and relatively thin test wall, but the former is a rapidly tapering, strongly striated form. The gradually tapering, straight test, thin test wall, and subtle axial striae appear to set *B. boucoti* apart from all other large species discovered so far in the Cretaceous deep-marine successions of the eastern Pacific.

Large, thin-walled modern forms also are known. For example, Gooday (1988a) described the lectotype of *Bathysiphon capbri-tonensis* de Folin, 1886 from the Mediterranean Sea as having a thin test wall (0.10–0.16 mm thick) and a wide lumen occupying 89% of the external width.

#### TAPHONOMY AND PALEOECOLOGY

Specimens used in this study occurred on the soles of sandstone beds in clusters of approximately 5–20 large test fragments measuring several centimeters in length, sometimes grouped together with numerous smaller fragments measuring only a few millimeters in longest dimension (Fig. 4.1). No complete, unbroken tests were observed. Most of the largest tests appear to have random orientations parallel to the sole of sandstone beds (Fig. 4.1, 4.4). Only one example of unimodal current alignment was found (Fig. 4.5). If the growth orientation was vertical to diagonal with respect to the seafloor, the typical polymodal orientations and clustering of tests would reflect toppling of localized patches of *B. boucoti* n. sp. in a highly turbulent flow followed immediately by burial beneath a turbidite sand blanket. However, if these large foraminiferans were endobenthic organisms, turbidity currents might have exhumed the tests, exposing them momentarily and then fixing them in the base of the turbidite sand blanket without extensive transportation and fragmentation. The small fragments co-occurring with the large specimens may represent tests destroyed by predators or deposit feeders attempting to recycle the contents of the lumen, or simply may reflect many generations of degraded, broken tests that accumulated in the vicinity of a long-established (epi- or endobenthic) aggregation of *B. boucoti*. The clumps of tests each cover approximately 0.25–1.00 m<sup>2</sup> of sandstone soles.

Little is known about the biologic properties of fossil bathysiphonids. In general, these large, monothalamous foraminiferans appear to have maintained a simple tubular test morphology at least since the early Mesozoic (Loeblich and Tappan, 1964, 1988), but they may actually extend essentially unchanged right back to the beginning of the Phanerozoic (see discussion in Miller, 1988). Probable relationships to the earliest tubular agglutinated taxa such as *Platysolenites* Eichwald, 1860, the skeletons of which are virtually identical to tests of post-Paleozoic *Bathysiphon*, have been discussed recently by Lipps and Rozanov (1996) and McIlroy et al. (2001). Ecologic interpretations of the Mesozoic and Cenozoic taxa have depended mostly on comparisons with the modern species.

One of the most remarkable features obviously is the enormous size of the tests, compared to sizes of the more familiar microscopic foraminiferans. Consider, for example, the largest specimens of *B. boucoti* described herein, which may have had a maximum length of 100 mm and were up to 5 mm wide: these specimens have lumens with volumes exceeding 400 mm<sup>3</sup>. If the cell body completely filled only the terminal 5 mm of the mature section of the test, the cell would have been enormous, having an approximate volume of 20 mm<sup>3</sup>. Le Calvez (1938, fig. 1) illustrated the cell body of the modern species *B. filiformis*, which is shown in a rather idealized drawing to be a gigantic multinucleate body extending for some 9–10 mm along the lumen. The area behind the cell is filled with detritus, apparently expelled from the cell and collected in the unoccupied portion of the lumen. More recently, Gooday (1988a, figs. 9, 11) illustrated protoplasm of the modern species *B. major* de Folin, 1886. The cell consists of a dense, granular, dark-colored material, and is sausage-shaped or rather ropy in appearance. Protoplasmic components of other modern examples of *Bathysiphon* were illustrated by Gooday and Claugher (1989, fig. 14) and Gooday et al. (1992, pls. 2–4).

Seilacher et al. (2003, p. 46–49) evaluated the requirements for “unicellular gigantism” by listing the devices employed by protists to bypass the presumed structural and physiologic problems created by extremely large cell size—like that occurring in the largest species of bathysiphonids. Considering their list of devices, giant *Bathysiphon* appear to have exploited some combination of *multinuclearity* (providing control centers deployed throughout a large protoplasmic mass), *special shape* (the sausage or ropy shape of the cell may obviate problems associated with globular morphology), and possibly *fill skeletons* (controlling or supporting the cell shape and function by incorporation of foreign material in the protoplasm). A fourth device, that of *endosymbiosis* involving mutualistic bacteria, is certainly possible but needs to be evaluated by culturing modern material.

Finally, the ecologic role of *B. boucoti* must have been significant, considering their large size and localized abundance at the seafloor. This species was a component of the resident benthic ecosystem, which was disrupted by turbidity currents at intervals of roughly 10 to 10<sup>3</sup> years (see the review of turbidite depositional processes in Einsele, 1991). The species may have preferred a region of the seafloor receiving sedimentation and nutrients from an adjacent landmass, and may have been able to exploit a pulsed delivery of phytodetritus and other organic material, like their modern counterparts in some situations (Gooday et al., 1992). The food preferences of this species cannot be determined, but analysis of protoplasm of comparable modern species suggests that *B. boucoti* could have functioned variously as predator/scavenger of small organisms and also as detritus/surface deposit feeder (Gooday and Claugher, 1989; Gooday et al., 1992). Perhaps their nutritional requirements were supplemented through association with bacteria, possibly living within the protoplasm, in contact with the cell at the mature end of the test, or in a detrital plug in the unoccupied portion of the lumen. These giant foraminiferans

likely did not escape the attention of predators or deposit feeders, which may explain the localized concentrations of small test fragments occurring with some of the clusters of large tests.

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