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Three new limpets of the family Pseudococculinidae from abyssal depths (Mollusca, Archaeogastropoda)

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Taxonomic descriptions of three new species of Pseudococculinidae, which are treated anatomically in a concurrent paper by Haszprunar, are given: *Amphiplica venezuelensis* from the Venezuelan Basin, *A. knudseni* from the Tasman Basin and *Yaquinabyssia careyi* from the Cascadia Abyssal Plain off Oregon.

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Introduction

The family Pseudococculinidae was recently proposed by Hickman (1983), who separated it from the Cocculinidae Dall, 1882 on the basis of radular characters: the innermost lateral teeth are large and triangular, unlike the adjacent laterals. Cocculinid genera lack these enlarged inner laterals. Marshall (1986) also supported the separation of the two taxa at the family level. Anatomy in cocculiniform limpets has been studied by Haszprunar (1988*b*), who has made a detailed study of anatomy in Cocculinidae (1987) and Pseudococculinidae (1988*a*), the latter published concurrently with the present paper. Haszprunar concludes that anatomical differences between the two families are sufficient to place them in separate superfamilies—Cocculinidae in Cocculinacea (Cocculinoidea of Haszprunar) and Pseudococculinidae in Lepetellacea (Lepetelloidea of Haszprunar). The present paper provides the taxonomic descriptions of those species treated by Haszprunar (1988*a*) that were not described by Marshall (1986).

The three species described here were collected at abyssal depths by various deep sea expeditions: by the Galathea Expedition in the Tasman Basin in 1951, by the University of Oregon in the Cascadia Abyssal Plain in 1970 and by the Naval Ocean Research and Development Activity (NORDA) in the Venezuelan Basin in 1981. All species were associated with wood, as is most frequent in Pseudococculinidae.

All specimens of each species were eroded at the apex, making it impossible to give characters of the protoconch, as previously done by Moskalev (1976) and Marshall (1986). SEM illustrations and detailed discussion of the pseudococculinid radula have recently been given by Hickman (1983, 1984) and Marshall (1986).

Type material is placed in the Indian River Coastal Zone Museum, Fort Pierce, Florida (IRCZM), Los Angeles County Museum of Natural History (LACM), the National Museum of Natural History, Washington, D.C. (USNM), the National Museum of New Zealand, Wellington (NMNZ), and the Zoological Museum, Copenhagen (ZMC).

Family PSEUDOCOCCULINIDAE Hickman, 1983

Genus *Amphiplica* Haszprunar, 1988

Type species. Amphiplica venezuelensis McLean, sp.n. (this paper)

Diagnosis. Shell relatively large, apex nearly central, concentric sculpture with fine radial microstriae. Outer lateral massive, with 5 stubby denticles; second marginal enlarged. Secondary subpallial gill leaflets on both sides; right cephalic tentacle (copulatory organ) with open groove.

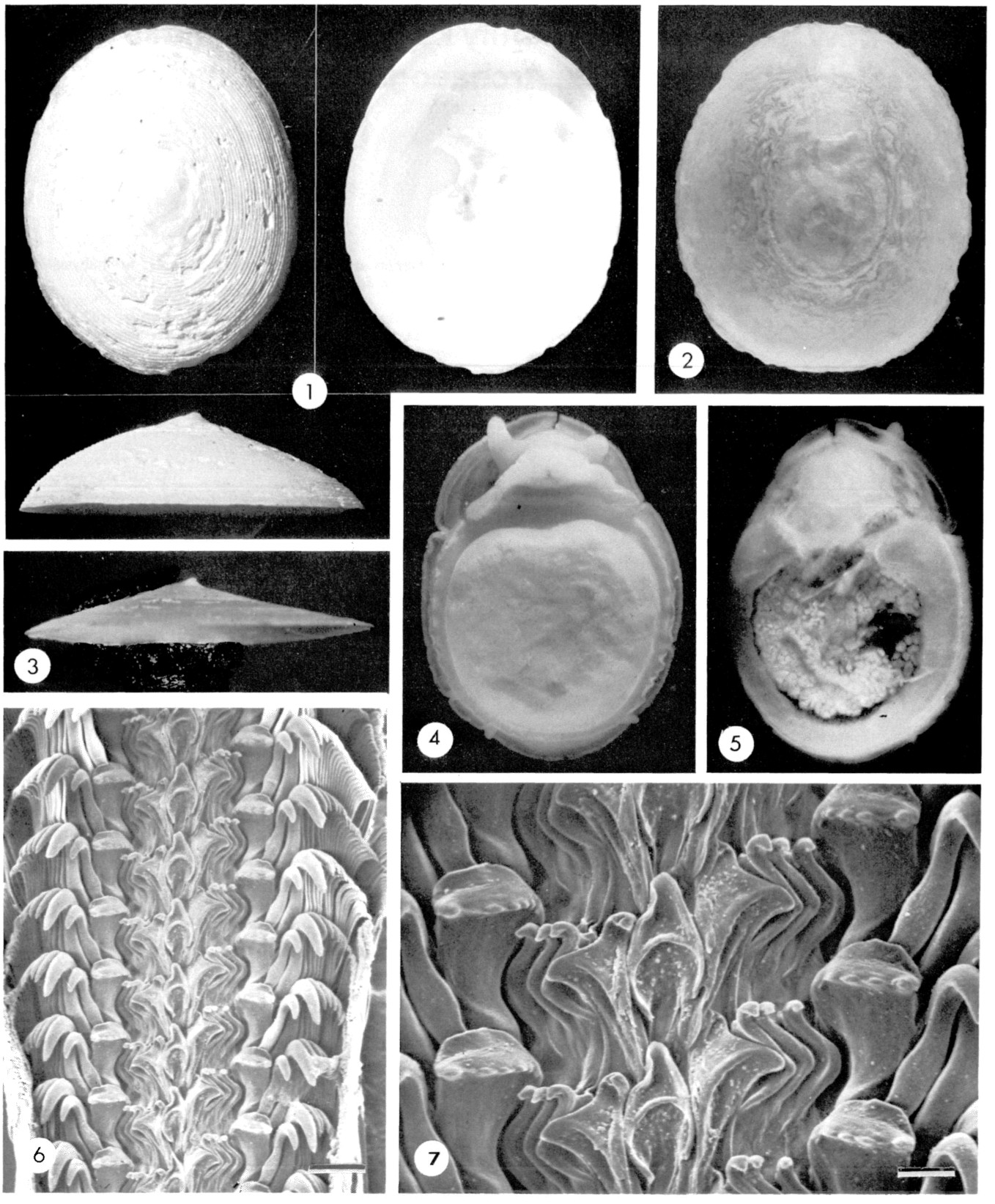
Remarks. This genus is characterized by its large size, shell microsculpture, numerous gill leaflets and a distinct radular configuration. These are the largest known pseudococculinids. Except for the genus *Kurilabyssia* Moskalev, 1983, in which a maximum length of 8.7 mm is attained (Marshall 1986), other pseudococculinids are under 4 mm in length. Anatomical characters are further discussed by Haszprunar (1988*a*).

Three species are known, two of which, including the type species, are described here. The third species, *A. concentrica* (Thiele, 1909), comb.n., is mentioned below.

Amphiplica venezuelensis sp.n. (Figs. 1–7)

Type locality. Venezuelan Basin, due N of Caracas, Venezuela (14°20′N, 67°00′W), 5057 m.

Type material. 23 specimens collected alive from type locality, USNS *Bartlett*, Cruise 1301–82, station 96, 30 Nov. 1981; 45 foot otter trawl, bottom time 317 min. Holotype, USNM 784758; 4 paratypes, USNM 784759; 4 paratypes, IRCZM 065:02595; 12 paratypes, LACM 2265; 2 paratypes, NMNZ. Specimens from station 96 were sectioned by Haszprunar. Five additional paratypes (LACM 2266) collected alive,



Figs. 1–7. Amphiplica venezuelensis sp.n.—*1*. Exterior and interior views (anterior at top) and lateral (left side) views of holotype. Length 9.3 mm.—*2*. Exterior of paratype (LACM 2265) from station 96 showing erosional pattern revealing muscle scar. Length 10.2 mm.—*3*. Lateral view (left side) of low-profile paratype (LACM 2266) from station 92, showing apical spur. Length 10.6 mm.—*4*. Ventral view of paratype (shell in Fig. 2) showing head with blunt cephalic tentacles, oral lappets on either side of mouth, broad foot with thin edge and posterior pair of epipodial tentacles. Length 7.5 mm.—*5*. Dorsal view of same specimen showing horseshoe-shaped shell muscle and ovary; the rectum shows a fecal pellet in place next to the termination of right shell muscle.—*6*. SEM view of radular ribbon. Note enlarged second marginal. Scale bar 50 μm.—*7*. Same preparation, showing detail of rachidian, four inner marginals and large fifth marginal with stubby denticles. Scale bar 20 μm.

Venezuelan Basin (13°30'N, 64°45'W), 3476–3518 m, *Bartlett*, Cruise 1301–82, station 92, 27 Nov. 1981; 45 foot otter trawl, bottom time 260 min.

Etymology. The name derives from the type locality, the Venezuelan Basin.

Description. Shell (Figs. 1–3) large for family (maximum length 14.8 mm), white; periostracum not evident. Height moderate to low, that of holotype 0.30 × length. All slopes moderately convex; anterior slope more convex than posterior slope. Outline in dorsal view oval; anterior end slightly narrower than posterior; plane of aperture usually resting flat. Apex central, at highest point of shell; apical area of all specimens deeply eroded, although some retain an apical spur marking deposition of shell in the apical pit. Sculpture of fine, even, sharply raised concentric rings, about 12 per mm on sides near margin; interspaces broader than ribs; radial sculpture of extremely fine striae, producing a fine reticulate pattern under high magnification. Shell edge thin and sharp, easily chipped; shell interior opaque, thickened away from margin. Muscle scar horseshoe-shaped, with large anterior terminations. Anterior pallial attachment line well marked, irregular, not as prominent as muscle scar. Area within pallial line and muscle scar opaque, lumpy.

Dimensions: length 9.3, width 7.3, height 2.8 mm (holotype).

Radula (Figs. 6, 7). Rachidian triangular, with broadly indented basal element and tapered shaft leading to simple beak-like overhanging cusp; innermost lateral with thick inner edge to its basal element and strong lateral projection. Second, third and fourth pairs of lateral teeth with major lateral projections and simple tips. Outer laterals massive, with 5 stubby denticles in a row, the outermost much more prominent. Marginal teeth with short shafts and long cusps, second marginal the largest; bases of marginals apparently not fused.

External anatomy (Figs. 4, 5). Oral lappets prominent, posterior epipodial tentacles present; secondary gill leaflets on both sides; right cephalic tentacle (copulatory organ) of same size as left, with dorsal groove (Haszprunar 1988*a*).

Remarks. *Amphiplica venezuelensis* resembles *'Pseudococculina' concentrica* Thiele, 1909 from the Atlantic Ocean north of the Azores, which has similar sculpture, attaining a length of 9.5 mm. The specimen figured by Thiele (1909, pl. 4, figs. 5, 6) shows erosion near the apex and the apical tip is represented by a strong spur, as in *A. venezuelensis*. The radula as figured by Thiele (1909, pl. 1, fig. 7) is also similar, but differs in having a much wider projecting shaft of the rachidian element. This difference in radula is considered sufficient to warrant the recognition of separate species in this genus. Although anatomical comparisons cannot be made, Thiele's species clearly is a member of the genus *Amphiplica* on the basis of large size and similarities in the shell and radula.

There is considerable variation in shell height and proportion in this new species. Two shells (Fig. 3) from station 92 have an extremely low profile (height 1.9, length 8.0; height 2.0, length 7.9 mm); these specimens were initially thought to represent a separate species, but have the same microsculpture and radular characters as the typical form. One shell from station 96 (height 2.7, length 7.0 mm) shows a change in proportions with growth, starting with a high profile, then changing to a flatter profile and finally reverting to the higher profile. The existence of this specimen shows that shell proportions can readily change and that differences in shell proportions are not sufficient grounds to separate species in this genus. Most shells have a flat base, but three specimens have unusually compressed sides and raised ends (e.g. length 11.5, width 7.9, height 3.1 mm). These differences in proportions are probably due to differences in the wood with which the limpets were associated and its state of decomposition.

Some of the shells are extremely eroded, the surface having lost the concentric ridges of original sculpture and appearing etched, exposing shell layers unevenly in a wavy pattern, with the etching extending all the way to margin (Fig. 2). These shells compensate for exterior erosion by internal thickening. The muscle scar pattern in these shells shows on the deeply eroded exterior surface. All specimens from station 96 over 9.8 mm in length were deeply eroded; those under 9.8 mm were pitted, but retained some of the original concentric sculpture. This suggests that the erosion is a function of time, as the larger shells are presumed older. The two shells from station 92 with the low profile mentioned above were over 9.8 mm in length, but were evidently faster growing, as their shells were free of erosion. Again, the difference was probably a result of a different wood substrate.

Amphiplica venezuelensis is the only cocculiniform species reported from the Venezuelan Basin. For information on the habitat and details of the collecting expedition see Briggs & Richardson (1984).

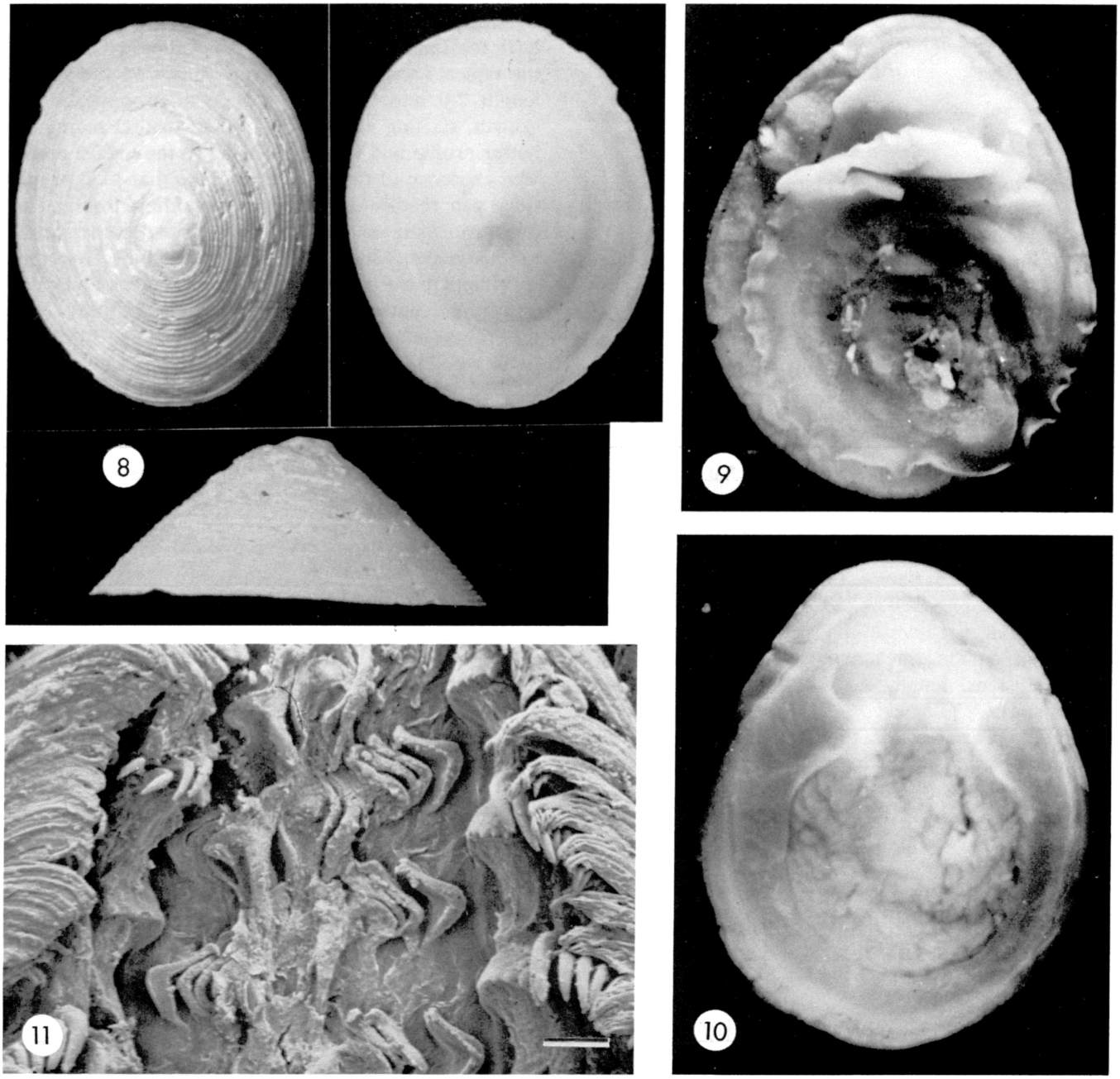
Amphiplica knudseni sp.n. (Figs. 8–11)

Type locality. Tasman Basin, W of South Island, New Zealand (44°18'S, 166°46'E), 3610 m.

Type material. 4 specimens collected alive from type locality, Galathea station 607, 17 Jan. 1951. Holotype, ZMA; 2 paratypes, ZMA; 1 paratype, NMNZ. Bodies of two specimens were sectioned by Haszprunar; one body was used for radular studies by Hickman (unpublished); one paratype body remains, which is illustrated here (Figs. 9, 10) and from which I subsequently prepared the radula.

Etymology. The name honors Dr Jörgen Knudsen, emeritus curator at the Zoological Museum, Copenhagen.

Description. Shell (Fig. 8) large for family (maximum length 9.0 mm), white; periostracum not evident. Shell height relatively high, that of holotype 0.42 × length. All slopes slightly convex. Outline in dorsal view oval; neither end of shell narrower than the other; plane of aperture resting flat. Apex slightly posterior to center, at highest point of shell; apical area of all specimens deeply eroded. Sculpture of fine, even, sharply raised concentric rings, about 7 per mm on sides near margin; interspaces broader than ribs; radial sculpture of extremely fine striae, producing a fine reticulate pattern under high magnification. Shell edge thin and sharp, easily chipped; shell interior opaque, thickened away from margin. Muscle scar



Figs. 8–11. Amphiplica knudseni sp.n.—*8*. Exterior and interior views (anterior at top) and lateral (left side) views of holotype. Length 8.4 mm.—*9*. Ventral view of paratype (ZMA) showing head with blunt cephalic tentacles and greatly extended oral lappets (surface of foot damaged).—*10*. Dorsal view of same specimen showing horseshoe-shaped shell muscle enclosing ovary. Length 4.8 mm.—*11*. SEM view of radular ribbon: a poor preparation, but roughly comparable to that in Fig. 7. Scale bar 20 μm.

scarcely visible, horseshoe-shaped, with large anterior terminations. Anterior pallial attachment line thin, irregular, not prominent. Shell interior glossy, not lumpy.

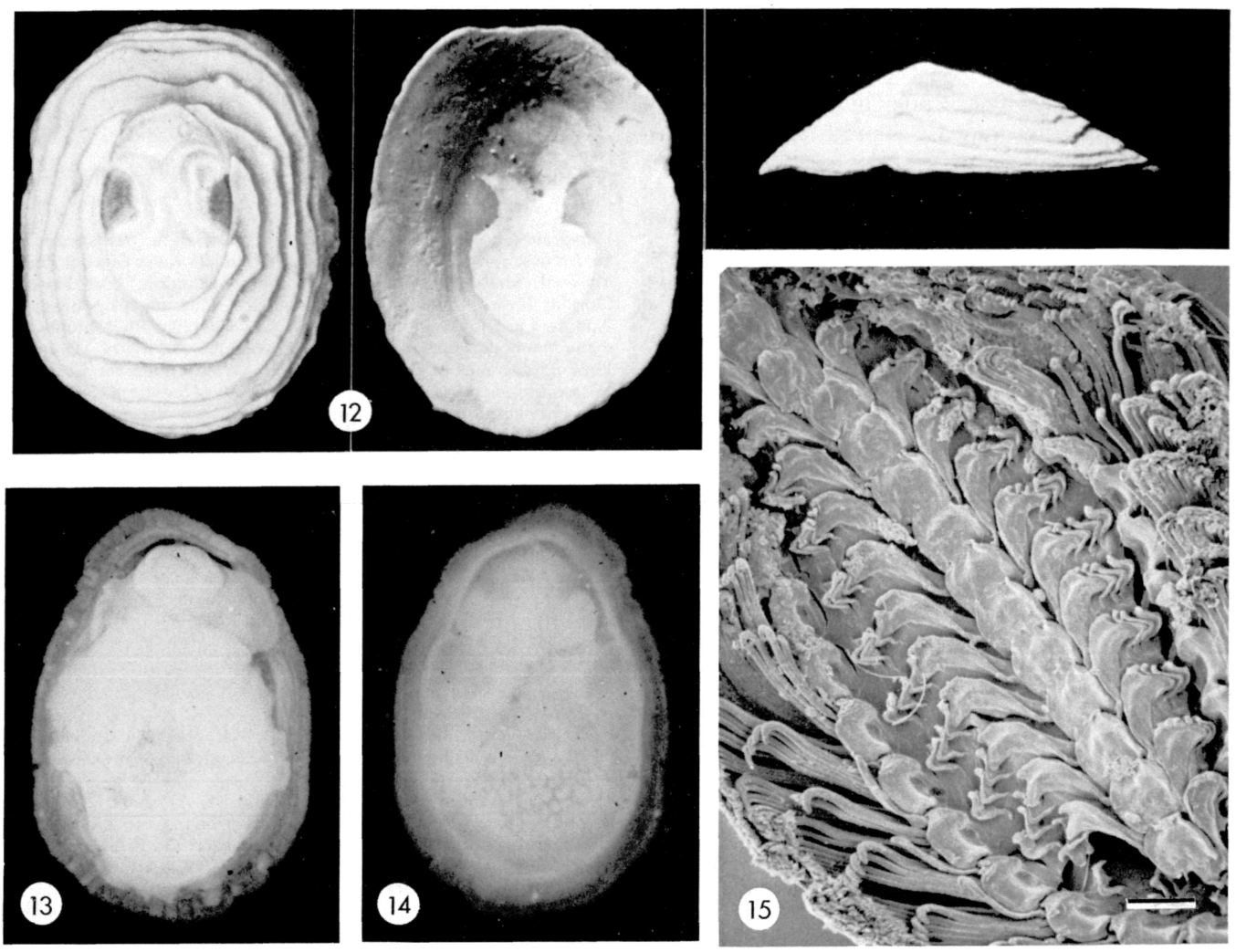
Dimensions: length 8.4, width 6.6, height 3.5 mm (holotype).

Radula (Fig. 11). The preparation is poor, as was that made by Hickman (personal communication), but an illustration is included for comparison with that of *A. venezuelensis*, to which it is similar. The outline of the rachidian is similar, although the ridge that marks the basal indentation of that species cannot be seen and is probably lacking. The morphology of the four inner laterals and the outer laterals agrees with that of *A. venezuelensis*. Five short denticles are present on the outer laterals, as in *A. venezuelensis*. Second marginal the largest.

External anatomy (Figs. 9, 10). Oral lappets prominent, posterior epipodial tentacles present; secondary subpallial leaflets on both sides of foot; right cephalic tentacle (copulatory organ) of same size as left, with open groove (Haszprunar 1988*a*).

Remarks. The morphology of the radula and the oral lappets and details of shell sculpture indicate that *Amphiplica knudseni* is closely related to *A. venezuelensis*. *Amphiplica knudseni* has a more posterior apex, fewer concentric rings per mm (7 compared to 12) and the shell profile is higher.

The four known specimens have proportions similar to the holotype; the sample is not large enough to tell whether there are flat or compressed forms, as in *A.*



Figs. 12–15. Yaquinabyssia careyi sp.n.—*12*. Exterior and interior views (anterior at top) and lateral (left side) views of holotype. Length 3.8 mm.—*13*. Ventral view of paratype (LACM 2070) body showing broad oral lappets on either side of mouth and irregular outline of foot (due to poor preservation). Length 2.3 mm.—*14*. Dorsal view of same specimen showing horseshoe-shaped muscle enclosing ovary, rectum coursing to right and contracted cephalic tentacles through thin mantle skirt.—*15*. Radular ribbon, showing broad rachidian, broad inner laterals, three smaller laterals and broad fifth lateral; note that all marginals are similar. Scale bar 350 μm.

venezuelensis. The surface of all specimens is pitted, but most of the original sculpture is retained. None of the specimens have the strongly marked muscle scars characteristic of senile shells. The outline of the muscle scar may best be taken from the dorsal view of a preserved specimen (Fig. 10). Some specimens show a breakage and repair pattern at successive stages of the margin; further erosion superimposed on this would probably produce the irregular pattern of lines typical of eroded shells in this family.

Amphiplica knudseni is the only cocculiniform species known from abyssal depths in the Tasman Basin. Although Marshall (1986) treated the Cocculinidae and Pseudococculinidae of New Zealand and New South Wales, none of the species he treated were truly abyssal.

Genus *Yaquinabyssia* Haszprunar, 1988

Types species. Yaquinabyssia careyi McLean, sp.n. (this paper)

Diagnosis. Shell small, apex nearly central; surface with etched erosional pattern. Rachidian broad, outer lateral massive, second marginal not enlarged. Secondary subpallial gills numerous on right, a single leaflet on left; right cephalic tentacle (copulatory organ) equal to left, with ciliary band.

Remarks. This genus is as yet monotypic. The condition of the subpallial gill and the radular morphology is unique.

Yaquinabyssia careyi sp.n. (Figs. 12–15)

Type locality. Cascadia Abyssal Plain, 171 km west of Cape Foulweather, Lincoln Co., Oregon (44°53.7′N, 126°33.4′W), 2774 m.

Type material. 8 specimens from the type locality dredged by the R/V *Yaquina*, Oregon State University station BMT 162, 19 Jan. 1970. Holotype, LACM 2069; 4 paratypes, LACM 2070; 2 paratypes, USNM 784753; 1 paratype, NMNZ. Specimens from this lot were sectioned at the LACM and studied by G. Haszprunar.

Etymology. Named after Dr Andrew G. Carey Jr, of Oregon State University, who directed the sampling program on the Cascadia and Tufts Abyssal Plains by the University of Oregon during the late 1960s and early 1970s.

Description. Shell (Fig. 12) small for family (maximum length 4.7 mm), white; periostracum not evident. Height

moderate, that of holotype 0.34 × length. All slopes slightly convex. Outline (in dorsel view) oval; anterior and posterior ends of equal breadth. Apex slightly anterior to center, at highest point of shell; apical area of all specimens deeply eroded. Sculpture not evident; surface etched in pattern of irregular concentric growth 'steps', maximum number 8 on posterior slope of holotype. Steps evidently produced by periodic growth spurts, in which new growth descends below previous position. Muscle scar pattern apparent on deeply eroded exterior surface. Anterior slope of holotype more eroded than posterior, 6 steps remaining. Shell edge and interior chalky (formalin damage?); muscle scar pattern prominent; terminations of muscle scar slightly forward of midpoint of shell; anterior terminations of muscle scar bulging toward central region. Shell markedly thickened within area enclosed by muscle scar and within area bordered by pallial attachment line in front of muscle terminations.

Dimensions: length 3.8, height 2.8, width 1.3 mm (holotype).

Radula (Fig. 15). Rachidian broad, uncusped; inner lateral large, inner edge broadly curved, outer edge broadly projecting, cusp small. Second, third and fourth inner laterals outwardly bowed to correspond to the projection of the innermost lateral; outer lateral massive, cusps poorly developed. Marginals numerous, second lateral not enlarged.

External anatomy (Figs. 13, 14). Gill leaflets numerous on right, a single leaflet on left (Haszprunar 1988*a*, fig. 2); right cephalic tentacle (copulatory organ) equal to left, with ciliary band (Haszprunar 1988*a*).

Remarks. Similarly eroded shells have been illustrated for two species from the Indian Ocean, *Pseudococculina rugosoplicata* Schepman, 1908 and *P. granulata* Schepman, 1908, both of which retain traces of the original sculpture. The former species has an enlarged right tentacle and is not congeneric with *Y. careyi*; the external features of *P. granulata* are unknown. *Yaquinabyssia careyi* differs from both in having a broader rachidian element.

Shells in the type lot may have been damaged by the initial preservation in formalin. The concentric pattern of 'steps' appears to coalesce, because erosion has removed whole layers of shell, particularly near the apical area. The lines coalesce where two 'steps' or layers are removed. Thickening of the shell from within keeps the shell intact.

Yaquinabyssia careyi is the only cocculiniform species reported from the Cascadia Abyssal Plain. For further information on the biotic community see Carey (1981) and Griggs *et al.* (1969).

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