Demetrion & Squires, 1994



*Bull. Southern California Acad. Sci.*
93(2), 1994, pp. 83–90


# Middle Miocene Pholadid Borings at the Base of the Isidro Formation, Arroyo Mezquital, Baja California Sur, Mexico

Robert A. Demetrion[1] and Richard L. Squires[2]

[1]*Holmes International Middle School, 9351 Paso Robles Ave., Northridge, California 91325*
[2]*Professor, Department of Geological Sciences, California State University, Northridge, California 91330*

*Abstract.*—Abundant sediment-infilled clavate (club-shaped) borings, assignable to ichnogenus *Gastrochaenolites,* are reported from the base of the Miocene Isidro Formation, Baja California Sur, Mexico. The infilled borings were made by pholadid bivalves that lived in a nearshore-marine environment on a semi-consolidated substrate ("*Glossifungites*" ichnofacies). Some borings are connected by horizontal burrows that are sculptured (*Spongeliomorpha*) or unsculptured (*Thalassinoides*). The localized pholadid community was short lived and abruptly terminated by an influx of sediment.

---

During the course of field investigations in Baja California Sur, Mexico, an assemblage of ichnofossils was found in the Isidro Formation at California State University, Northridge (CSUN) locality 1495 near the mouth of Arroyo Mezquital about 13.5 km south of the village of San Juanico on the Pacific coast (Fig. 1). The assemblage is at the erosional contact between the Eocene Bateque Formation and the overlying Miocene Isidro Formation. The ichnofossils are dominated by sediment-infilled clavate (club-shaped) borings that range in length from 5 to nearly 30 cm. The contact that contains these infilled borings is well exposed, at a height of some 40 m on the side of a mesa that borders the southeast margin of the arroyo. The infilled borings are confined to an approximate linear distance of 1 km along the mesa wall, which is deeply incised by a number of semi-circular re-entrants.

Fischer (1990), in a general review of the subject of boring bivalves, showed pictures of infilled borings from the Isidro Formation as examples of cylindrical-shaped burrows, but he did not give any locality data nor any ichnological details.

The purposes of this paper are to describe the ichnofossils and to consider their paleoenvironment. Abbreviations used are: CSUN, California State University, Northridge: LACMIP, Natural History Museum of Los Angeles County, Los Angeles, Invertebrate Paleontology Section.

## Geologic Setting

The uppermost 30 m of the Bateque Formation at Arroyo Mezquital is a vertical exposure of bioturbated, yellow, very fine-grained sandstone that is moderately indurated. Rare lamination is preserved and it seems to be parallel or nearly so. Scattered shell fragments are present as are some oblique *Ophiomorpha*-like bur-

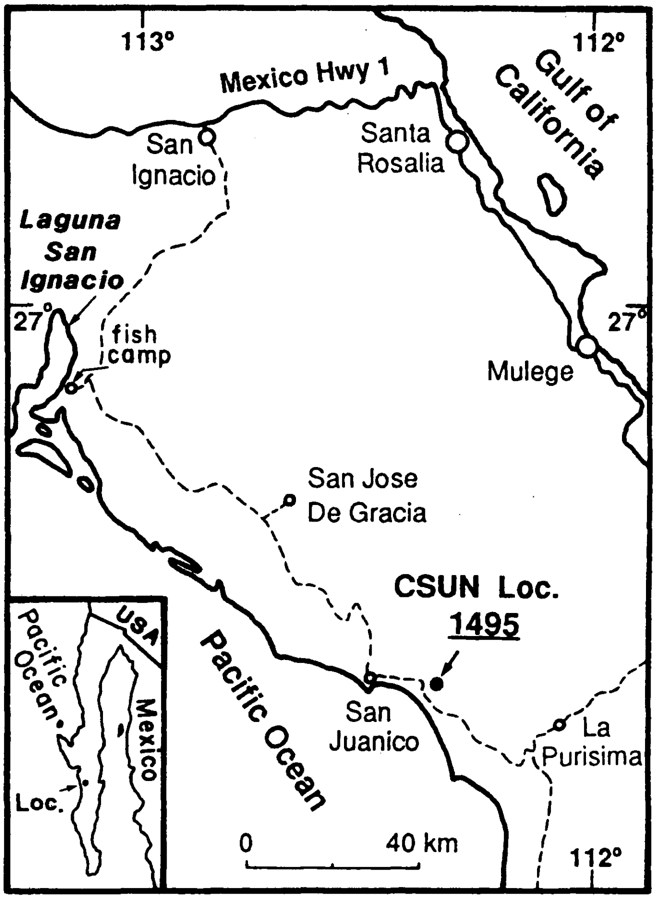


Fig. 1. Index map showing location of the study area and CSUN loc. 1495.

rows filled with the same type of sediment found in the Bateque Formation country rock. Squires and Demetrion (1992) interpreted the paleoenvironment of the Bateque Formation in this area to be "middle shelf" and equivalent to a depth range between normal-storm wave base and maximum-storm wave base. Microfossil evidence indicates a middle Eocene age equivalent to the Pacific coast molluscan "Tejon Stage." For a more complete discussion of the Bateque Formation at this locality, see Squires and Demetrion (1992).

Approximately 15 m of the overlying Isidro Formation is exposed in near-vertical to vertical cliffs. The outcrop consists of several horizontal shell-hash layers (coquinas), ranging in thickness from 10 cm to 2 m, in a white, coarse-grained sand matrix, separated by grayish-green mudstone and sandstone that are virtually barren of macrofossils. The shell-hash layers tend to be variable in terms of dominant genera. Barnacles and oysters, as well as pectinids and clypeasteroid echinoids (sand dollars), are the main components. Post-mortem transport of the fossils was minimal as some of the bivalves are articulated and delicate sculpture on the shells of most of the fossils has not been worn off. The stratigraphically lowermost layer is dominated by barnacles (as individuals up to 5 cm height, and

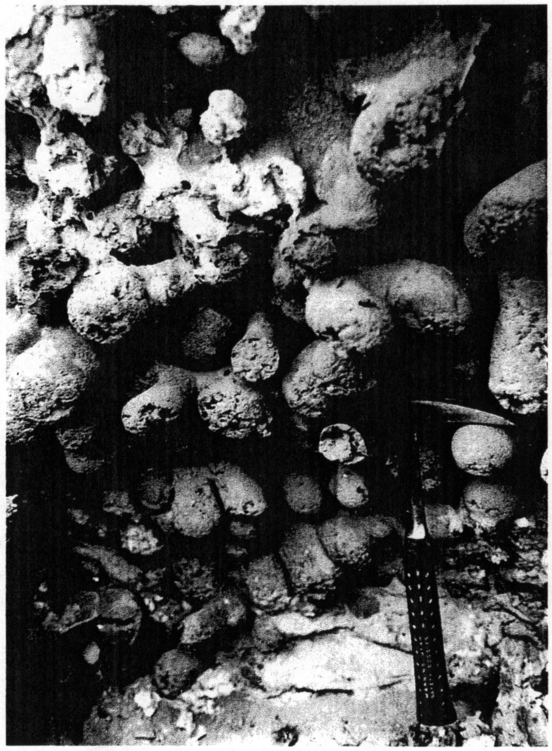

Fig. 2. Infilled clavate borings along basal contact of the Isidro Formation at CSUN loc. 1495 (where a large block of rock has fallen from the cliff face). Hammer is 30 cm in length.

in clusters) with significant numbers of small-sized (up to 3 cm height) and large-sized (up to 8 cm height) pectinids, internal molds of *Turritella* and unidentified bivalves, and rarer components of clypeasteroid echinoids, large-sized (up to 17 cm length) oysters, and bone fragments. A nearshore depositional environment is indicated by the fossil content and lack of significant post-mortem transport of the fossils. A late middle Miocene age for the Isidro Formation at this locality has been reported by Squires and Demetrion (1993) on the basis of the presence of the sand dollar *Astrodapsis bajasurensis* Squires and Demetrion, 1993.

The horizontal contact of the two formations at the study site is clearly delineated by a remarkable trace-fossil assemblage. The contact is accessible in two ways. A number of spurs have been created by erosion of prominences along the cliff face. They are rather steep and precarious. Safer, but more limited, access is possible at several places where huge blocks have fallen from the cliff face. Some of these fallen blocks provide excellent specimens of the trace fossils (Fig. 2). *In situ,* the contact presents a limited three-dimensional view due to differential weathering of less highly indurated Eocene substrate penetrated by Miocene borers.

## Ichnofossils

*Sediment-infilled clavate borings.*—Infilled borings are predominantly smooth but rare individuals (Figs. 3A, B) display basal concentric, serrated tool marks

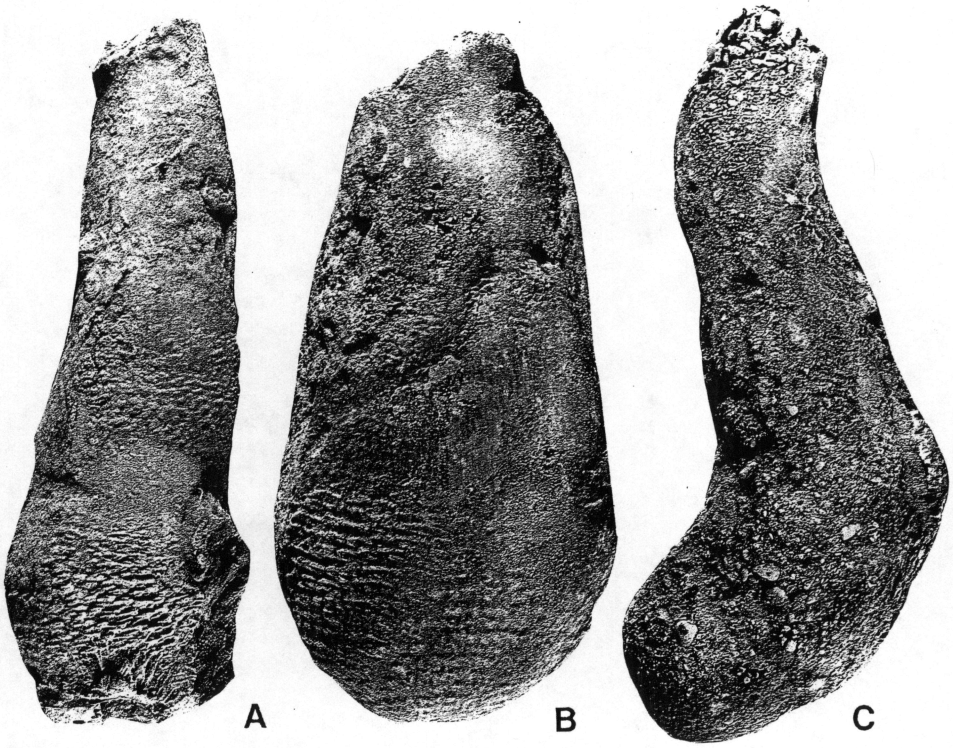


Fig. 3. Individual infilled, clavate borings of *Gastrochaenolites* from CSUN loc. 1495. (A–B), Rare specimens showing basal concentric, serrated tool marks accentuated by the presence of gypsum. A, Hypotype LACMIP 12271, 13 cm in length, ×1.4. B, Hypotype LACMIP 12272, 14.2 cm in length, ×1.5. C, Specimen showing prominent bend near base, hypotype LACMIP 12273, 16.5 cm in length, ×1.7.

that are accentuated by the presence of gypsum. Shape is elongate with little or no neck constriction. Cross section is circular throughout, and maximum diameter is close to the hemispherical base. Infilled borings are usually straight, but some (Fig. 3C) have a bend that ranges from 10 to 45 degrees from the vertical. Measurement of 25 individuals provide the following: length ranges from 4 to 27 cm, maximum diameter ranges from 1.3 to 9.5 cm, and conical angle ranges from 12 to 17 degrees. A number of infilled borings have a hemispherical or slightly pointed terminal protrusion of 1 to 2 cm in length. These small protrusions are probably secondary burrows that were begun and then abandoned.

Sediment infill is mostly coarse sandstone similar to the immediately overlying lithology. The fill sandstone can be poorly cemented to well-indurated, and there can be shell fragments and well-rounded volcanic pebbles (up to 13 mm in diameter). Clear-crystalline gypsum is also common. Sectioned infilled borings commonly display well-delineated secondary infilled borings or burrows.

*In situ* infilled borings commonly have the upper terminus cut by the overlying shell-hash layers, and only rarely do the borings extend a few centimeters upward into the overlying strata. Densities of infilled borings range from 1 to 2 per linear meter at the eastern and western margins of the study area to well in excess of

Fig. 4. Infilled clavate borings interspersed with horizontal burrows of *Thalassinoides* along *in situ* basal contact of the Isidro Formation at CSUN loc. 1495. Square end of hammer is 2 cm in width.

100 per square meter in the central part of the study area. With increasing density, there is a pronounced tendency for infilled borings to become longer with more bulbous ends, for the infilled borings to display directional changes, and for penetration angles of the infilled borings to deviate from vertical and become as much as 45 degrees from the vertical to nearly horizontal. Infilled borings do not intersect each other, even where they are crowded.

According to Kelly and Bromley (1984), the geologic range for clavate borings in lithic substrates is Jurassic to Recent. Miocene reports of infilled clavate borings are common, and examples that resemble those from the Isidro Formation have been reported from Japan (Uozumi and Fujie 1956), California (Adegoke 1966), the Gulf of Mexico (Warme and McHuron 1978), Poland (Radwanski 1977) and New Zealand (Bradshaw 1980). Modern borings that resemble those from the Isidro Formation have been reported from Oregon by Evans (1970), from San Diego by Warme (1970), and from the Texas Gulf Coast by McHuron (1976). The resemblance involves size and shape, substrate affected, presumed environment of creation, and associated trace fossils. Based on these similarities, the infilled clavate borings at CSUN loc. 1495 are identified as *Gastrochaenolites*. Kelly and Bromley (1984) provided a detailed review of this ichnogenus.

*Horizontal burrows.*—Approximately five percent of the infilled clavate borings are connected by horizontal burrows (Fig. 4) with circular cross sections whose diameters range from 1.5 to 2.5 cm. The fill in these burrows is similar to that in the infilled clavate borings. Most of these burrows have walls which exhibit extensive scratch marks, although a few bear no sculpture. In the cases where burrows branch, they usually do so at a 60-degree angle. Some burrows loop out from and then re-enter an individual infilled boring. The sculptured horizontal burrows are assigned to *Spongeliomorpha* on the basis of comparison to descriptions by Ekdale et al. (1984, pp. 31, 33, 192), and the unsculptured horizontal burrows are assigned to *Thalassinoides* on the basis of comparison to illustrations in Ekdale et al. (1984, figs. 3-5, 15-5).

## Ichnofacies

According to Ekdale et al. (1984), firm but uncemented substrates are associated with the ichnofacies *Glossifungites,* which is characterized by the ichnogenera *Gastrochaenolites, Spongeliomorpha,* and *Thalassinoides.* Pemberton and Frey (1985) asserted that the *Glossifungites* ichnofacies typically is associated with dewatered muds. They also noted that thalassinoidean traces in this ichnofacies commonly display well-developed cheliped sculptings. The *Trypanites* ichnofacies, as described by Ekdale et al. (1984), is associated with fully lithified substrates (generally a relict surface) and can also contain the ichnogenus *Gastrochaenolites.* Recognizing that the two ichnofacies are intergradational, we assign the trace-fossil assemblage at the base of the Isidro Formation to the *Glossifungites* ichnofacies on the basis of the ichnogenera present and the lack of complete cementation of the Eocene substrate.

## Discussion

On the basis of their strong resemblance to the morphology of modern borings described by McHuron (1976), Evans (1970), and Warme (1970), as well as to fossil borings whose producers have been positively identified (see references on Miocene borers in "Sediment-infilled clavate borings" section), we believe that the organisms responsible for the Isidro Formation borings were pholadid bivalves. Several other lines of evidence support this conclusion.

According to Pemberton and Frey (1985), pholadids dominate foreshore-like, wave-influenced deposits. Evans (1968a) noted that morphology of pholadid borings in a given substrate is controlled by population density, with greater crowding producing greater variability. McHuron (1976) observed that the same species of pholadids could produce borings with or without bioglyphic ornamentation (i.e., serrated tool marks), depending on the substrate hardness (harder substrates tend to diminish sculpture). Kennedy (1974) pointed out that pholadid borings in an open-coast marine environment tend to be filled with coarser sediments and that some secondary nestlers extract calcium carbonate from pholadid shells, thereby dissolving them. He also distinguished pholadid from mytilid borings on the basis of the virtually constant cross-sectional area of mytilid borings and the fact that they are bilaterally symmetrical, in contrast with the conical body and circular cross sections of pholadid borings.

Given the evidence at hand and the assumption that pholadid bivalves produced the clavate borings, it is possible to interpret the environmental conditions at the base of the Isidro Formation. Incompletely cemented Eocene deposits of the Bateque Formation were subaerially exposed and eroded. Subsequent transgression by the Miocene seas provided a relatively hard surface which was colonized by pholadid borers. Ekdale et al. (1984) stated that heavy infestation of lithic substrates by ichnogenus *Gastrochaenolites* is large a shallow-water phenomenon. A shallow-water environment for the Isidro Formation borers is also indicated by the shell-hash infill of the boreholes. The shell-hash contains remains of near-shore animals that do not show evidence of significant post-mortem transport. As pholadid colonization progressed, secondary inhabitants took advantage of the pioneering efforts of the pholadids and became nestlers in the borings. At this point, a departure from "textbook" descriptions takes place.

According to Warme and McHuron (1978), the species richness of modern-marine hardgrounds is due to borers that open the substrate "frontier" for secondary settlers. They stated that abandoned borings become inhabited and modified by an assortment of organisms. Warme (1970) noted that in advanced stages, borings become interconnected to form networks of passageways. Kennedy (1974) remarked that erosion rates are higher where pholadids colonize, due to a weakened substrate and wave action. Evans (1968b) found that erosion in such areas increased by a factor of 24. However, in the assemblage studied at Arroyo Mezquital, there is no ichnologic evidence of species richness. Nor is there evidence of significant erosion of the substrate, even in the populous central area of study.

Our interpretation is that the set of environmental conditions that gave rise to the pholadid community was very short-lived. The central, "seed" area of the colony reached a population maximum and the secondary settling by horizontal-burrowing crustacean opportunists then began while the pholadids were in the process of peripheral expansion. Abruptly, a sediment influx overwhelmed the filter-feeding pholadids. The few borings that extend upward into the overlying strata represent the efforts of surviving crustaceans. Ultimately, in a regimen of increasing storm-generated sedimentation, they too perished.

## Acknowledgments

We thank George L. Kennedy (San Diego, California) for sharing his knowledge about pholadid borings. The manuscript benefitted from the reviews of two anonymous referees.

## Literature Cited

Adegoke, O. S. 1966. Silicified sand-pipes belonging to *Chaceia* (?) (Pholadidae: Martesiinae) from the late Miocene of California. The Veliger, 9(2):233–235.

Bradshaw, M. A. 1980. Boring bivalves in the New Zealand Cenozoic with a redefinition of *Teredolites.* Recs. Canterbury Mus., 9(5):289–294.

Ekdale, A. A., R. G. Bromley, and S. G. Pemberton. 1984. Ichnology. Soc. of Econ. Paleont. and Mineral. Short Course No. 15, Tulsa, Oklahoma. 317 pp.

Evans, J. W. 1968a. The effect of rock hardness and other factors on the shape of the burrow of the rock-boring clam, *Penitella penita.* Palaeogeogr., Palaeoclimatol., Palaeoecol., 4:271–278.

———. 1968b. The role of *Penitella penita* (Conrad, 1937) (Family Pholadidae) as eroders along the Pacific coast of North America. Ecology, 49(1):156–159.

———. 1970. Palaeontological implications of a biological study of rock-boring clams (Family Pholadidae). Pp. 127–140 *in* Trace fossils. (T. P. Crimes and J. C. Harper, eds.), Geolog. J. Special Issue 3, Seel House Press, Liverpool. 547 pp.

Fischer, R. 1990. Significado paleoecologico y geologico de perforaciones fosiles de bivalvos. Rev. Soc. Mex. Paleont., 3(1):79–95.

Kelly, S. R., and R. G. Bromley. 1984. Ichnological nomenclature of clavate borings. Paleont., 27(pt.4):793–807.

Kennedy, G. L. 1974. West American Cenozoic Pholadidae (Mollusca: Bivalvia). San Diego Soc. Nat. Hist. Memoir 8. 127 pp.

McHuron, E. J. 1976. Biology and paleobiology of modern invertebrate borers. Ph.D. dissertation, Rice University, Houston. 173 pp.

Pemberton, S. G., and R. W. Frey. 1985. The *Glossifungites* ichnofacies: modern examples from the Georgia coast, U.S.A. Pp. 237–259 *in* Biogenic structures: their use in interpreting depositional environments. (H. A. Curran, ed.), Soc. Econ. Paleont. and Mineral., Spec. Publ. 35. 347 pp.

Radwanski, A. 1977. Present-day types of trace in the Neogene sequence; their problems of nomenclature and preservation. Pp. 227–264 *in* Trace fossils 2. (T. P. Crimes and J. C. Harper, eds.), Geolog. J. Special Issue 9, Seel House Press, Liverpool. 351 pp.

Squires, R. L., and R. A. Demetrion. 1992. Paleontology of the Eocene Bateque Formation, Baja California Sur, Mexico. Nat. Hist. Mus. Los Angeles Co., Contri. in Sci., 434:1–55.

———. 1993. A new species of the clypeasteroid echinoid *Astrodapsis* from the Miocene Isidro Formation, Baja California Sur, Mexico. J. Paleont., 67(2):258–263.

Uozumi, S., and T. Fujie. 1956. The sand-pipe, created by the pelecypods: *Platyodon nipponica* n. sp. and *Pholadidea* (*Penitella*) *kamakurensis* (Yokoyama). J. Fac. Sci., Hokkaido Univ., ser. 4, Geol. and Mineral., 9(3):351–369.

Warme, J. E. 1970. Traces and significance of marine rock borers. Pp. 515–525 *in* Trace fossils. (T. P. Crimes and J. C. Harper, eds.), Geolog. J. Special Issue 3, Seel House Press, Liverpool. 547 pp.

———, and E. J. McHuron. 1978. Marine borers: trace fossils and geologic significance. Pp. 67–118 *in* Trace fossil concepts, Short Course No. 5. (P. B. Basan, ed.), Soc. Econ. Paleont. and Mineral., Oklahoma City. 201 pp.

Accepted for publication 27 September 1993.

## CONTENTS



### Research Notes



COVER: *Sauromalus australis* from the Sierra Vizcaíno.

ISSN 0038-3872



SOUTHERN CALIFORNIA ACADEMY OF SCIENCES

# BULLETIN

Volume 93 Number 2

BCAS-A93(2) 45–90 (1994) AUGUST 1994