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THE BORING CLAM, *PENITELLA CONRADI*, (BIVALVIA: PHOLADIDAE) IN NEPHRITE FROM MONTEREY COUNTY, CALIFORNIA

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ABSTRACT

Cobbles and boulders of nephrite jade collected subtidally and on Pleistocene marine terraces in Monterey County, California, contain numerous teardrop-shaped burrows typical of pholadid clams. Most burrows examined were vacant or occupied secondarily by nestling clams and other organisms. One burrow contained valves of a primary borer, Penitella conradi *Valenciennes, and represents the first record of pholadids boring nephrite. Emendation of the widespread belief that pholadids burrow only by mechanical abrasion seems justified.*

In May, 1982, one of us (Wilson) was astonished to recognize a vacant pholadid burrow in a slabbed cobble of nephrite jade (Fig. 1) offered for sale at Gorda, Monterey County, California. Inquiry disclosed that the cobble had been collected by divers off the coast nearby between Jade Cove and Willow Creek (Fig. 2). Subsequently, more than 100 burrows in cobbles and boulders of nephrite from the same area were observed by us, including some reportedly from local Pleistocene marine terraces. Such burrows are common enough to be considered a minor nuisance by the local jade dealers. Most of the burrows were empty or occupied secondarily by the nestling clams, *Hiatella arctica* (Linnaeus, 1767) or *Petricola carditoides* (Conrad, 1837), and other organisms. One burrow (Fig. 3) however, contained shells (Fig. 4) of a primary borer, the pholadid *Penitella conradi* Valenciennes, 1846, a species that ranges from Washington to Baja California Sur on the west coast of North America.

In addition to the pholadid burrows, unoccupied cup-shaped depressions with diameters as great as 80 mm occur on the surfaces of some of the nephrite boulders (Fig. 5). They are

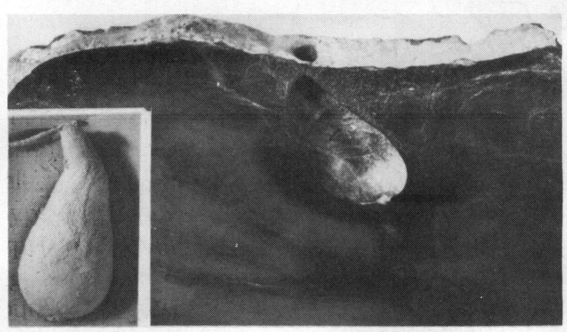


FIG. 1. Cut piece of nephrite cobble showing longitudinally sectioned pholadid burrow surrounded by dark halo. LACMIP hypotype 2480. Inset: latex cast made from this burrow. Both Figs. ×1.

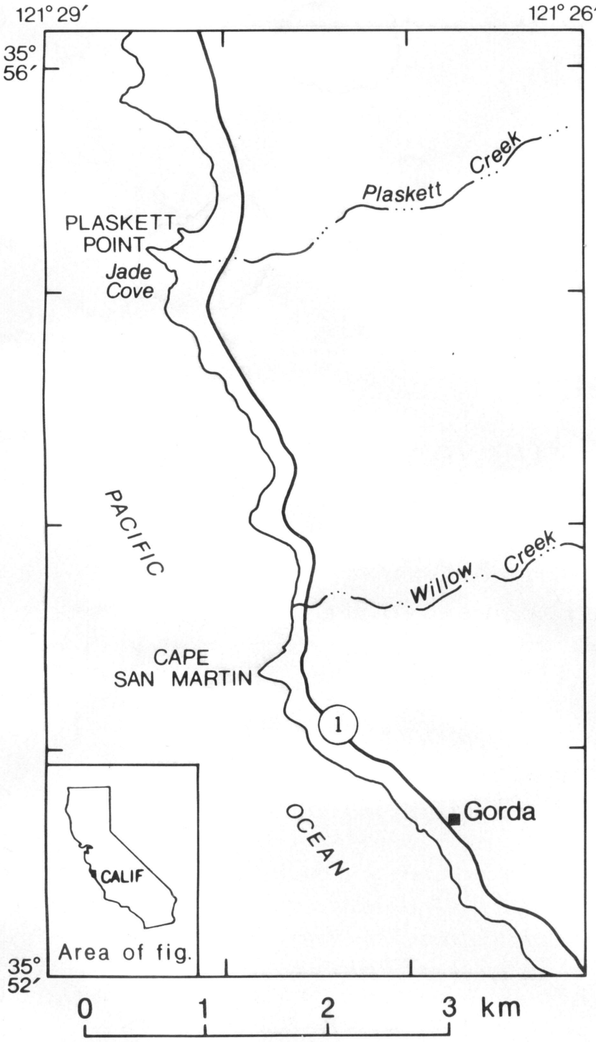
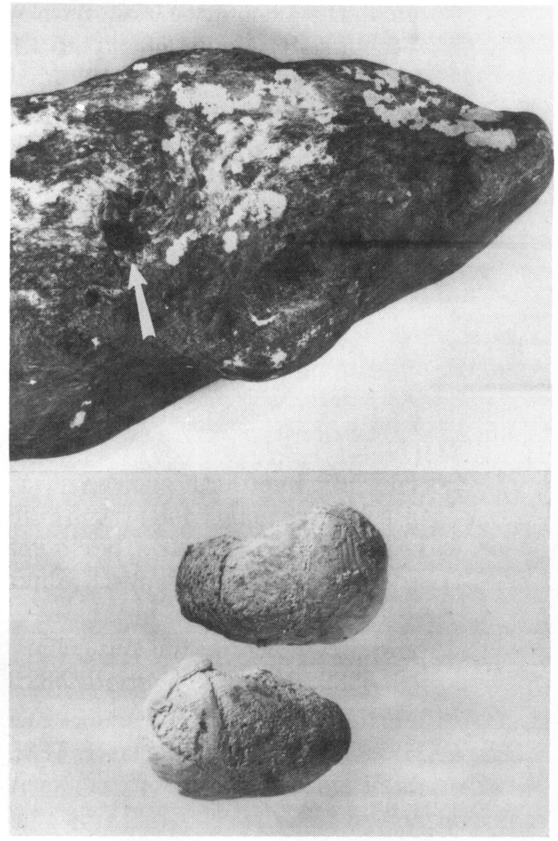


FIG. 2. Map showing general location of study area in California (inset) and more detailed map of the Plaskett Point-Cape San Martin region, Monterey County, where pholadid-bored nephrite jade occurs.



FIGS. 3-4. **3** (upper), portion of nephrite cobble with pholadid burrows. Collection of Mrs. Peggy McCain. ×0.5. **4**, paired valves of *Penitella conradi* removed from burrow shown by arrow in Fig. 3. LACMIP hypotype 2481. ×2.0.

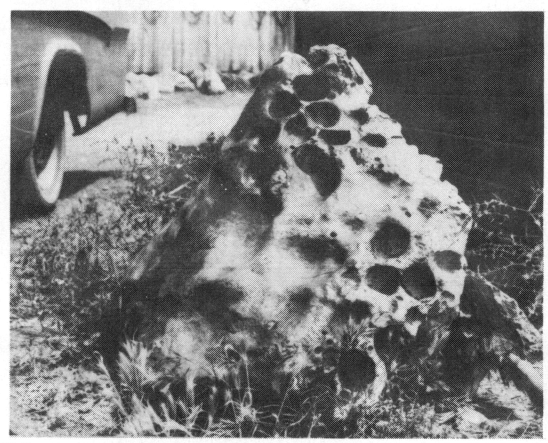


FIG. 5. Nephrite boulder showing small pholadid burrow openings and large surface depressions probably formed by echinoids. Boulder is 91 cm high. Collection of Mr. Kenneth Comello.

similar in shape and size to those formed by the sea urchin, *Strongylocentrotus* Brandt, 1835.

Nephrite

Between Plaskett Point and Cape San Martin, near Gorda, Monterey County, California (Fig. 2), nephrite crops out as lenticular masses associated with a complex of serpentine, schist, graywacke, and shale usually referred to the Franciscan Formation of Mesozoic age (Crippen, 1951). Pebbles, cobbles, and boulders derived from this formation, including nephrite, provide a substratum for epifaunal and infaunal marine organisms.

Nephrite is a silicate mineral with a legendary toughness that is due to an internal structure of filamentous crystals arranged in a dense, feltlike pattern, making it both difficult to break and to work. All of the nephrite cobbles and boulders with burrows tested by us have a hardness of between 5 and 6 on the Mohs scale and a specific gravity of 3 to 3.44. This would seem to be an inhospitable substratum for infaunal organisms.

Burrows

All of the burrows in nephrite seen in cross-section have the typical teardrop shape of pholadid burrows (Figs. 1, 6). Selected latex casts of other burrows in the nephrite show that they have similar shapes. No burrows were seen with shapes that are typical of boring clams other than pholadids. The size of the burrows is variable, with entrances that range from 1.5 to 4.5 mm in diameter. The largest burrow has a depth of 36 mm and a maximum width of 16 mm. A darkened halo around one of the sectioned burrows is as much as 7 mm wide (Fig. 1) and strongly suggests chemical alteration of the nephrite. The hardness in the discolored zone, however, is unaltered. Halos around burrows in mudstone formed by the boring mytilid *Lithophaga* Röding, 1798, considered to be a chemical borer by most workers, were attributed to subaerial weathering by Warme and Marshall (1969).

The specimen of *Penitella conradi* (Fig. 4) was taken from a subtidally collected nephrite cobble (Fig. 3). The valves are of an adult animal with callum and are 13 mm long (without siphonoplax). The shells are not misshapen, as is the case with some pholadids that bore into hard substrates, but the concentric ridges on the anterior slope are very tightly packed.

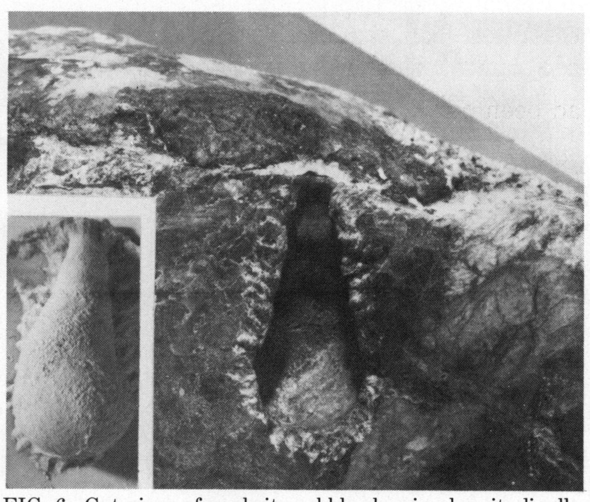


FIG. 6. Cut piece of nephrite cobble showing longitudinally sectioned pholadid burrow. Collection of Mr. Kenneth Comello. Inset: latex cast made from this burrow. LACMIP hypotype 2482. Both Figs. ×1.0.

Discussion

"Members of the family Pholadidae bore into stiff clays or muds, shales, friable or soft rock, shells, poor grade cement, wood, nuts, or other plant products" (Turner, 1969). The implication of "soft rock" is that it is either sedimentary or relatively nonresistant to erosion. However, pholadids infrequently have been reported boring into volcanic and metamorphic rocks. Boring generally is considered to be mechanical and not chemical in nature. On the basis of wear patterns on pholadid shells, Kennedy (1974) concluded that mechanical rasping of the burrow wall was done primarily with the fore edge of the last concentric ridge of the anterior slope. The mechanics of boring in numerous species of pholadids was discussed by Röder (1977).

Reports of two researchers (Smith, 1969; Haderlie, 1976, 1979, 1980) contradict the traditional view that pholadids bore only mechanically.

The process of boring by *Penitella conradi* was studied by Smith (1969). After examination of California abalone shells bored by this species, he concluded that "the role of mechanical abrasion by *P. conradi* is minor . . . The boring process in *P. conradi* proceeds mainly by chemical dissolution of the calcareous substrate". He suspected that epithelial glands in the mantle were used for chemical dissolution of the abalone shell.

Smith (1969) also observed that during the characteristic rocking motion of the pholadid boring cycle, the mantle of *P. conradi* was in contact with the anterior burrow wall as far as the maximum diameter of the burrow and that it simultaneously covered most of the anterior portions of the valves. Apparently a biochemical secretion was being deployed to the calcareous substrate by specialized cells in the mantle. The mantle was then withdrawn and the rotation cycle initiated, during which the mechanical abrasion occurred.

Haderlie (1976, 1979, 1980) reported that *P. conradi* and six other species of pholadids bore into siliceous sediments of the Monterey Shale in Monterey Bay, California. The rocks were reported to be chert and to have a hardness of seven on the Mohs scale.

The presence of burrows of *P. conradi* in nephrite seems to substantiate the findings of Smith (1969) that the species uses chemical assistance for boring and Haderlie (1976, 1979, 1980) that it somehow bores into substrata much harder than its shell. Further studies are necessary to elucidate the method of substratum dissolution.

Acknowledgments

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The shells of *Penitella conradi* and selected specimens of nephrite with pholadid burrows are in the Natural History Museum of Los Angeles County, Invertebrate Paleontology Section (LACMIP) as hypotypes 2480-2482.

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