BATHYSIPHONID (PROTISTA: FORAMINIFERIDA) LOCALITIES IN FRANCISCAN FLYSCH, NORTHERN CALIFORNIA, WITH A REDESCRIPTION OF *BATHYSIPHON AALTOI* MILLER, 1986

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I. ABSTRACT

Four bathysiphonid localities are described from the Late Jurassic to mid-Cretaceous Yolla Bolly terrane of northern coastal California: Point Saint George near Crescent City (with abundant *Bathysiphon aaltoi*); Little Lost Man Creek near Orick (rare *Bathysiphon* sp.); Redwood Creek also near Orick (abundant *B. cashmanae*, rare *B. aaltoi*); and Berry Summit east of Arcata (rare *Bathysiphon* sp. cf. *B. aaltoi*). All occurrences are in fine-grained deep-sea fan deposits containing trace fossils characteristic of the *Nereites* ichnofacies. A series of large, nearly complete tests approximately 100 mm in length from Point Saint George permits a more accurate and complete description of *B. aaltoi*.

II. INTRODUCTION

This paper reviews discoveries of large bathysiphonid foraminiferids in Franciscan flysch. These records are intended to supplement previous papers on taxonomy (Miller 1986a, 1988b) and paleoecology (Miller 1988a, 1989). Four localities are known (Fig. 1), which have yielded two different species of *Bathysiphon* in association with deepwater trace fossil assemblages. All the bathysiphonid localities are within the Yolla Bolly terrane and all the specimens occur in fine-grained turbidites. The bathysiphonids and traces appear to be the only fossils representing original deep-sea benthic communities of Yolla Bolly fan-trench environments; ammonoids and *Buchia* bivalves reported from the same rocks are almost certainly transported or displaced in some way and do not represent the indigenous fauna. It is significant also that the northern California specimens described here are among the largest fossil bathysiphonids ever described. In addition, there is evidence of a possible ecologic association involving an endobenthic trace-making organism and *B. aaltoi*, and I provide notes on the taphonomy and the nature of the material filling internal cavities of tests.

Extensive collecting at the Point Saint George locality (Fig. 1) has yielded hundreds of new specimens of *B. aaltoi*, including several nearly complete, mature tests. Because the original description was based on small fragments (Miller, 1986a), a redescription based on the new material is

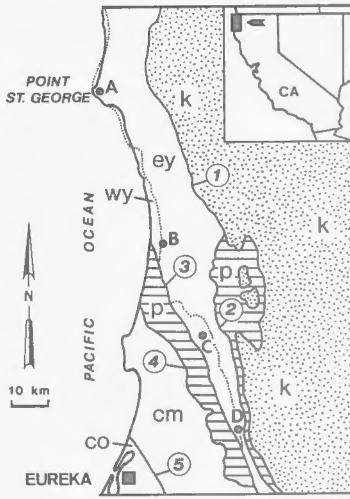

Figure 1. *Bathysiphon* localities in northern California: *A*, Point Saint George; *B*, Little Lost Man Creek; *C*, Redwood Creek; *D*, Berry Summit. Major faults bounding tectonostratigraphic terranes include: *1*, Coast Range; *2*, Redwood Mountain; *3*, Grogan; *4*, Bald Mountain; *5*, Coastal Belt. Terranes include: *k*, Klamath Province undifferentiated; *p*, Pickett Peak; *ey*, Eastern belt of Yolla Bolly terrane; *wy*, Western belt of Yolla Bolly; *cm*, Central melange; *co*, Coastal. Terranes west of the Coast Range fault are part of the Franciscan Complex; cover units are not shown (from Miller, 1988a).

warranted. Specimens used in the redescription, as well as specimens illustrating different modes of preservation, are designated topotypes and are housed in the Paleobiology Collections, U. S. National Museum, Washington, D. C. (USNM).

III. GEOLOGIC CONTEXT

All localities are within the Yolla Bolly terrane, one of about a dozen tectonostratigraphic terranes that make up the Franciscan Complex. The age and origin of Yolla Bolly rocks in northern California-southern Oregon have been discussed by Jayko and Blake (1987) and Aalto (1989a). Dominant lithologies include graywacke sandstone, mudstone/shale, and radiolarian chert occurring in melange or broken formation contexts at most localities. These rocks range in age from Late Jurassic to mid-Cretaceous: the older dates are based on radiolarians and an isolated occurrence of ichthyosaur remains in open-ocean siliceous sediments (Camp, 1942; Murchey and Jones, 1984); the younger dates are based on ammonoid specimens in flysch deposits (*e.g.*, Harden *et al.*, 1982), and probably cover an interval of development of near-continent deep-sea fans. *Buchia* bivalves suggesting Late Jurassic-Early Cretaceous ages have been reported from these rocks (Blake and Jones, 1974). Although frequently mentioned in the literature, the Franciscan bivalve dates have uncertain significance because shells may have been transported from possibly older, upslope deposits or could be tectonically reworked. The most reasonable age for the bathysiphonid-bearing flysch, then, appears to be Early to mid-Cretaceous.

The localities described here are all in blocks or disrupted sequences of fine-grained, thin-bedded turbidites (Facies D of Mutti and Ricci Lucchi, 1978). Turbidite deposits of this type accumulate in "distal"

Figure 2. Fine-grained turbidites at Point Saint George. *S*, Facies D beds with prominent, laterally continuous sandstone layers having Bouma T_{cde} or T_{de} divisions; *M*, mud-dominated Facies D beds with thin, wispy sand and silt laminations. Large bathysiphonids occur in both kinds of beds; small fragments are usually restricted to the thicker sandstone layers.

fan environments, such as outer fan lobes, fan fringes and interchannel basins. Yolla Bolly turbidites at Point Saint George contain a diverse and abundant trace fossil assemblage composed of graphoglyptids and burrow systems of both sedentary and motile deposit-feeders, typical of off-shelf or deep-basinal environments. Geologic setting, fine-grained turbidites and trace fossils taken together point to deposition in outer fan areas in a trench-slope basin or at a trench floor in abyssal depths.

IV. BATHYSIPHONID LOCALITIES

Point Saint George (Locality A, Fig. 1).– The site yielding the largest number of bathysiphonid specimens is a quarry road immediately west of Radio Road on Point Saint George. The exact locality is 500 m south of the old Coast Guard Station (now a medical clinic) on the Point and 1.9 km north of Castle Rock seastack, southwest quarter Crescent City 7.5' quadrangle. Turbidite beds containing bathysiphonid tests in varied states of preservation, from small transported fragments to nearly complete specimens, are shown in Fig. 2. This is the type locality of *Bathysiphon aaltoi*, and is the focus of several recent studies (Miller 1986a, b, 1987, 1988a, 1989, 1990). The geology of Franciscan rocks at Point Saint George has been described by Aalto (1989b) and Aalto and Murphy (1984).

The most important new material collected here consists of numerous large

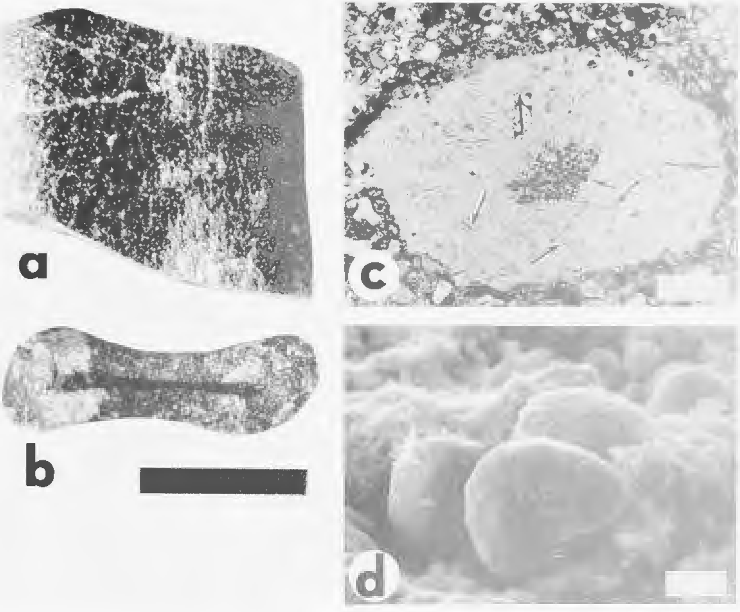

Figure 3. *Bathysiphon aaltoi* from Point Saint George: *a*, small segment showing microstriated exterior surface; *b*, end view of same segment; *c*, thin-section of immature region with ghosts of recrystallized sponge spicules in the thickest wall subdivision (plane-polarized light); *d*, pyrite framboids in the dark material filling internal cavity of a test. Bar scales: *a* and *b*, 2 mm; *c*, 0.2 mm; *d*, 10 micrometres (*a*, *b* and *c* from Miller, 1988a).

tests of *B. aaltoi* (Pl. 1, fig. 3, 5), which indicate the size of fully developed individuals that thrived for long intervals (decades?) between episodes of seafloor disturbance caused by turbidity currents. The largest specimens are almost 100 mm in length and could be close to the maximum size for the species (see redescription). Although tests 40 to 50 mm in length are moderately common in the shale interbeds, the largest specimens are slightly transported or toppled tests in the turbidite sandstone layers (Pl. 1, fig. 3). More typically, only small barrel-shaped fragments are found in the sandstone. Occasionally these fragments are concentrated as graded lag deposits near the base of turbidite beds (Pl. 1, fig. 2). Such accumulations would seem to represent the catastrophic disruption of a "thicket", or localized patch, of bathysiphonids, with thousands of individuals swept-up by a turbidity current and buried beneath a carpet of turbidite sand, probably during a single event. The sources of these accumulations – the original bathysiphonid thickets – are represented by specimens like that shown in Pl. 1, fig. 1. This is the sole of a turbidite sand bed with dozens of protuberances, many containing a small immature fragment of *B. aaltoi*. The protuberances are sand-cast pits that contained the living bathysiphonids, usually one individual organism per pit, with tests oriented vertically. Sediment gravity flows reaching this part of the seafloor sheared off the upper mature parts of the tests, while simultaneously filling the pits containing the immature parts of tests with sand (Miller, 1988a). Thus, these are the basal parts of small depressions that housed a living bathysiphonid, oriented vertically with the wider mature end protruding above the seafloor (see reconstruction of life orientation in Fig. 4). Beds with the sand-cast bathysiphonid pits can be traced laterally for several metres, indicating large aggregations of these peculiar foraminiferids at the seafloor.

Other remarkable discoveries at Point Saint George include bathysiphonids in life position associated with burrow systems in a way suggesting interaction between the foraminiferid and the trace-maker (Pl. 1, fig. 6). This is the only case of a possible ecologic association involving bathysiphonids in the Yolla Bolly. The nature of the interaction is unknown.

Rare individuals (Pl. 1, fig. 7) appear to have been toppled and rolled in sediment before burial, rather like rolling a mushroom in flour before pan-frying. The illustrated specimen has a first coat of sand and a second coat of mud. Processes responsible for this unusual form of preservation are not clear.

Two features of the Point Saint George specimens are worth mentioning. Thin-sections reveal that tests were constructed with sponge spicules and possibly diatom or radiolarian debris (Fig. 3c). Yet spicules and other siliceous bioclasts have not been found in the surrounding matrix. The

PLATE 1

Figures

1. Sole of turbidite sandstone bed from Point Saint George with sand-cast pits containing immature portions of *Bathysiphon aaltoi* tests; USNM 454582.
2. Slab-section of turbidite sandstone from Point Saint George showing density-graded lag of transported *B. aaltoi* tests; plane of section is perpendicular to bedding; USNM 454583.
3. Toppled *B. aaltoi* test in sandstone from Point Saint George.
4. Small specimen of *Bathysiphon* sp. cf. *B. aaltoi* from Berry Summit.
5. Bed of turbidite sandstone from Point Saint George, broken open and viewed end-on, showing the largest *B. aaltoi* test recovered so far. The toppled, broken test is 96 mm in length and located at the base of the bed; such specimens suggest that mature individuals were approximately 100 mm in length or perhaps longer; USNM 454581.
6. Association of trace fossils and *in situ* bathysiphonids, shown on sole of sandstone bed from Point Saint George.
7. Bathysiphonids in a sandstone stream pebble, probably derived from the Yolla Bolly terrane. (Rulers in 1, 6 and 7 graduated in cm's and mm's; bar scales in 2, 3, 4 , 5 and 8 represent 10 mm.)

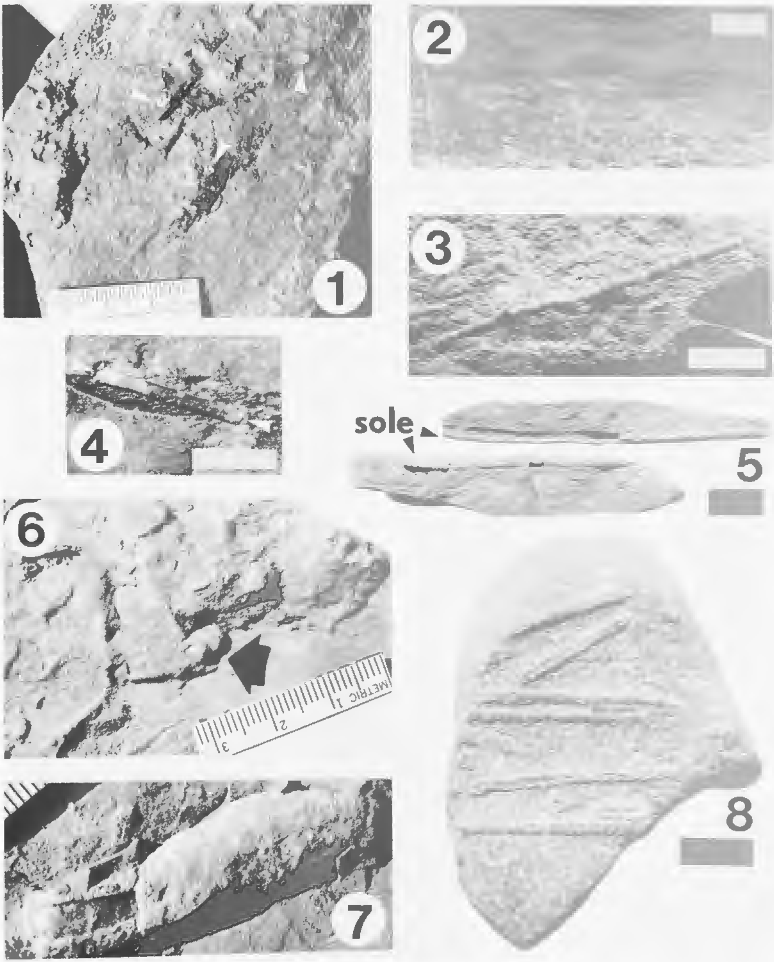

PLATE 1

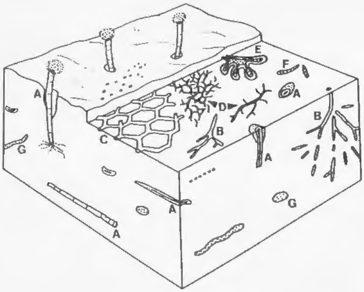

Figure 4. Probable orientation of *Bathysiphon aaltoi* in life and associated trace fossils. *A*, Live vertically-oriented tests and dead tests of *B. aaltoi; B, Chondrites; C, Paleodictyon; D, Megagrapton; E, Phycosiphon; F, Taenidium; G, ?Planolites. C* and *D* are graphoglyptid trace fossils; *B, E* and *F* are deposit-feeder burrows; *G* is burrow of a motile grazer or scavenger. (Not drawn to scale; from Miller, 1988a.).

microstriations on the exterior of *B. aaltoi* could result from recrystallized spicules that formed "thatching" on the outer surface of tests. Extensive use of spicules in the construction of modern bathysiphonid tests has been documented many times (Cushman, 1910; Hofker, 1972; Gooday, 1988a,b). In addition, the dark-colored material filling internal cavities of tests sometimes contains sulfide minerals. Close examination of these specimens shows that some of the material consists of framboidal pyrite (Fig. 3d), which might indicate activity of sulfate-reducing bacteria (*e. g.*, thiopneutes that require SO_4^{2-} for respiration and yield H_2S as a by-product [Margulis and Schwartz, 1988, p. 44]). Pyrite framboids, however, can be produced inorganically (Goldhaber and Kaplan, 1974). Nonetheless, it is tempting to interpret the framboids as the products of free-living sulfate-reducing bacteria that exploited the insides of bathysiphonid tests as anaerobic microhabitats, either after the "host" protist died or possibly while it was still occupying part of the test.

At the southern end of Enderts Beach, about 7.5 km southeast of Crescent City (east-central Sister Rocks 7.5' quadrangle), a few bathysiphonids resembling *B. aaltoi* were collected by Dr. Greg Harper in 1989. This locality is close to the Point Saint George site and specimens were in mudstone with thin silt interlaminations.

Little Lost Man Creek (Locality B, Fig. 1).– This locality is in the bed of Little Lost Man Creek near Orick. The site is a stretch of creek containing abundant shale cobbles, located between 2 and 3 km southeast of the County Fish Hatchery on U. S. Highway 101 and roughly 4.7 km northeast of the Redwood Creek bridge at Orick, east-central Orick 7.5' quadrangle.

The few bathysiphonids from this locality occur in shale with silt interlaminations. Although the specimens are referrable to *Bathysiphon*, they cannot be determined to species owing to poor preservation. The tests are bent into C-shapes; the largest is 28 mm long and 2.5 mm in diameter, while the smallest is 13 mm long and 0.8 mm in diameter. The bent, flattened specimens indicate that tests originally were flexible. The only other fossils found here are abundant deposit-feeder burrows assignable to *Phycosiphon*. Mr. Dana Waters presented the samples from this site, which he collected in 1990.

Redwood Creek (Locality C, Fig. 1).–The locality is in a tributary of Redwood Creek on the west side of Bald Hills Road. This is the type locality of *Bathysiphon cashmanae* Miller, 1988. Bathysiphonids were collected from an outcrop of folded argillite, approximately 100 m upstream from the Klamath-Korbel logging road owned by Simpson Timber Co., 3.2 km west of Schoolhouse Peak and approximately 2 km south of Childs Hill Prairie, central Coyote Peak 15' quadrangle. Geology of the Redwood Creek area was described by Harden *et al.* (1982), who reported the Cenomanian ammonoids *Desmoceras (Pseudouhligella) japonicum* and *Calycoceras* sp. from the same mapping unit containing the bathysiphonids. The ammonoids seem to fix the minimum age of near-continent flysch deposits in the Yolla Bolly terrane.

The Redwood Creek site has yielded abundant *B. cashmanae* and a few specimens of *B. aaltoi* described by Miller (1988b). Samples were collected by Mr. Sam Morrison in 1975.

Berry Summit (Locality D, Fig. 1).–A large earthflow at Berry Summit in eastern Humboldt County contains argillite blocks with small bathysiphonid tests (Pl. 1, fig. 4). The specimens were collected 50 to 200 m south (downslope) from the parking lot at the Summit overlook, south side of State Highway 299, southeast quarter of Lord-Ellis Summit 7.5' quadrangle.

The rare tests from this site are minute (18 to 12 mm long, 1.5 to 0.5 mm in diameter), straight-sided forms assigned provisionally to *B. aaltoi*. No other fossils have been found here, and the melange in which the earthflow is developed is not likely to yield well preserved bathysiphonids and trace fossils.

Cobbles and pebbles in Quaternary fluvial deposits.–A sandstone pebble presented by Mr. Lincoln Garlick contains several bathysiphonids that may be *B. aaltoi* (Pl. 1, fig. 8). The specimen was collected from driveway fill in Fieldbrook, Humboldt County, and was probably excavated from the vicinity of the Mad River. The ultimate source probably was in the Yolla Bolly terrane.

V. REDESCRIPTION OF *BATHYSIPHON AALTOI*

In 1986, I described *Bathysiphon aaltoi* based on only five test fragments from Point Saint George. Since those specimens were collected, hundreds of additional tests have been found at this same locality. Because these new discoveries appear to include nearly complete mature tests, the original description needs to be emended accordingly. The classification that follows is the new arrangement used in the comprehensive review of foraminiferids by Loeblich and Tappan (1988).

Order FORAMINIFERIDA Eichwald, 1830
Suborder TEXTULARIINA Delage and Hérouard, 1896
Superfamily ASTRORHIZACEA Brady, 1881
Family BATHYSIPHONIDAE Avnimelech, 1952
BATHYSIPHON M. Sars, 1872

BATHYSIPHON AALTOI Miller, 1986
Plate 1, figures 3, 5; Fig. 3a, b, c

Description: Test very large, straight-sided and gradually tapering, hollow cylinder, circular to elliptical in cross-section and open at both ends; wall made of microcrystalline quartz and apparently concentrically zoned; outermost division approximately 10 to 20 micrometres thick and associated with surface microstriations oriented subparallel to long axis of test (Fig. 3a); discontinuous layer beneath the surface layer approximately 10 micrometres thick with grains 1 to 5 micrometres in diameter; the most conspicuous wall division is 100's-of-micrometres thick and contains ghosts of recrystallized sponge spicules and other bioclasts (Fig. 3c), with the spicules generally 100-200 micrometres in length; internal cavity lined with discontinuous layer approximately 10 to 20 micrometres thick like that immediately beneath the outermost division (Miller, 1988a); largest test observed 96 mm long, suggesting maximum test length of 100 mm or slightly more, and 2.5-3.5 mm in diameter; maximum wall thickness approximately 1.0 mm; most specimens with weak annular constrictions at irregular intervals along length of test; original pliancy of test wall suggested by axial crease and figure-eight cross-section shapes of many larger compressed specimens (Fig. 3a, b).

Type specimens: Original type specimens, syntypes USNM 399552-399556; figured specimens in this paper (topotypes), USNM 454581-454583.

Discussion: Ecology of *B. aaltoi* has been evaluated by Miller (1988a; 1989). Biostratigraphic potential has not been assessed. However, the species has been found only in fine-grained turbidites within the Yolla Bolly terrane in northern California. Similar rocks of Early to mid-Cretaceous age along the western margin of North America should contain this species, and reports of siliceous tube fossils (often identified as *Terebellina* and regarded as annelid body fossils or grain-lined burrows) from the region probably include bathysiphonids.

VI. ACKNOWLEDGMENTS

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Emily Vokes for her editorship. Dania Redmond and Peggie Holverson typed the manuscript. Sam Morrison, Dana Waters, and Dr. Greg Harper contributed specimens. Figures 1, 3a, b, c, and 4 are reproduced with permission from the Lethaia Foundation.

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