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New fossil forms of Carelia and Partulina (Pulmonata) from Hawaiian Islands*

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BERNICE P. BISHOP MUSEUM

INTRODUCTION

Between 1946 and 1949 Mr. George F. Arnemann presented Bernice P. Bishop Museum with several new fossil forms of the genus *Carelia* from the island of Kauai and two new fossil forms of *Partulina* from Oahu. Dr. Cooke classified them provisionally in 1948, shortly before his death, naming the sinistral *Partulina* for Mr. Arnemann. It remained for me to name and describe the others and to discuss affinities and distribution. Described herein are one new species, two new subspecies, and one geographical race of *Carelia,*[1] and one new species and one new subspecies of *Partulina.*

Genus **Carelia** H. and A. Adams

Cooke, in his monograph on "The land snail genus Carelia" (B. P. Bishop Mus., Bull. **85,** 1931), discussed 20 species of *Carelia* with their subspecies and varieties. Later, because of his intimate knowledge of the genus *Carelia,* Dr. Cooke was able to make some accurate predictions as to where new forms would be found in the future. In May 1942 he mapped the areas on Kauai wherein living and fossil forms should occur. Four localities were mapped for fossils, namely, Moloaa, Lihue, the area between Lawai and Kukuiula Bays, and a locality near Barking Sands off Waikamoo Valley. The new forms described in this paper were found at or in the vicinity of the first and last localities. Living forms may be expected principally in the interior region. (See map, figure 1.)

* Funds for the printing of this paper were contributed by the Charles M. and Anna C. Cooke Trust.

[1] *C. paradoxa waipouliensis* is here named, but it was described by Cooke in 1931.

Among those forms discussed by Cooke in 1931 are 10 species, six subspecies, and two varieties described by him. These are summarized in the following list and combined with the new additions to make a total of 21 species, eight subspecies, two geographical races, and two varieties. Asterisks indicate the new forms.

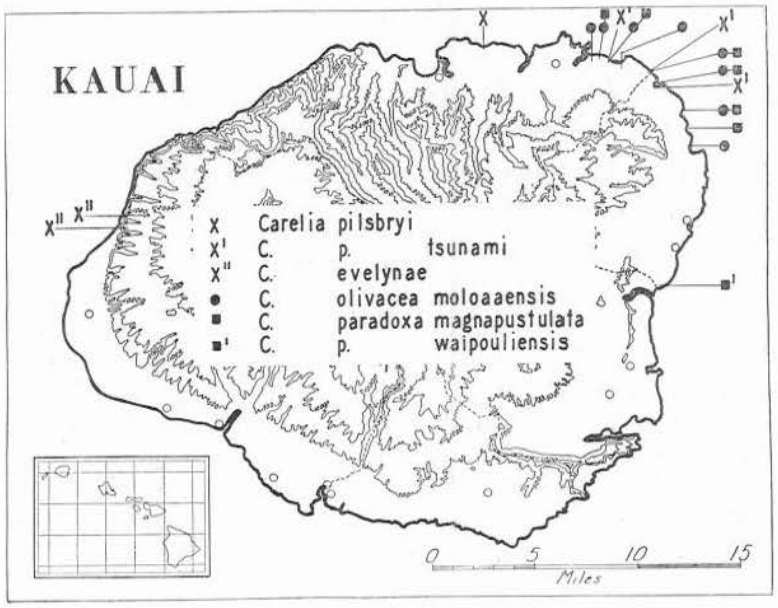

FIGURE 1.—Map showing distribution of *Carelia* discussed in this paper (University of Hawaii outline map, based on topographic map of U.S. Geological Survey).

Sinclairi Group

Carelia sinclairi Ancey, fossil (p. 22)[2]
Carelia pilsbryi Sykes, fossil (p. 25)
**Carelia pilsbryi tsunami,* new subspecies
Carelia mirabilis Cooke, fossil (p. 29)
**Carelia evelynae,* new species, fossil
**Carelia evelynae,* new geographical race?, fossil

Bicolor Group

Carelia anceophila Cooke, dead (p. 31)
Carelia kalalauensis Cooke, living (p. 32)
Carelia bicolor (Jay), living (p. 37)
Carelia bicolor angulata Pease, living (p. 42)

[2] Pages in parentheses in this list refer to B. P. Bishop Mus., Bull. 85, and are given here because that volume is not indexed.

Carelia cumingiana Pfeiffer, fossil (p. 44)
Carelia cumingiana meineckei Cooke [subspecies], living (p. 46)
Carelia cumingiana meineckei? [Cooke], dead (p. 47)

Cochlea Group

Carelia dolei Ancey, fossil (p. 48)
Carelia dolei isenbergi Cooke [subspecies], fossil (p. 53)
Carelia cochlea (Reeve), fossil (p. 54)

Turricula Group

Carelia turricula (Mighels), living (p. 59)
Carelia hyattiana Pilsbry, fossil, dead (p. 65)
Carelia olivacea Pease, living (p. 67)
Carelia olivacea, new subspecies? [Cooke], dead (p. 71)
Carelia olivacea baldwini Cooke [subspecies], dead (p. 71)
Carelia olivacea propinquella Cooke [subspecies], living (p. 72)
Carelia olivacea priggei Cooke [variety], dead (p. 73)
Carelia olivacea infrequens Cooke [variety], fossil (p. 74)
**Carelia olivacea moloaaensis*, new subspecies, fossil
Carelia lymani Cooke, fossil (p. 74)
Carelia tenebrosa Cooke, living (p. 75)
Carelia lirata Cooke, fossil (p. 78)

Glossema Group

Carelia glossema Cooke, living (p. 80)
Carelia knudseni Cooke, dead (p. 82)
Carelia periscelis Cooke, dead (p. 83)

Paradoxa Group

Carelia necra Cooke, fossil (p. 85)
Carelia necra spaldingi Cooke [subspecies], fossil (p. 88)
Carelia paradoxa (Pfeiffer), fossil, dead (p. 89)
Carelia paradoxa thaanumi Cooke [subspecies], fossil (p. 92)
**Carelia paradoxa waipouliensis*, new geographical race, fossil (p. 89)
**Carelia paradoxa magnapustulata*, new geographical race, fossil

CARELIA SINCLAIRI GROUP?

Carelia evelynae, new species (fig. 2, *a-f*).

Shell fossil (fig. 2, *a*) small, oblong-ovate, solid though not thick, capucine buff or white. First 3.5 whorls slightly convex forming a moderately sharp cone, thence whorls become decidedly convex, the increase in size to the seventh being quite regular and rapid. Earliest whorl usually smooth, the following 2.5 with fine striae which become gradually coarse from the fourth to the seventh, in general coarsest on the back of the last whorl, the sculpture definitely continuing on base in front of aperture. From fourth whorl onward are faint spiral lines, which become faint lirae in some specimens on last whorl opposite aperture, strongest just before peristome. Last whorl with weak peripheral angle. Aperture subovate. Parietal wall with pearly callus, which is continuous with the columella, forming a rather sharp ridge there. Columella slightly concave with a small basal reflexure (or truncation) that forms a tiny beak on base of aper-

ture, the beak backed posteriorly and to left of columella by a short, blunt ridge which may be a type of "umbilical carina"; columellar lamella weak. Peristome usually thick (0.5-1 mm.) though some have a sharp edge, with the characteristic lamination behind it in many specimens; this thickening is not the amastroid interior type.

Range of measurements: 30.4 × 14.6 to 40.3 × 18.5; coll. nos. 212325E (fig. 2, *b*) and 212325A (fig. 2, *c*). Average of 60: 34.5 × 16.0 mm. Broadest specimen, 18.7 mm.; coll. no. 212327.

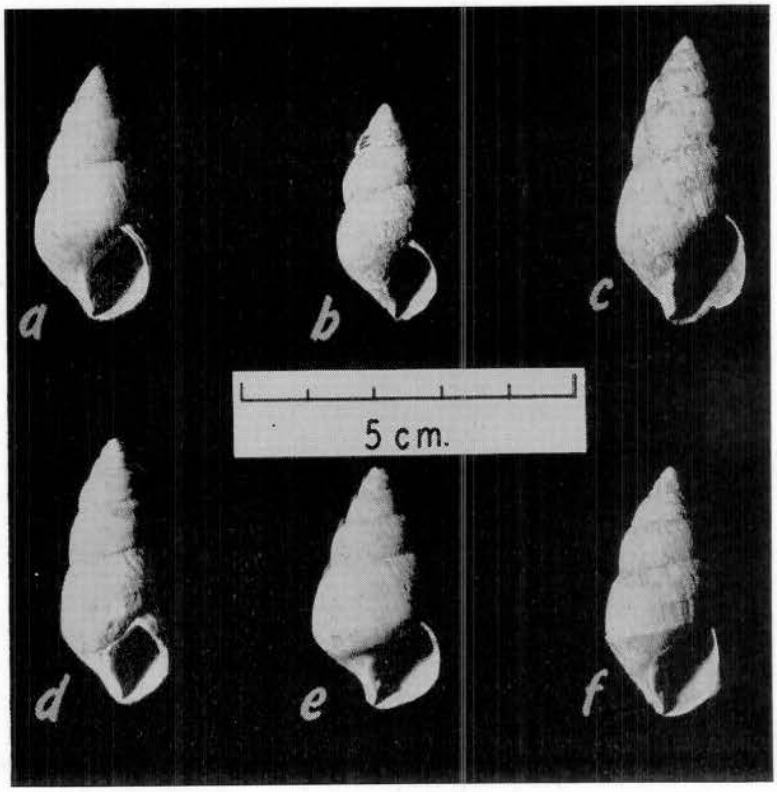

FIGURE 2.—*Carelia evelynae:* **a,** holotype, BBM 9092 ex 212325; **b,** small form, 212325E; **c,** longest specimen, 212325A; **d,** elongate form, 212325D; **e,** broad (but not broadest) form, 212325B, having unique shape; **f,** strongly carinate, 212325C, unique.

Holotype: 35.7 × 17.2 mm., whorls seven. The specimen shows a faint capucine buff coloration, the characteristic weak spiral lines on the last 2.5 whorls, a moderately thickened lip with the characteristic preperistomal lamination, the basal reflexure of the columella to-

gether with the characteristic post-basal ridge paralleling and to the left of the columella, a weak peripheral angle, and the parietal callus. The shell has a round hole at the termination of the sixth whorl. It is with some misgivings that this over-average length specimen is selected for the holotype. This particular specimen is chosen to represent the species because none of those near the average show all the characteristics of the species.

Kauai, Polihale, base of Polihale Ridge: 500 ft. inland from ocean, 150 ft. alt., July 24, 1948. Holotype BBM 9092; paratypes nos. 212325-212329 (115 specimens); paratypes no. 212298 (137 specimens), May 22, 1948. All collected by Arnemann. (Arnemann coll. nos. 205, 218, 222; 92 specimens.)

C. evelynae is quite distinct from all the other known species of *Carelia,* in that it has a thick lip with well-defined preperistomal lamination and a definite, short, laminated ridge to the left of and paralleling the columella.

The fact that this species resembles some of the broader and shorter specimens of *C. bicolor* and *C. kalalauensis* suggests a common ancestor. The resemblance is supported by the distribution of the *bicolor* group on the northwestern periphery of Kauai from Wainiha to Makaha. The westernmost colony of the fossil *C. kalalauensis* comes from Makaha, which is only 2.9 miles north of Polihale, the locality of *C. evelynae.* In addition, the lines on the embryonic whorls are much finer in *C. evelynae,* in this respect resembling those of *C. sinclairi* and *C. pilsbryi* of the *sinclairi* group. These lines are coarse in the *bicolor* group. However, because *C. evelynae* is characterized by sculpturation on the base of the last whorl in front of the aperture, it is placed, with a question mark, in the *sinclairi* group.

When this study was started, it was thought that *C. evelynae* would fill most of the specifications for the ancestral form of *Carelia* as enumerated by Hyatt (Man. Conch. **21:** 101-102, pl. 16, fig. 7, 1911); but though it meets some of the requirements—an angulated base, convex dorsal sides, a smoother surface than that of *Kauaia kauaiensis,* and a resemblance to the juvenile of C. bicolor—it lacks the perforation, and the angle of the base is weak.

The position of *C. evelynae* is probably between that of the *sinclairi* and *bicolor* groups, as it fits into neither group exactly. However, it is closer to *sinclairi* in that its embryonic striae are fine and

the faint sculpturing is present on the base in front of and behind the aperture. In the embryonic whorls it is difficult to determine whether it is slightly convex, as in the *sinclairi* group, or flat, as in the *bicolor* group, though it is on the flattish side. Other variations in the population are illustrated in figure 2, *d-f*.

The species is named in honor of the late Evelyn Arnemann, whose husband has contributed much toward the knowledge of the genus *Carelia* since he began collecting in 1943. Mr. Arnemann contributes the following account of his discovery of *C. evelynae*:

> "On Sunday, Jan. 18, 1948 Mr. Hubert Beardin and I . . . drove to the end of the dirt road beyond Mana, and explored the coastline . . . In front of the Polihale ridge, I stopped to examine a dirt and gravel bank back of the rock-covered shore-line. I was rewarded by finding a number of fossils. After about half an hour, I came across the real find, a *Carelia* imbedded in the dirt and different from any I had seen before. It was an adult specimen in very good condition, but with a small hole in one whorl.
>
> "Lack of time forced me to quit hunting, but on May 22, 1948 I returned [and] found one of the richest fossil deposits I have seen. Thousands of shells, amongst them many *Carelia*, were imbedded in an outcropping of soft, dry greyish dirt and rocks."

On Kaaweiki Ridge on July 25, 1949, approximately 0.60 mile north of Polihale Ridge, Mr. Arnemann discovered another fossil deposit of *Carelia evelynae*, in association with species of other families. Except for the fact that most of these shells were smaller, no noteworthy differences are discernible to justify the application of a varietal name at the present time. The average shell resembles the smallest specimen in *evelynae* (fig. 2, *b*). One broken shell (no. 212355A) compares favorably with the largest specimen in the Polihale deposit, and a larger series from Kaaweiki may reveal others of approximate size.

Range of Measurements: Kaaweiki: 25.8 × 13.0 mm. to 35.8 × 15.8 mm., coll. nos. 212355D, 212355B. Average of 60: 30.05 × 14.18 mm. Broadest specimen 19.7 mm.; only last whorl recovered, coll. no. 212355A. Polihale: 30.4 × 14.6 mm. to 40.3 × 18.5 mm., coll. nos. 212325E, 212325A. Average of 60: 34.5 × 16.0 mm. Broadest specimen 18.7 mm., no. 212327.

Kauai, west coast Kaaweiki Ridge, July 25, 1949, Arnemann, coll. nos. 212355-212357; 69 adults plus 29 juveniles complete, plus fragments. (Arnemann coll. no. 245, 49 specimens.)

CARELIA SINCLAIRI GROUP

Carelia pilsbryi tsunami, new subspecies (fig. 3, *a-d*).

Shells of this form differ from *C. pilsbryi* in that they have more compact embryonic whorls, have spiral striations, have a more inflated appearance, have more convex whorls, and are less solid. The first three whorls of *C. pilsbryi* increase abruptly, whereas in *C. p. tsunami* the increase is less abrupt (fig. 3, *c*), also, the immediately succeeding whorl (± 3 to 3.85) is greatly inflated in most specimens, followed by a whorl less inflated (± 4 to 4.85). The spiral striations of the subspecies are pronounced in the unabraded specimens, commencing at the third whorl and disappearing at about the seventh, giving the middle area a weakly beaded appearance. Most of the specimens have a more inflated appearance than *C. pilsbryi*, owing to a wider middle portion (fig. 3, *d*) which is accentuated by the more convex whorls. The shells of the subspecies are less solid, very fragile. Not a single entire specimen was collected among the fragmentary 60 examples. In figure 3, *a-d* are shown portions of four shells.

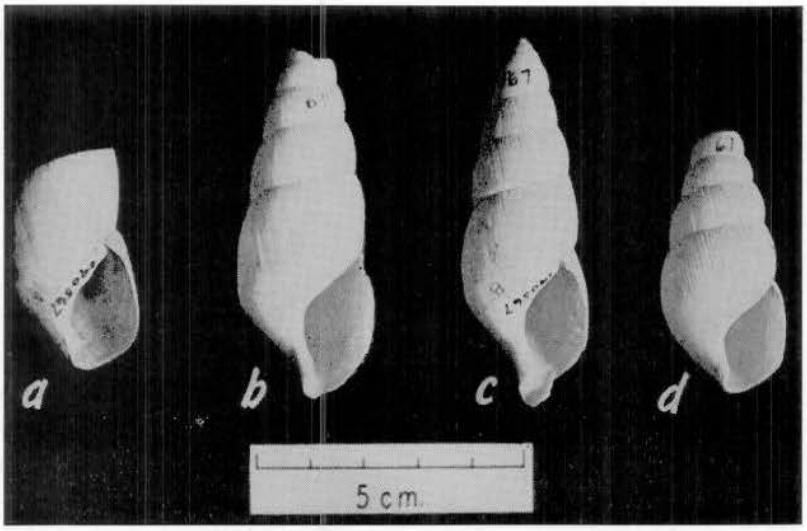

FIGURE 3.—*Carelia pilsbryi tsunami:* **a,** last whorl and complete aperture (cotype 190567A); **b,** nearly complete shell, less apex and part of last whorl (cotype 190567D); **c,** complete spire; about half of last whorl lost (cotype 190567B); **d,** specimen with characteristic spiral lines (cotype 190567C).

Kauai, Lepeuli Beach, May 15, 1946: Cotypes nos. 190567A to 190567D; paratypes no. 190567; November 20, 1946, no. 193998. All collected by Arnemann. (Arnemann's coll. nos. 67, 73, 96, 122, 150, 196, Lepeuli; 104 Kilauea; 214 Moloaa; 29 specimens.)

These fossil shells were uncovered by the far-ranging tidal waves of April 1, 1946 and are given the technical name tsunami.

It seems appropriate at this point to mention that one specimen of *C. pilsbryi* was found by Mr. Arnemann (Arnemann no. 80) at the mouth of Anini Stream (fig. 1, X) which increases the narrow range of the species by one mile westward.

CARELIA COCHLEA GROUP

Carelia dolei Ancey.

Cooke (B. P. Bishop Mus., Bull. **85:** 50, 1931) states that, except for Ancey's, Baldwin's, and Thwing's specimens—which "are probably from a fossil deposit somewhat to the east of the deposit from which the rest of the Museum's specimens were obtained . . . " —the Museum lacked, in 1931, specimens from Haena proper, which he defines (op. cit., p. 49) as "the coastal plain between the Manoa Stream and Wainiha Bay." The specimens noted above he considered to be "somewhat intermediate in character between the specimens found near Wet Cave and those from Haena treated under *C. d. isenbergi.*" This subspecies was found a few hundred yards east of the Manoa Stream by Cooke in 1914 and in 1922. These are apparently the only specimens in Bishop Museum from Haena proper. Cooke writes (op. cit., p. 53), "Undoubtedly, if additional material can be found at or near the eastern extremity of the Haena plain this should show a still further divergence from the *dolei* form." He states also that *C. d. isenbergi* occupies a position intermediate between typical *C. dolei* on the west and *C. cumingiana* on the east.

Since he started collecting on the eastern limit of Haena proper near the Wainiha River, Mr. Arnemann has uncovered well-preserved specimens of *dolei* which can only belong to the subspecies *isenbergi.* He has given 12 specimens to the Museum (coll. no. 190230), but the following discussion is based upon 142 specimens from two adjacent localities about 300 feet from each other, one in front of the school grounds close to a bluff and the second near the hotel.

The 100 specimens from the hotel location are fairly close to typical *isenbergi,* diverging occasionally toward the *dolei* form or the *cumingiana*-like forms. The longest of five extra long specimens is 58.3 × 15.7 mm.

The 42 specimens from the school location range from those which barely show the shoulder and peripheral angles to eight with exaggerated shoulder angles which may be termed pagodiform. The

weakly angled forms consist of individuals which may be classified as *isenbergi* or *dolei*.

Comparison between the shells from the two above-mentioned localities shows that for two adjacent colonies the differences are remarkable, even in coloration. The "hotel" colony consists of very dark specimens, whereas those from the "school" colony are on the light side. However, no great significance need be attached to these differences, since the species is highly variable. This divergence in the forms was predicted by Cooke in 1931, and future findings will no doubt further confirm his belief.

Seventy-one excellent specimens of *Carelia* labelled *"dolei"* in the Arnemann collection were also examined (Arnemann numbers 2, 3, 4, 11, 20, 22, 24, 31, 32, 33, 36, 38, 39, 52, 53, 53A, 118, 147, 162, 167). These were collected near the village of Haena close to the Manoa Stream. About 24 of them could be classed as *dolei*, but the remainder tend slightly toward *C. dolei isenbergi*, owing to their larger size. In other words, they are more intermediate in character. One specimen is an almost exact duplicate of the holotype (Arnemann 53A; 50.8 × 15.7 mm., aperture length=14, depth=8.0, whorls 9.5).

The differences are as follows:

Arnemann 53A	Holotype
First three whorls bicolored	not bicolored
Penultimate and ultimate whorls with submarginal white spiral band	none
Penultimate and ultimate whorls with white shoulder angle	none
All whorls nearly smooth except for fine lines on embryonic	post embryonic whorls with faint costae on fourth, fifth, sixth.

Arnemann's specimen has slightly broader whorls, and a glance will show that it is slightly larger than the holotype.

On December 12, 1933, Donald Anderson collected 225 specimens of *Carelia dolei* among the dunes east of Limahuli River. The specimens are much shorter than typical shells, ranging from 33.7 to 40.4 mm. in length, with an average of 36.9 for 20 specimens. The typical specimen somewhat resembles collection number 16063G figured by Cooke (B. P. Bishop Mus., Bull. **85,** pl. 8, fig. 2), but the shoulder angle is not as pronounced. All have weak shoulder angles, and there are no elongate members among them such as illustrated by Cooke

(op. cit., pl. 7, fig. 2). This form may eventually merit an infraspecific title.

CARELIA TURRICULA GROUP

Carelia olivacea moloaaensis, new subspecies (fig. 4, *a-f*).

Shell (fig. 4, *a*) fossil, medium-sized (smaller than *olivacea* but larger than Cooke's *o. baldwini, o. propinquella, o. priggei,* or *o. infrequens*), with fairly strong shoulder on penultimate and ultimate whorls and a peripheral angle on the ultimate, the whorls increasing rapidly and having the typical submarginal white band. Embryonic whorls broadly conical.

Base mars violet to vinaceous brown, intermediate whorls of various shades of cinnamon buff, darkening again at the apical whorls, which are bicolored. Some specimens with only base and apical whorls colored, the intermediate whorls uncolored.

First whorl smooth, next two to 2.5 whorls finely and closely striate, striae becoming heavier and more widely and irregularly spaced thereafter. At end of third or commencement of fourth, between five to eight weak spiral lirae appear which become stronger on fourth, are heaviest on fifth, where they meet the low but comparatively heavy costae to give surface of the whorl a ruffled appearance. First spiral cord is largest and each succeeding one below it generally smaller. All but first lirae disappear by gradual degrees at sixth whorl; first lira persists to last whorl forming a shoulder on this and penultimate whorl. In most specimens, eighth whorl is smooth; but some show occasional vague ripples caused by persisting costae.

Aperture (fig. 4, *b*; coll. no. 190568B) subrhombic, outer lip angled, columella curved, lamella weak. In all specimens except the one figured basal portion has been broken off.

Average of 40 specimens: 46.3 × 17.3 mm.

Holotype (fig. 4, *a*): 46+ × 17.7 mm., whorls 8.5; whorls increasing rapidly, the last the broadest; embryonic whorl broadly conic and dark; intermediate whorls light with shoulder and peripheral angle; two vertical scars on last whorl and a 1.5 × 0.5 mm. puncture between them; lip with large fractures above and below.

The typical and commonest form is represented by the holotype. Its last whorl is markedly shouldered and angled at the base. The narrow form (fig. 4, *c*; coll. no. 190568C) is also quite common; its slightly narrow last whorl is apparent without measuring (length 45.3, diameter 16.4 mm., whorls 8.3). As in any population the large form is present (fig. 4, *e*; coll. no. 193999A); this specimen measures: 53+ × 19.4 mm., whorls 8+. The longest specimen in the collection (fig. 4, *d*; coll. no. 190568D) measures: 57.5 × 19.7 mm., whorls 9, and is well-weathered and worn. The small forms are not distinguishable, because they are all damaged. These should range between 40 and 43 mm. One peculiar form (fig. 4, *f*; coll. no. 193999B) has a

very broad ultimate whorl which is sharply angled. This same form is repeated by two juveniles (coll. no. 190568F) and is remarked upon because it appears to be a mutant. In a few specimens the shoulder has two lirae, and in a few others the spiral lirae are very pronounced (coll. no. 190568G).

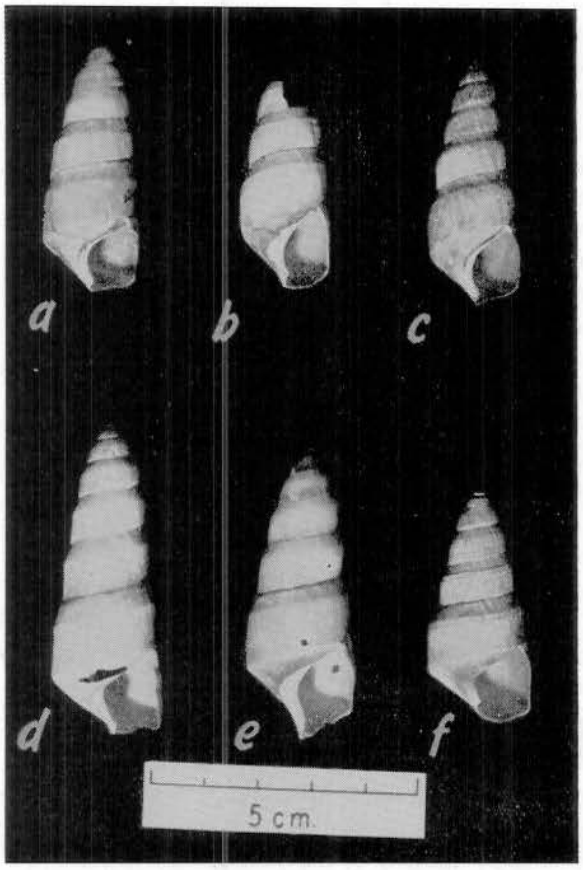

FIGURE 4.—*Carelia olivacea moloaaensis:* **a,** holotype, BBM 9091 ex 193999; **b,** nearly perfect aperture, 190568B; **c,** narrow form, 190568B; **d,** longest specimen, 190568D; **e,** large form, 193999A; **f,** strongly keeled, 193999B.

C. o. moloaaensis is probably closest to *C. o. infrequens,* a subspecies characterized by vague shoulder and peripheral angles with the last three whorls coarsely costate. *C. o. moloaaensis* is much

larger, has a broader embryonic whorl, is spirally lirate, has much more rapidly increasing whorls, and has the shoulder and peripheral angles much more pronounced.

In a large lot of shells (coll. no. 190568) were two incomplete and well-worn specimens (coll. no. 190568A) the apices and spires of which come close to those of *infrequens*. The larger specimen has coarse costae similar to those of *infrequens*, whereas the smaller one has the costae and a shoulder angle plus indications of the worn off spiral lirae. They may be the intermediate form between the two subspecies, but without more unabraded material their status must remain uncertain.

C. o. moloaaensis may also be distantly related to the unnamed new subspecies cited by Cooke (B. P. Bishop Mus., Bull. **85:** 71, pl. 13, fig. 7) in that this subspecies (coll. no. 86082) has spiral lirations. And from the close resemblance to *moloaaensis* of the lower and upper parts of two shells collected by Pilsbry and Cooke (coll. no. 118639) in 1933, these may belong to the subspecies.

The Bishop Museum has 25 lots of fossils from the following localities on the north and northeast coasts of Kauai: Kilauea, Pilaa, Lepeuli, Moloaa-Kaakaaniu region, Papaa, Aliomanu, and Anahola. Arnemann contributed 23 of these lots, one was collected by David Walker, and a small lot of three portions of shells was collected by Pilsbry and Cooke.

Kauai, Lepeuli Beach: May 15, 1946: Holotype BBM 9091; paratypes no. 190568 (288 specimens, 125 whole or nearly whole shells); no. 193999 (29 specimens), November 20, 1946. All collected by Arnemann. (Arnemann no. 121; 14 specimens.)

CARELIA PARADOXA GROUP

Carelia paradoxa waipouliensis, new geographical race.

Carelia paradoxa (Pfeiffer), Cooke, B. P. Bishop Mus., Bull. **85:** 91-92, pl. 17, figs. 1-6, 1931.

Cooke (op. cit., 89-92, pl. 18, figs. 4-6) describes and figures a typical specimen of *Carelia paradoxa* (Pfeiffer) in the Museum of Comparative Zoölogy (MCZ 45166). He also describes three unnamed races, two of which are from remnants, and a subspecies (*C. p. thaanumi* Cooke). Of the three unnamed races, one is represented by three broken portions (BBM 88457) and one by an incomplete specimen (BBM 104112). The third race is represented by several

hundred specimens, principally from Waipouli, Kauai (BBM 100173-100175, 100177-100181, and others). Because this third race is sufficiently distinct from the Museum of Comparative Zoölogy specimen and from those recently discovered by Arnemann at Moloaa, Kaakaaniu, and Lepeuli on Kauai, it seems to me appropriate to designate it as *C. p. waipouliensis,* a new geographical race.

The holotype (op. cit., pl. 17, fig. 1) is nearly perfect, except for the loss of the very edge of the peristome. The embryonic whorl is sorghum brown, the middle warm buff, the last whorl ochraceous buff, with a narrow white subperipheral band from the end of the last whorl to the lower peristome, below which is a broad russet band covering the entire base. There is a vertical repaired crack on the early part of the fifth whorl, heavy wrinkles on the seventh to ninth whorls, and 20-21 pustules per 5 mm. in the middle of the last whorl, front.

Holotype: 49.8 × 16.2; length aperture 13.0, depth aperture 8.8; whorls 9.75 (Cooke), coll. no. 100173B.

Comparative notes are recorded by Cooke on page 91 (op. cit.), and he gives the measurements of six specimens.

In the type collection the following distinguishing modifications have been made in the numbers: 100179 to 100179A (op. cit., pl. 17, fig. 3); 19442 to 19442A (op. cit., pl. 17, fig. 5).

Kauai, Olohena, northwest corner of Waipouli race track, in freshly plowed ground (C. M. Cooke, Jr., Sept. 16, 1930). Holotype 100173B, paratypes 100173A, 100173C-E, 19442A, 100179A, 100173-100175, 100177-100181.

Carelia paradoxa magnapustulata, new geographical race (fig. 5 *a-c*).

The shells of this race differ from those of *C. p. waipouliensis* and others principally in the protoconch. The first 1.5 whorls are smooth, thence weak striae appear which become stronger in the second whorl, are most pronounced in the third, and fade away on the fourth. The striae and costae do not stand out strongly as in *waipouliensis,* but look as if they were worn down by sandpapering. This impression is further strengthened by the relative smoothness of the fourth whorl and the vague pustulations of the fifth and the early part of the sixth. The fourth whorl is not as swollen as in *waipouliensis* although the tendency to swell slightly is indicated in a few specimens. In *waipouliensis,* harsh striae commence at the second whorl, become coarse and blunt on the third and fourth, and the pustulations commence on the third whorl to become strongly defined.

The above-mentioned adult differences are foreshadowed by their respective embryos. In *magnapustulata* the embryos (coll. no. 210122) are narrow with subdued striae and costae, whereas those of *waipouliensis* (coll. nos. 100173C; 100175B, 100175C, 100175E, 100175S, 100176)[3] have an inflated fourth whorl and strong striae and costae.

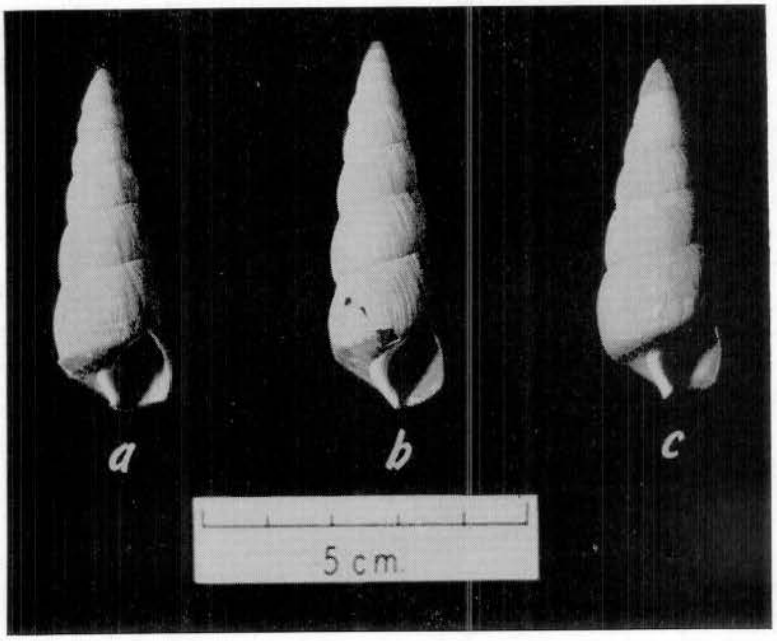

FIGURE 5.—*Carelia paradoxa magnapustulata:* **a,** holotype, BBM 9090 ex 190569; **b,** narrow form, 190569C; **c,** broad form, 190569E.

Other adult differences are: Pustules larger in *magnapustulata* (no. 190569A), 14 to 15 in 5 mm. at the last whorl opposite the aperture, whereas there are 19 to 20 in *waipouliensis* (100173E). There is no white subperipheral band, such as is present in *waipouliensis.*

Most of the specimens are perilla purple in various degrees on nearly the entire shell area, whereas the coloration in *waipouliensis* is generally confined to the base. Typically, the shell of *magnapustulata* (coll. no. 190569D) has a perilla purple base or some lighter shade of it which becomes cinnamon buff in the upper whorls irregularly, so that the lower half of the shell is predominantly dark with vaguely

[3]In embryo type collection.

defined lighter areas. The upper part is predominantly light with vague patches of dark coloration. The first 3 to 3.5 embryonic whorls generally become darker again but, when magnified, show a submarginal buff band paralleling a dark portion. Some specimens are nearly all white, except for the dark apex; others range from light buff to the typical. In some, only the base below the periphery is colored. In the living state the color is probably like that of the Museum of Comparative Zoölogy specimen, which is predominantly seal brown to dark maroon.

Samples of adults from the type locality range from 45.2 to 54.3 mm. in length and from 15.3 to 18 mm. in diameter. The average is 48.2 × 16.6 mm.

The holotype (fig. 5, *a*) is 49.2 × 16 mm., with 9.25 whorls. The base is perilla purple, the last whorl lighter, the remainder with color weathered off, but on the first two whorls the bicolored arrangement remains. The base of the aperture is broken. The last whorl is obsoletely angled; the fourth whorl not inflated.

The elongate form shown in figure 5, *b* (coll. no. 190569C) has the following measurements: length 52.6 × diameter 16.3 mm., whorls 9.5. This specimen has a nearly complete aperture.

The broad form shown in figure 5, *c* (coll. no. 190569E) measures: length 48.3 × diameter 18.0, whorls 9.25.

Kauai, Lepeuli: On beach, collected by Arnemann, May 15, 1946. Holotype BBM 9090; paratypes no. 190569 (688 specimens, of which about 260 are whole or nearly whole shells); no. 194000 (52 specimens), November 20, 1946; Arnemann no. 120 (15 specimens).

Range is from Kilauea to Anahola. About 12 lots of this geographic race have been collected in fossil beds on the northeast beaches of Kauai. Three specimens were found at Kilauea (Arnemann 85, 105, 106). Seven lots were found in the area near Moloaa Bay or northwestward at Kaakaaniu and Lepeuli (coll. nos. 190569 and 194000, 190541, 190527, 190544, 190552, 190575, and 190577, Arnemann; 190399, D. Walker). The area occupied by this geographic race is about six miles in a direct line and its southernmost colony (Aliomanu, 190581, Arnemann) is seven miles north of the Waipouli race track (*C. p. waipouliensis*).

William J. Clench of the Museum of Comparative Zoölogy kindly sent me the specimen described and figured by Cooke (MCZ 45166) for comparison with this new race. The whorl numbers and dimen-

sions are given by Cooke (B. P. Bishop Mus., Bull. **85:** 89, 90) as follows: "49.3 mm. × 17.4, length aperture 14.3, diameter 11.0; whorls 8.5." Last 0.3 whorl seal brown, lightening to dark maroon at the end of the eighth, a 12 mm. patch of claret brown from end of eighth dextrally, then dark maroon to end of seventh, thence buffy olive and light brownish olive from the fifth to apex. Pustules on back of lip 13 to 15 per 5 mm. Large vertical scar 18 mm. back of midlip.

There is a close relationship between the Museum of Comparative Zoölogy specimen and *magnapustulata* on the following points: The striae and costae of the third and fourth whorls of both have a worn appearance; the early pustules (fourth, fifth, and early sixth whorls) are vague in both; the pustules of both are relatively large (14 to 15 per 5 spiral mm. versus 19 to 20 in *waipouliensis*); and both are obsoletely angled at the periphery. The Museum of Comparative Zoölogy specimen compares well with some of the specimens of *magnapustulata* except that its apical whorls form a broad cone because of their rapid increase to the fifth whorl, which has very convex outlines. In *magnapustulata* the apical whorls are narrowly conic and there is no swollen fifth whorl.

It is possible, if a careful search is made in the area around Puu Ehu, that more specimens of the race represented by MCZ 45166 and BBM 88457 may be uncovered.

Partulina dubia perantiqua, new subspecies (fig. 6, *c*).

Shell fossil, dextral, perforate, fusiform, beautifully symmetrical, spire sharp, apex sharp. Surface with easily discernible and numerous spiral striae, the growth striae wrinkling the surface but not coarsely. White background with light cinnamon in places or throughout shell in streaks. Whorls 6.75, increasing gradually; the first 3.75 smooth, flat; the remainder slightly wrinkled with growth striae; last whorl fairly large, not inflated, tapering gradually to base. Aperture vertical, ovate; peristome with slight callus within, thin, reflexed; columella with obtuse callus; parietal wall with thin nacreous layer.

Measurements: 23.3 mm. × 11.3; axis aperture 11.5, diameter 7.4; last whorl 16.5.

Holotype: BBM 9094; type locality, Kahuku Point. Oahu, Kahuku Point: January 15, 1939, holotype BBM 9094, paratypes no. 181114 (2 specimens), C. M. Cooke, Jr.; May 25, 1924, no. 77321 (3 specimens) Cooke, C. M. Cooke III, C. A. Cooke, C. Murphy; February 11, 1924, no. 93001 (1 specimen), Cooke; November 23, 1940, no. 188769 (3 specimens), Cooke. Kahuku wireless station:

May 11, 1930, no. 98232 (2 specimens), Cooke and E. L. Cooke; December 10, 1939, no. 181117 (2 + 1 broken specimens), Cooke, C. M. Cooke III, and C. M. Cooke IV; December 2, 1933, no. 181097 (2 specimens and fragments of 2), B. Lawrence, H. Brown, and Cooke. Kahuku, in front of airfield: February 1, 1947, no. 210212 (2 broken specimens), Arnemann (Arnemann coll. no. 1567, 32 specimens). All the above specimens were dug out of limestone matrix, a part of an elevated reef. A total of 16 complete specimens has been collected during the 23-year period.

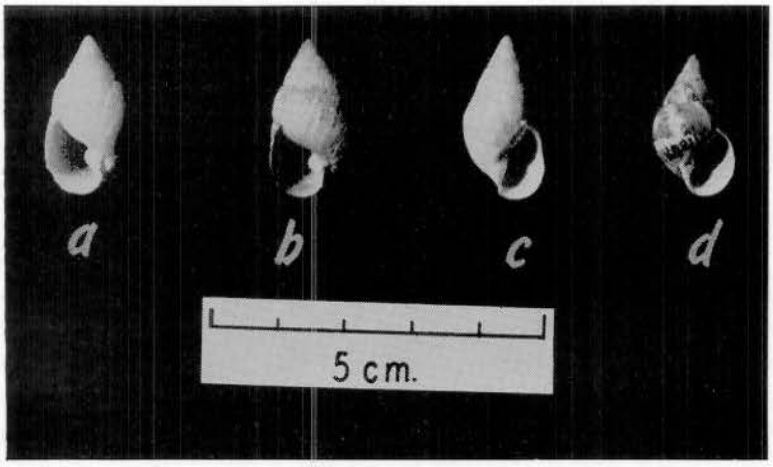

FIGURE 6.—**a,** *Partulina arnemanni,* holotype, BBM 9093 ex 210213; **b,** *Partulina redfieldii kamaloensis,* 34995A; **c,** *Partulina dubia perantiqua,* holotype, BBM 9094 ex 181114; **d,** *Partulina dubia,* 211867.

P. dubia perantiqua is so clearly distinguishable from *P. dubia* that it could be given specific rank even though the derivation of one from the other seems obvious. But in order to emphasize its close relationship with the only living species of Oahu *Partulina,* it is here given only subspecific rank. *Perantiqua* is a longer, larger, and heavier form with a straightly sharp spire, nearly flat whorls, and a more expanded body whorl which tapers symmetrically to its base. *P. dubia* (fig. 6, *d*) is a smaller, shorter, and lighter form with convex whorls, a spire not as sharp; consequently, even the embryonic whorls appear inflated when placed next to that of the subspecies. Its body whorl is not as inflated and terminates less symmetrically to its base. The two

forms have the same type of peristome, aperture, and obtuse columellar callus.

Three para-metaneanic juveniles (coll. nos. 77321, 188769, 210212) show a fairly strong peripheral angle, which is nearly lost in the paraneanic stage (coll. no 181117) and disappears by the subadult stage (coll. no. 77321). No younger stages, including embryonic, were found.

Partulina arnemanni, new species (fig. 6, *a*).

Shell fossil, sinistral, minutely perforate, ovate-conic, solid, apex acute. Surface with very fine spiral striae, most noticeable up to 3.75 whorls, thence only occasional and very weak. Color ivory yellow with aboral side cinnamon. Whorls 6.5; the first smooth, flat; the remainder roughened by coarse growth lines at irregular intervals; fourth and fifth whorls slightly convex, increasing rapidly to last, which is inflated. Aperture oblique, subovate; peristome with inner thickening, slightly reflexed (mostly worn off, small portion remaining); columella with strong flexuous fold.

Measurements: Length 22.4 mm., diameter 14.3; axis aperture 12.0, diameter 8.0; last whorl 16.7.

Holotype: BBM 9093. Type locality, Kahuku, in front of airfield. Oahu, Kahuku: In front of airfield, February 1, 1947, BBM 9093 holotype, paratypes no. 210213 (1 adult and 1 juvenile, minus tips), Arnemann (Arnemann coll. no. 1566, 7 specimens).

The shells were excavated out of limestone, as in the case of *P. dubia perantiqua. P. arnemanni* is not related to either *P. montagui* (a fossil) or to *P. d. perantiqua* (fig. 6, *c*). Some of the specimens of Molokai's *P. redfieldii kamaloensis* (coll. no. 34995A, paratypes; fig. 6, *b*) appeared to resemble the holotype of *arnemanni,* with which it is figured for comparison. Compared with the typical *P. r. kamaloensis,* the holotype is smaller, thicker, and heavier, the apex much more acute, the surface smoother, the spiral striae much weaker, and the columellar callus much weaker. In general, it is quite close to the specimen of *kamaloensis,* with which it is figured for comparison but which is far from being typical.