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A new genus and species of caridean shrimp (Crustacea: Decapoda: Bresiliidae) from hydrothermal vents on Loihi Seamount, Hawaii

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Abstract.—*Opaepele loihi,* new genus and species, is described from hydrothermal vents on Loihi Seamount, Hawaii, a mid-plate, hot-spot volcano at 18°55'N, 155°16'W, 980 m depth. This new form is related to several other bresiliid shrimps associated with hydrothermal vents, brine and hydrocarbon seeps. It has a laterally broadened triangular rostrum inconspicuously toothed on dorsal and ventral margins, carapace with pterygostomian spine present, and eyes reduced and fused mesially. This combination of characters places it in an intermediate position between a group of species in the genus *Alvinocaris* Williams & Chace with well developed compressed toothed rostrum, carapace with pterygostomian spine present, and eyes on separate movable stalks, and a group of species with rostrum absent (genus *Rimicaris* Williams) or much reduced (genus *Chorocaris* Martin & Hessler), carapace with pterygostomian spine absent, and eyestalks reduced and fused mesially. Only two of the vent/seep bresiliid species are now known from depths less than 1000 m, *A. stactophila* Williams, from hydrocarbon seeps at 534 m in the Gulf of Mexico, and the present new species at 980 m.

Most deep-sea hydrothermal systems discovered to date have been at or near tectonic plate boundaries. An exception is the system on Loihi Seamount, a mid-plate hot spot, submarine volcano located near the southern terminus of the Hawaiian Islands. The area of active hydrothermal fluid discharge is restricted to the flank of a relatively small volcanic cone on the southwest portion of the seamount approximately 10–15 m below the summit. The active field named Pele's Vents, <0.25 km^2 in area, is characterized by numerous individual vents, a few to 20 cm across, which discharge waters at temperatures as high as 37°C; ambient seawater temperature is 4°C (Karl et al. 1988, 1989). The vent fluid is exceptionally clear and nearly devoid of suspended particulate matter. Discharge velocities are 1–10 cm sec^{-1}.

Geochemical and biological evidence suggest that hydrothermal vent systems at mid-plate sites differ fundamentally from those at plate boundaries, e.g., mid-ocean ridges (Karl et al. 1988, 1989; Sedwick et al. 1992). In particular, vent waters at Pele's Vents contain extremely high amounts of total dissolved CO_2 (ca. 300 mM), more than 100 times the concentration at the Galapagos Rift vents (Edmond et al. 1987). Consequently, pH of vent waters can be as low as 4.2 (Sedwick et al. 1992). Levels of dissolved iron (ca. 1 mM) are 2×10^6 greater than ambient seawater and approximately

40 times greater than at the Galapagos Rift vents (Edmond et al. 1987). Furthermore, active vent fields on Loihi Seamount lack the luxuriant macrobenthic communities characteristic of vents at mid-ocean ridges (Grassle 1986). It is unknown whether this seemingly anomalous condition results from Loihi's geographic isolation, relatively young age, the inability of such organisms to recruit on the seamount's sediment-covered substrata, the extremely low levels of sulfide (Sedwick et al. 1992), or the potentially toxic conditions created by elevated concentrations of carbon dioxide and dissolved metals in the vent waters. Indeed, the only macrofaunal species found in Loihi's vent fields is the bresiliid shrimp described here.

Materials studied are deposited in the National Museum of Natural History, Washington, D.C. (USNM).

In the following descriptions, some anatomical structures are abbreviated as follows: mx, maxilla; mxp, maxilliped; p, pereopod; pl, pleopod. Measurements are abbreviated as: al, length of abdomen including telson; cl, carapace length, including rostrum, along dorsal midline; scl, postorbital carapace length along dorsal midline.

Description

Opaepele, new genus

Diagnosis.—Rostrum carinate; dorsal margin sweeping obliquely downward from most elevated point of carapace to tip, reaching midlength of basal article of antennular peduncle, toothless or bearing up to 6 small, subapical teeth; ventral margin toothless or bearing tiny subapical tooth; outline triangular in dorsal view, lateral margins diverging posteriorly to merge with orbital margins. Carapace with antennal and pterygostomian spines. Telson bearing 6–8 submarginal dorsal spines, convex terminal margin bearing dense row of setae and armed at either posterolateral corner with 1–3 spines. Eyestalks rather large but degenerate, broadly fused mesially, cornea unfacetted, poorly organized retinal pigment evident. Antennal scale broadly oval, blade far exceeding distolateral spine. Mandible with 2-segmented palp, distinct separation between incisor and molar processes. Mx2 with endites narrowly separated; scaphognathite rounded anteriorly, narrowed, elongate, and bearing strong setae posteriorly. Mxp1 with exopod. Mxp2 somewhat pediform but flattened, with small exopod. Mxp3 of conventional shape, distal segment trigonal in cross section, transverse tracts of fairly dense setae along lateral surface. Pereopods without exopods; p1 and p2 with merus and ischium distinct. P1 robust; chela larger than that of p2 and with long curved fingers pectinate along prehensile edges; carpus hollowed distally to receive proximal end of palm. P2 about as long as and more slender than p1. P3–5 similar, not chelate. Arthrobranchs on mxp3 and pl–4, pleurobranchs on p1–5. Pls with appendix interna simple, well developed coupling hooks only on p1 5.

Type species.—*Opaepele loihi,* new species.

Etymology.—The generic name is a construct from the Hawaiian words "opae," general term for shrimp, and "Pele," the volcano goddess. Gender feminine.

Opaepele loihi, new species
Figs. 1–3

Material studied.—Loihi Seamount, Hawaii, 18°55'N, 155°16'W, 980 m, taken in traps baited with flying fish, set and recovered by Craig Moyer in the DSRV *Pisces V*: USNM 251447, ♀ holotype; USNM 251448, ♂ allotype; USNM 251449, 6 ♂, 7 ♀, paratypes; dive #213, 28 Aug 1992. USNM 251450, 26 ♀, paratypes; dive #242, 7 Sep 1993.

Description.—Integument smooth, shining, fairly thin and pliable, inconspicuously pitted with shallow punctations and usually bearing scattered tiny setae dorsally and dorsolaterally. Carapace compressed, noticeably deeper than broad, greatest depth at about ⅔ length from tip of rostrum and

greatest width approximately at midlength between tip of rostrum and posterior dorsal margin; dorsal midline arched, or slightly sinuous in some specimens.

Rostrum well developed; as in generic diagnosis. Orbit with margin evenly rounded, ending ventrolaterally in acute buttressed suborbital angle, usually bearing small spine. Pterygostomian spine small, acute, directed anteriad. Branchiostegite with ventral margin reinforced by submarginal ridge posterior to level of coxa of third pereopod, broadly rounded posterolaterally and overlapped by pleura of first abdominal segment. Posterior submarginal groove shallow but well marked.

Abdomen evenly rounded dorsally; pleura of short segment 1 broadened and asymmetrically rounded; pleura of segment 2 greatly expanded, conspicuously overlapping segments 1 and 3; pleura of segment 3 with posterolateral corner broadly rounded but bearing 0–5 spines of irregular shape, size and dispersal; pleura of segment 4 rounded anteroventrally, nearly straight ventrally, either rounded and more strongly spined around posterolateral margin than segment 3, or produced into variably spined posterolateral angle; segment 5 with posterolateral angle strongly produced into acute spine, posterior margin above angle slightly convex, bearing up to 6 or more variable small spines; segment 6 deeply notched for insertion of uropods, posterior margin sinuous and drawn to point laterally. Sternite 1 bearing pair of rudimentary, slender, poorly sclerotized submesial spines, similar spines better developed and more widely separated on sternites 2 and 3, but again closely approximated mesially on sternite 4, strong median keel on sternite 5 drawn to stout acute posterior spine bearing against sternite 6 with abdomen flexed.

Telson with length of dorsal midline 1.4 times that of segment 6; sides moderately convergent; dorsal surface with very slight suggestion of median longitudinal concavity and with submarginal row of 6–8 spines (sometimes asymmetrical) at either side along distal ⅔ of length, continued as 1–3 spines at either end of convex terminal margin bearing dense row of setae.

Eyestalks as in generic diagnosis; smooth base of obsolescent spine or tubercle evident on anterior surface of each eye near rostral margin.

Antennular and antennal peduncles well developed. Antennular peduncles stout, dorsoventrally flattened but slightly convex on dorsal side, mesial margins closely parallel; proportional length of articles from base to tip about 3.5:2.2:1; basal article with distal width nearly half its length, article 2 slightly narrower than its length, and article 3 shorter than its width. Stylocerite very strong, swollen ventrally along its middle portion but tapering to very slender point reaching to or beyond midlength of middle article. Basal article with strong distolateral spine extending as much as ¼ length of middle article, mesiodistal spine smaller, transverse fringe of setae across distodorsal margin. Second article with mesial spine stronger than corresponding spine of basal article. Flagella strong, subequal in length, inserted side by side on oblique terminal margin of distal article, lateral ramus with annuli much coarser than those on mesial ramus, and with prominent sensory setae at joints between annuli.

Antennal peduncle (Fig. 1) shorter than that of antennule, exceeded by broadly oval antennal scale almost twice as long as wide, convex lateral margin ending in short stout spine considerably exceeded by blade fringed with plumose setae, blade reinforced by oblique median ridge originating basally; flagellum similar in structure to those of antennules in their distal parts but larger in all dimensions, sweeping to tip reaching level of tail fan, scattered inconspicuous sensory setae at joints between annuli.

Gills as described for genus *Rimicaris* (Williams & Rona 1986) and cited for *Chorocaris* by Martin & Hessler (1990).

Mouthparts as figured (Fig. 3).

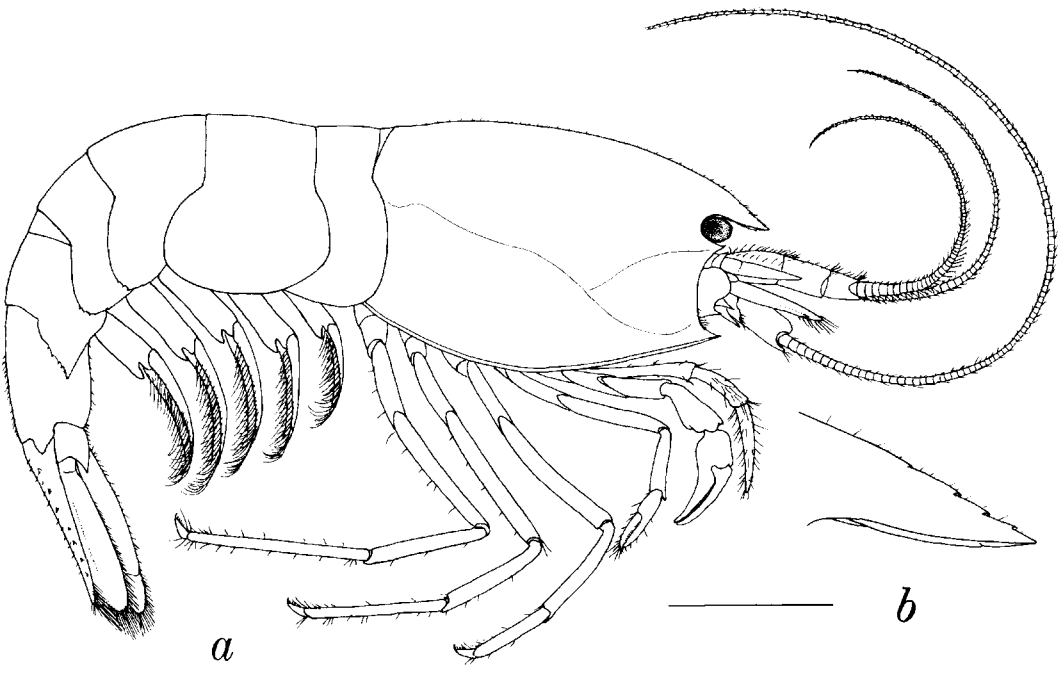

Fig 1. *Opaepele loihi*, new genus and species. Female holotype: *a*, lateral view, scale = 5 mm; *b*, rostrum enlarged.

Mx2 with proximal endite composed of 2 straplike lobes, distal endite subtriangular, elongate and flanked laterally by slightly curved straplike palp; scaphognathite greatly expanded, anterior subovate lobe with densely setose margin bearing longest setae along distomesial sector, stout posterior subtriangular lobe fringed on distomesial margin with long strong somewhat tangled and stiffened setae.

Mxp1 with prominent 2-lobed endite; palp rather stout, bearing terminal and subterminal tufts of setae; exopod symmetrically rounded and setose distally; large epipod foliaceous, bilobed.

P1 rather stout, reaching (if extended) beyond antennal peduncle by at least length of fingers but normally folded on itself at mero-carpal joint at right angle or diagonal to axis of leg, with chela and carpus oriented toward midline. Outline of chela shaped like "bird-head with bent beak" (flamingo-like); palm inflated and smooth. Fingers curved and closing without gape; flexor surfaces concave; extensor surfaces of each finger convex, opposed edges uniformly offset, each armed with row of almost uniform, minute, erect, closely set setae; acute tip of each finger slightly spooned by curved setal row, that of dactylus with elongate teeth slanting distad and curving around its distal end; line of curved sensory setae mesial to each cutting edge; dactyl broadened at base for articulation with palm but uniformly narrowed throughout most of length to about ⅓ width of fixed finger. Carpus inflated, irregularly funnel-shaped, extensor surface bent almost at right angle near tapered proximal end articulating with merus, distal margin irregularly flared, cupped to conform with shape of palm in flexed or extended position, strong tooth on flexor surface with patch of setae on its external surface. Merus club-shaped but somewhat flattened, submarginally concave along flexor surface for reception of flexed carpus.

P2 slightly more slender than other legs, extending to near distal end of antennal pe-

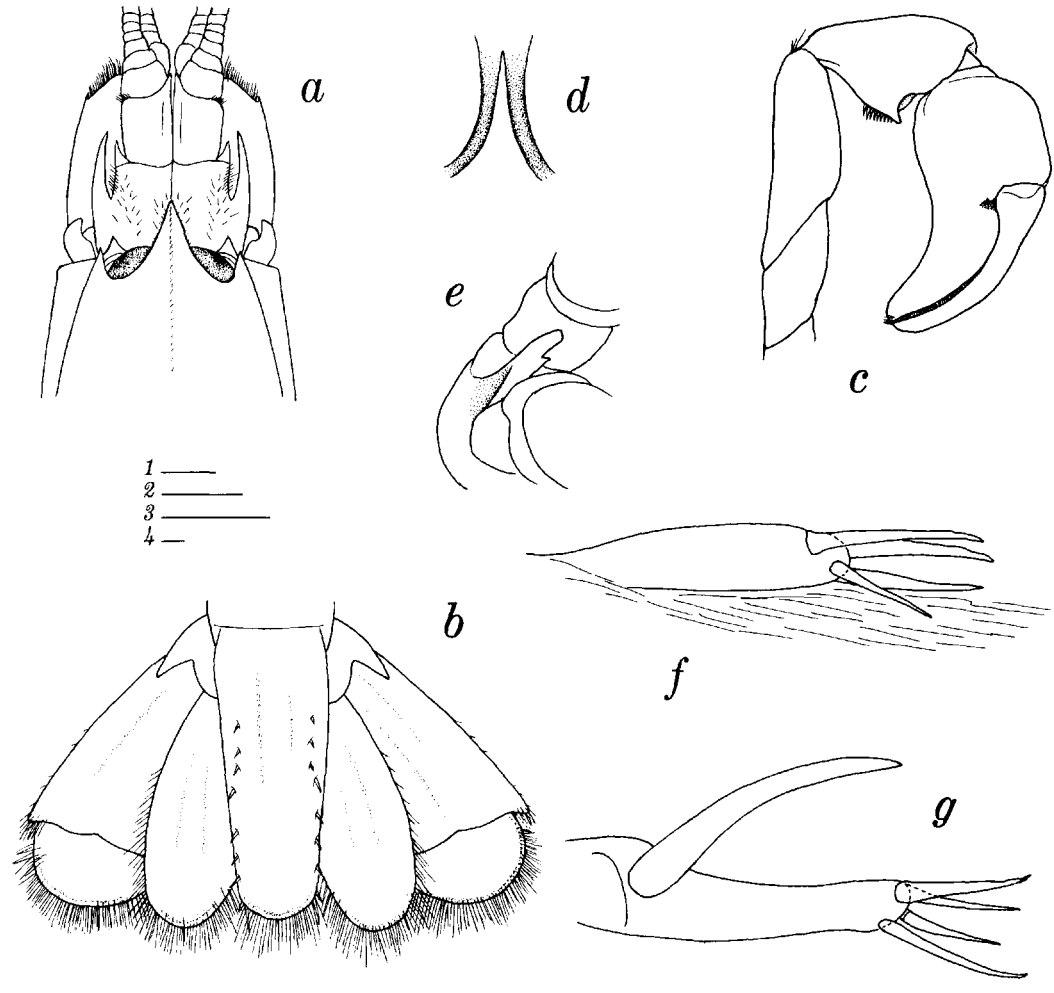

Fig. 2. *Opaepele loihi*, new genus and species. Female holotype: *a*, anterior region (dorsal view); *b*, telson and uropods (dorsal view); *c*, right first pereopod. Paratype female: spine between coxae of fifth pereopods, *d*, ventral view, *e*, oblique lateral view, left side. Paratype male: appendix masculina, *f* lateral, *g*, mesial. Scales: 1 (*a–b*); 2 (*c*); 3 (*d–e*) = 1.0 mm; 4 (*f–g*) = 0.1 mm.

duncle; chela and carpus about equal in length; fingers, slightly longer than palm, similar in size and shape, opposed edges without gape, each pectinate with single row of short spines directed obliquely distad and increasing slightly in size to end in noticeably stronger terminal spine crossing opposite member when closed.

P3–5 similar in structure but increasing in relative length from p3 to p5, p3 reaching well beyond tip of antennal peduncle by full length of propodus and dactylus; dactylus of each essentially equal in length and armed with 6 strong curved spines on flexor surface, distalmost strongest; propodi increasing in length from p3 to p5, that of p5 twice length that of p3, that of p4 intermediate in length, each armed with setae scattered along flexor surface, mainly on distal ½ and most dense on distal ⅓, prominent slender setae along extensor surface most prominent distally and in dense distal tuft; respective length of carpi, meri and ischia on p3, p4, p5 respectively similar in length, carpi dis-

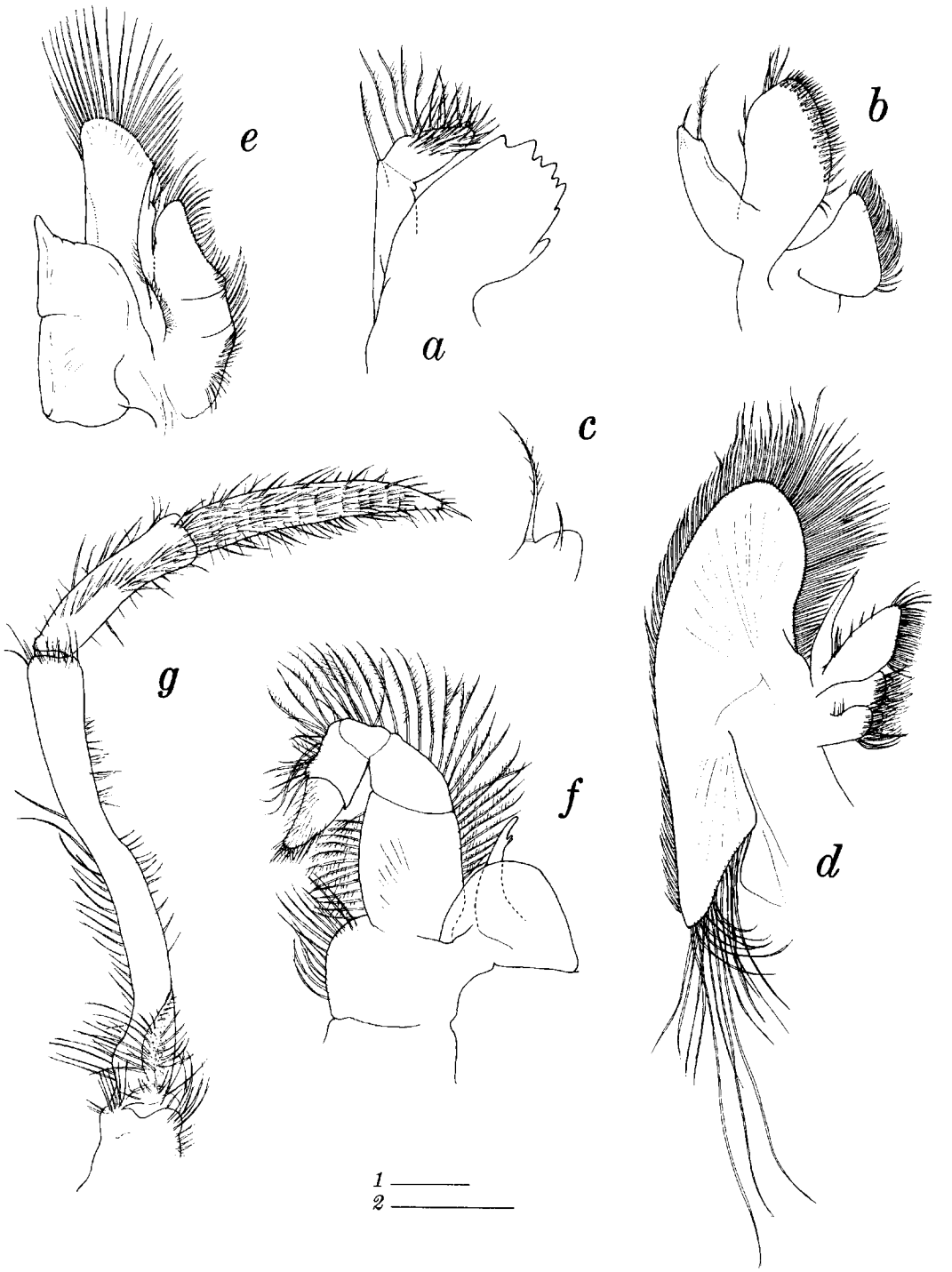

Fig. 3. *Opaepele loihi*, new genus and species, female paratype: *a*, right mandible; *b*, right first maxilla; *c*, same, tip of palp, internal view; *d*, right second maxilla; *e*, right first maxilliped (ventral view); *f*, right second maxilliped; *g*, third maxilliped, mesial oblique view. Scales: 1 (*d–g*); 2 (*a–c*) = 1 mm.

tally extended in dorsal "stop" overhanging base of propodi to prevent hyperextension.

Posterior thoracic somite (XIV) with portion of sternite posterior to base of fifth coxae smooth, slightly inclined anteriorly toward base of fifth coxae and shallowly concave mesially, that portion of sternite lying posteromesial to each fifth coxa drawn mesially from each side into flattened, weakly calcified median process, tapered, distally subtruncate, and bearing small acute spur anteriorly near base; process often obscured by appressed fifth coxae.

Pls 2–5 with appendix interna on mesial ramus slightly increasing in size from anterior to posterior in series, well developed coupling hooks only on appendix of pl 5. Small appendix masulina on mesial ramus of pl 2 in males bearing 4 terminal setae.

Uropods with both rami elongate oval, subequal in length, exceeding distal end of telson, outer ramus wider than inner ramus, with sinuous diaresis and movable spine beneath rather broad, asymmetrically acuminate distolateral tooth.

Measurements in mm.—Holotype ♀, cl 11.5, scl 10.1, al 21.8; allotype ♂, cl 13.6, scl 11.9, al 21.8; paratype ♀ 251450, cl 13.1, scl 11.3, al 23.0; paratype ♂ 251449, cl 7.9, scl 6.7, al 13.8.

Paratypes ♀, $n = 26$, scl 9.1–12.0, $\bar{X} = 10.3$. Paratypes ♂ that can be measured, n = 4 scl 6.8–9.3, $\bar{X} = 6.5$.

Color.—Color when collected, intensely orange (astaxanthin pigment). All preserved specimens examined basically white but variously mottled with deciduous orange to yellowish deposit, densest and most intense on segments of abdomen and tail fan, antennular and antennal peduncles, and proximal segments of their flagella, and as bands on pereopods, especially on carpi and adjacent portions of meri and propodi. This deposit is an accumulation of the iron oxyhydroxide particles that cover the summit of the seamount. Some of the particles are formed inorganically; others originate from the mat created by the growth and metabolism of iron-oxidizing bacteria (Karl et al. 1989, color figs.).

Etymology.—The specific name, a noun in apposition, refers to the seamount from which the species was collected.

Remarks.—Holthuis (1993) gave an ample discussion of the family makeup of the infraorder Caridea, with particular attention to recent treatments of family realignments within the group. Among the latter was recognition by Christoffersen (1989) of a dichotomy among the Bresiliidae that in his view justified elevation of one of these clusters to family status, the Alvinocarididae, which appear to be associated only with hydrothermal vents, cold brine and hydrocarbon seeps (Segonzac et al. 1993). The latter authors, in their exhaustive examination of trophic behavior, accepted this subdivision, acknowledging that many features of the group are similar to those of the genus *Bresilia* but noting absence of exopodites on thoracic appendages posterior to the maxillipeds and reduced eyestalks more or less attached to each other and adjacent regions. However, appealing, the action leaves the thus diminished Bresiliidae as a less unified group than is the family in its undivided state. Since neither of these choices is entirely satisfactory, we accept the more conservative approach of Holthuis (1993), following Chace (1992), in retaining the Bresiliidae as a unified though somewhat disparate assemblage.

Among species of bresiliids associated with hydrothermal vents and cold brine or hydrocarbon seeps are some shared morphological characters, but other features cut across these seemingly neat clusters in contrasting manners. *Opaepele loihi* is immediately recognizable as one of these bresiliids by virtue of the characteristic chelipeds shared by all members of the group. Within the group this species seems to occupy an intermediate position between those having a carinate carapace with well developed rostrum that reaches at least to mid-length of the antennal peduncle and antennal scale

(including *Alvinocaris lusca* Williams & Chace, 1982, and *A. markensis, A. muricola, A. stactophila* Williams, 1988), and those in which the carapace is not carinate and the rostrum is absent (including *Rimicaris exoculata* Williams & Rona, 1986), or greatly reduced in length (including *Chorocaris chacei* (Williams & Rona, 1986) and *C. vandoverae* Martin & Hessler, 1990). Moreover, the rostral teeth of *O. loihi* are much smaller and less numerous than in species that have a long rostrum. Viewed dorsally, the lateral rostral margins of *O. loihi* are triangular in outline and merge imperceptibly with the orbital margins, but the rostrum of *C. vandoverae,* broadly oval in dorsal view, has margins that join each orbital margin at the site of an orbital prominence.

The anterior margins of the carapace in the sharply rostrate species bear antennal and pterygostomian spines, as does *O. loihi*; this set of species shares spinose margins on the posterolateral corners of the fourth and fifth abdominal segments. Those species with short rostrum or no rostrum lack these spines. It thus appears that there are two groups of species that have contrastingly spinose or non-spinose sectors on both carapace and abdomen, but this neat cleavage is compromised by other morphological features.

Alvinocaris lusca has a telson with sometimes sinuous terminal margin. This margin is convex in other species of the genus, though general breadth of the telson is much greater in *R. exoculata, C. chacei* and *C. vandoverae.*

The scaphognathite of Mx2 has a greatly expanded or anteriorly subtruncate anterior lobe in *Alvinocaris, Rimicaris* and *Chorocaris* species, whereas this element is more rounded and relatively narrower in *O. loihi.*

The relatively broad dactyls of P3–5 in *Chorocaris* species bear both marginal and plantar rows of setae on the flexor surface whereas those dactyls of the sharp spined *Alvinocaris* species have only a single row of spines on the flexor surface; between these two extremes, *R. exoculata* exhibits only marginal rows of spines on the flexor surface of its comparable rather broad dactyls.

P12–5 of *Rimicaris* and *Chorocaris* species bear obvious coupling hooks on the appendix internae of the inner ramus; *Alvinocaris* species apparently do not bear such hooks, and *Opaepele loihi* has them well developed only on the appendix internae of p5.

A feature possessed by all species discussed above that has not been emphasized in published descriptions is the process on thoracic sternite 5 (somite XIV) lodged between the coxae of p5. This process is much more prominent in *O. loihi* than among other genera and species in the family. There is considerable variety in development of the process, and to our knowledge only in *O. loihi* does it bear a small acute spur anteriorly near its base. The process is present on both males and females. Its function is unknown.

Bresiliid shrimps associated with hydrothermal vents, brine and hydrocarbon seeps are known from depths as great as 3660 m (Martin & Hessler 1990). Only two of these species are reported from depths less than 1000 m, *A. stactophila* from hydrocarbon seeps at 534 m in the Gulf of Mexico (Williams 1988), and the present species at 980 m.

A key to the 12 currently accepted genera of the family Bresiliidae, modified to accommodate *Opaepele* new genus, is adapted from the key given by Holthuis (1993).

1. Eyes with distinct dorsal spine on peduncle, overreaching base of cornea. Dactyl of first pereopod longer than fixed finger and with single large tooth on basal part of cutting edge ..... *Encantada*
– Eyes without spine on peduncle. Dactyl of first pereopod, if longer than fixed finger, without single large tooth on cutting edge. 2

2. Exopods on first two pairs of pereopods at most. Telson with three or more dorsolateral spines. First pereopod with ischium and merus distinct 3
– Exopods on all five pairs of pereopods. Telson with three or fewer dorsolateral spines. First pereopod with ischium and merus fused .. 8
3. First two pairs of pereopods with exopods 4
– None of pereopods with exopods 5
4. Articulation of palm and carpus of first pereopod normal, proximal end of palm articulated with distal end of carpus. Pleurobranch at base of fifth pereopod reduced. Arthrobranchs absent ..... *Bresilia*
– Carpus of first pereopod articulating with chela at middle of propodus below base of dactyl, so that larger posterior part of propodus projects beyond this articulation. Pleurobranchs associated with all five pereopods. Arthrobranchs present at base of all pereopods, but that of pereopod 5 reduced ..... *Agostocaris*
5. Carapace with well developed rostrum bearing dorsal teeth and at least 1 ventral tooth (may be minute). Pterygostomian spine present. Eyes on separate movable stalks variously fused mesially .. 6
– Carapace with rostrum absent or visible as depressed angle of frontal margin, without any teeth. Pterygostomian spine absent. Eyes reduced, fused mesially 7
6. Carapace with compressed rostrum, dorsal and ventral teeth clearly evident. Eyes on separate movable stalks narrowly fused mesially at base ..... *Alvinocaris*
– Carapace with rostrum broadly triangular in dorsal view, dorsal teeth and ventral tooth minute (sometimes absent). Eyes on separate movable stalks rather broadly fused mesially ..... *Opaepele*
7. Carapace inflated, rostrum absent, frontal margin of carapace concave. Stylocerite, scaphocerite and antennular peduncle fitting tightly and forming an operculiform structure. Third maxilliped with 4 long and 2 short articles. .. *Rimicaris*
– Carapace not inflated, rostrum present, broadly rounded anteriorly. Antennules and antennae not forming an operculum. Third maxilliped with 3 long and 2 short articles ..... *Chorocaris*
8. Antennal scale narrowing distally, blade not overreaching distolateral tooth. Mandible without deep division between incisor and molar processes 9
– Antennal scale broad distally, blade overreaching distolateral tooth. Mandible with moderate to deep division between incisor and molar processes 10
9. Mandible with palp. Last three pereopods pseudochelate, i.e., dactyl opposing distal spine of propodus, forming structure somewhat resembling a chela. Carapace without pterygostomian spine ..... *Pseudocheles*
– Mandible without palp. Last three pereopods normal, not pseudochelate, no long distal spines on propodus. Carapace with pterygostomian spine present ..... *Kirnasia*
10. Rostrum reaching to end of antennular peduncle. Third abdominal somite forming gibbous cap over base of fourth somite. Third maxilliped with terminal article obliquely truncate distally. Dactyl of first pereopod not semicircular ..... *Lucaya*
– Rostrum not reaching to end of antennular peduncle. Third abdominal somite not forming gibbous cap over base of fourth somite.

Terminal article of third maxilliped lanceolate. Dactyl of first pereopod semicircular 11

11. Carapace with supraorbital and branchiostegal spines present. Exopods on pereopods 1 to 3. Telson with 5 lateral and 5 distal spines ..... *Tridiscias*

– Carapace without supraorbital and branchiostegal spines. Exopods on all pereopods. Telson with 2 or 3 lateral and 3 posterior spines .. *Discias*

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