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New Cretaceous and Tertiary decapod crustaceans from western North America

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Abstract

Several new decapod crustaceans have been recovered from Cretaceous and Tertiary rocks of western North America. New species include *Palaeastacus trisulcatus*, *Glyphea micheleae*, *Hoploparia tshudyi*, *Ctenocheles hokoensis*, *Callianopsis*? *inornatus*, *Palaeopentacheles? starri*, *Eucorystes platys*, *Archaeopus lunicarina*, *Brecanclawu rathbunae* gen. nov. and sp. nov., *Pagurus malloryi*, *Paguristes hokoensis*. One new combination has resulted from this work, *Paguristes subaequalis* comb. nov. (Rathbun, 1926). Family level diagnostic characters of the chelae are given for each paguroid family; chelae are the only portion of paguroid decapods commonly preserved in the fossil record. *Palaeopentacheles* and *Eucorystes* appear to have had north polar distributions, and *Glyphea* and *Palaeastacus* have bipolar or amphitropical distributions, corroborating the patterns observed by Schweitzer (2001) for Cretaceous and Tertiary decapods of the North Pacific rim.

Key words: Cretaceous, Cenozoic, Decapoda, North America

Introduction

The history of study of fossil decapod crustaceans on the west coast of North America has been disjunct. Several studies in the latter part of the 19th Century and the early 20th Century resulted in the recognition of fossil decapods in the area and the description of several new species. This phase of study culminated in publication of *The Fossil Stalk-eyed Crustacea of the Pacific Slope of North America* (Rathbun, 1926). In that work, 91 species, 54 or which were new, were described from rocks ranging from Cretaceous to Pleistocene (Rathbun, 1926, p. 2). In the subsequent 60 years very little was added to our understanding of the decapods of this region. The second pulse of activity began about 15 years ago, largely in response to the intense collecting activity of non-professional collectors in the states of Washington and Oregon. Their skill in collecting and meticulous record of geological and geographical data produced a massive collection of new and previously described species. Through their generosity, much of that material was made available to us for study. Their collections were supplemented by those of geologists working in Alaska, often under the auspices of the U. S. Geological Survey or petroleum companies. Numerous papers, cited in the work to follow, have resulted from the study of this material. Many of these recent publications have been directed at description of new taxa and revision of family-level taxa. Others have been synthetic works in which patterns of biogeographic distribution have been elucidated and major extensions of geographic and geologic ranges have been described.

Inevitably, certain specimens sent to us for study over the years have not “fit” into any of the groups under study. Therefore, it is the purpose of this work to describe those taxa and to interpret their biogeographic and stratigraphic patterns. The fossils range in age from Cretaceous through Oligocene and were collected from Southern California to Alaska, U. S. A. The material includes macrurans, anomurans, and brachyurans, many of which have not been recorded previously from the area. Because the

majority of recent studies have focused on Cenozoic occurrences, the Cretaceous records are of particular note.

Systematic Paleontology

Order Decapoda Latreille, 1802
Infraorder Astacidea Latreille, 1802
Superfamily Erymoidea Van Straelen, 1924 [1925]
Family Erymidae Van Straelen, 1924 [1925]

Genus *Palaeastacus* Bell, 1850

Type species: *Astacus sussexiensis* Mantell, 1833.

Other species: *Palaeastacus*? *decorat* (Frentzen *in* Frentzen and Hoffmann, 1937) ; *P. edwardsi* Etallon, 1861 ; *P. falsani* (Dumortier, 1867) ; *P. foersteri* Taylor, 1979 ; *P. fuciformis* (Schlotheim, 1822) ; *P. kimzeyi* Rathbun, 1935 ; *P. scaber* (Bell, 1863) ; *P. spinosus* (Etallon, 1861) ; *P. terraereginae* (Etheridge, Jr., 1914) ; *P. triglyptus* (Stenzel, 1945) ; *P. triculcata* sp. nov.

Discussion: Enough of the anatomy of the sole specimen under consideration here is available to assign it to *Palaeastacus* with reasonable assurance. The carapace is cylindrical, is ornamented by moderately coarse granules, exhibits a well-developed dorsal suture, and is crossed by cervical, postcervical, and branchiocardiac grooves, the latter two of which are parallel to one another and cross the midline. There is no evidence of a dorsal intercalated plate ; however, the dorsal part of the carapace is preserved in such a way as to preclude observing the plate. The dorsal suture has been ruptured and the right side of the carapace is thrust over the left side. In addition, the cuticle of the fossil has been altered to a blue-black, vitreous, brittle material exhibiting conchoidal fracture. The anterior of the specimen is sufficiently damaged, and the cuticular material is shattered enough, that it would be virtually impossible to observe the intercalated plate.

Members of *Palaeastacus* are most commonly confused with those of *Eryma* von Meyer, 1840, and *Enoploclytia* McCoy, 1849 ; however, there are sufficient points of distinction to eliminate these two genera from consideration. Glaessner (1969) considered *Palaeastacus* to be a subgenus of *Enoploclytia* and observed that some species of *Enoploclytia* were difficult to distinguish from those of *Eryma*. However, Förster (1966) provided compelling evidence to support separating the three taxa into distinct genera. *Eryma* spp. have more subdued carapace ornamentation. The postcervical and branchiocardiac grooves are closely spaced, may nearly merge ventrally, and do not extend to the dorsum. Species of *Enoploclytia* tend to have very coarse carapace ornamentation as well as postcervical and branchiocardiac grooves that are closely spaced and do not extend ventrally below mid-height of the carapace. *Palaeastacus* has carapace ornamentation that is less coarse and is often confined to the dorsal part of the carapace as well as longer postcervical and branchiocardiac grooves that typically extend below the midline.

Species of *Palaeastacus* have been described from rocks ranging in age from Early Jurassic to Late Cretaceous (Campanian) and in localities in Europe, United States (Texas), Australia, and Antarctica. The earliest occurrence is in Europe and the latest occurrence is in the United States. No species are known from low latitudes so that the distributional pattern is amphitropical.

Palaeastacus trisulcatus sp. nov.
(Figs. 1, 2)

Material: The holotype and sole specimen, USNM 512150, is deposited in the United States National Museum of Natural History, Smithsonian Institution, Washington, D.C.

Etymology: The trivial name is derived from the Latin words, "*tres*", meaning three, and "*sulcus*", meaning furrowed or grooved, alluding to the observation that the three carapace grooves are equally well-developed.

Diagnosis: Carapace elongate, cylindrical; cervical, postcervical, and branchiocardiac grooves equally well-developed, nearly parallel to one another, extend to midline; abdominal terga smooth.

Description: Carapace elongate, cylindrical, smoothly inflated between carapace grooves. Front, ventral, and posterior margins of carapace not visible. Cephalic region with row of four postorbital spines and two suborbital spines. Base of rostrum narrow, upturned slightly. Rostrum may be about 20 percent carapace length, excluding rostrum. Cervical, postcervical, and branchiocardiac grooves nearly parallel to one another. Cervical and postcervical grooves broad, deep, well-defined. Cervical groove approaches midline at 52 degree angle; postcervical groove approaches midline at 46 degree angle. Branchiocardiac groove distinct but less deeply impressed than cervical and postcervical; approaches midline at 46 degree angle. Dorsal suture apparently well-developed. Entire cephalothorax covered by broadly-spaced moderate-sized granules.

Abdominal terga smooth, separated from pleura by broad, swollen ridge extending between points of articulation. Pleura smooth overall, with single small spine near anterior margin at midheight. Terminations of pleura sharply pointed, directed posteroventrally, becoming broader posteriorly.

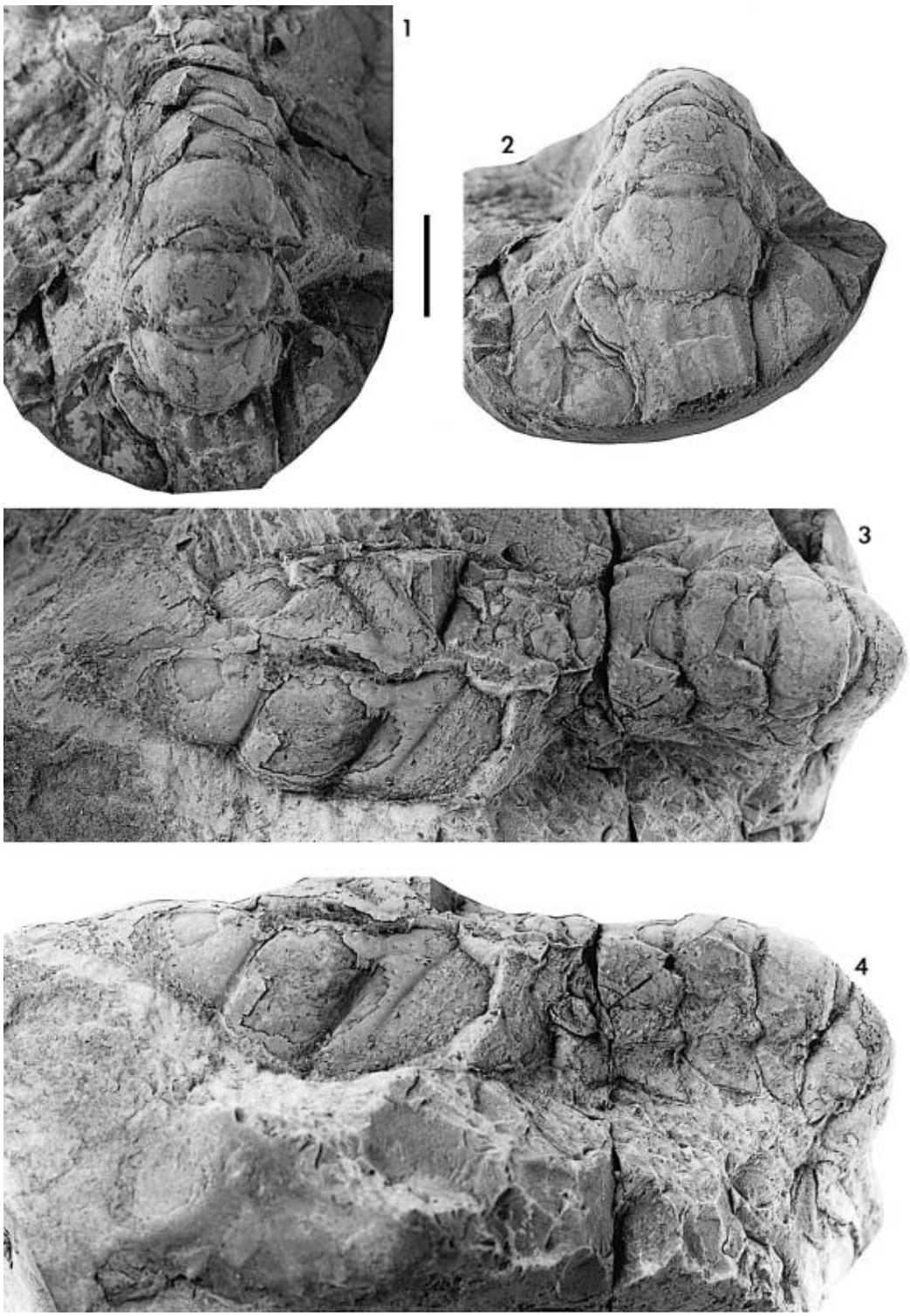


Fig. 1. *Palaeastacus trisulcatus* sp. nov., holotype, USNM 512151. 1, dorsal view of abdominal somites. 2, posterior view of telson and uropods. 3, dorsal view of carapace and abdomen. 4, left lateral view of carapace and abdomen. Scale bar equals 1 cm.

Telson tapering distally, straight-sided; bearing two contiguous axial ridges and one lateral ridge on each side defining flattened surface bounded by steeply sloping sides. Uropods with longitudinal keels on endopod and exopod. Exopods broken at presumed position of diaresis.

Measurements: Measurements taken on the sole specimen are given in Fig. 2.

Discussion: Several species of *Palaeastacus* have previously been recognized in North America. Each is recognizably different from *P. trisulcatus*. Whitfield *in* White (1880) named *Paramithrax*? *walkeri* and the species was subsequently (Rathbun, 1935, p. 21) referred to *Palaeastacus* and then (Stenzel, 1945, p. 416) to *Enoploclytia*. Rathbun noted that the type specimen had been lost but that a cast of the type is housed in the U. S. National Museum of Natural History. She observed two carapace grooves which she identified as the cervical and branchiocardiac grooves; however, examination of her illustration of the plaster cast (1935, pl. 4, figs. 1-2) strongly suggests that the posteriormost obvious groove is the postcervical groove and that there is a reduced branchiocardiac groove that is short and only slightly impressed below the carapace surface. Based upon examination of a carapace discovered in the area of Fort Worth, Texas, and the plaster cast, Stenzel confirmed the existence of just two grooves. It would seem that this species cannot be referred to *Palaeastacus*, which always has three well-developed carapace grooves, but that it might be related to *Phlyctisoma* Bell, 1863, which does have a greatly reduced branchiocardiac groove.

Rathbun (1935, p. 23) named *Palaeastacus kimzeyi*, but not enough material is available to make an accurate comparison. The type description is confined to characters of the chelae although Rathbun illustrated (1935, pl. 12, fig. 15) a part of a carapace with three transverse grooves. Thus, her material might be assignable to *Palaeastacus*, but it is not adequate for comparison. Rathbun (1935, p. 24) also described *P. selmaensis*. This species, based upon a single portion of a manus, cannot be compared to *P. trisulcatus* and may not be related to the genus.

Stenzel (1945, p. 415) named *Enoploclytia triglypta* based upon parts of two carapaces and a cheliped. The specimen has since been referred to *Palaeastacus* by Förster (1966, p. 135). Stenzel's material is much more coarsely ornamented in the cephalic and thoracic regions than is *P. trisulcatus*, and has a stronger branchiocardiac groove than postcervical groove. The postcervical groove is strongly curved and does not parallel the branchiocardiac groove. These features readily distinguish *P. triglypta* from *P. trisulcatus*.

In general, species within the genus can be distinguished from one another on the basis of conformation of the three carapace grooves and the degree of development of carapace ornamentation. One important distinguishing feature of *Palaeastacus trisulcatus* is that the three grooves are nearly parallel to one another; there is only a 6 degree difference between the angle at which the cervical groove approaches the midline (52 degrees) and that at which the postcervical and branchiocardiac groove approach the midline (46 degrees). The difference between comparable angles in specimens illustrated by Förster (1966) is 15-17 degrees. In addition, the postcervical and branchiocardiac grooves are straighter and more deeply impressed in *P. trisulcatus* than in other species.

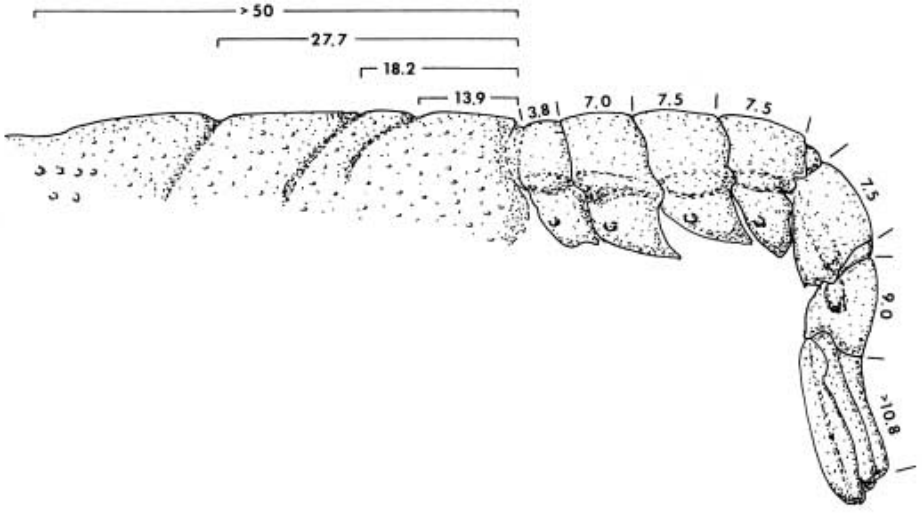


Fig. 2. Line drawing of *Palaeastacus trisulcatus* sp. nov., showing the position and values of measurements taken (mm).

Finally, the carapace ornamentation as well as the ornamentation on the abdomen is more subdued on the new species than on other known species within the genus.

Occurrence: The type specimen was collected on a ridge 6.5 km northeast of Sites, California, about 1.6 km west from the Old Peterson Ranch house, in a unit of gray shale with sideritic nodules between two prominent sandstones that form waterfalls, NE1/4, NE1/4, NE1/4 sec. 5, T17N, R4W, Sites 7.5' Quadrangle, Colusa County, California, by G. J. Retallack, from the Cenomanian (Late Cretaceous) Antelope Shale.

Superfamily Glypheoidea Winckler, 1883
Family Glypheidae Winckler, 1883

Genus *Glyphea* von Meyer, 1835

Type species: *Palinurus regleyanus* Desmarest, 1822, by original designation.

Included species: *Glyphea arborinsularis* Etheridge Jr., 1917; *G. bathonica* de Ferry, 1865*; *G. bohemica* Fritsch, 1887*; *G. calloviensis* H. Woods, 1927; *G. carteri* Bell, 1863; *G. christeyi* Feldmann and Maxwell, 1999; *G. crassa* Oppel, 1861*; *G. cretacea* McCoy, 1854; *G. gussmanni* Schütze, 1907*; *G. jeletzkyi* Feldmann and McPherson, 1980; *G. liasina* von Meyer, 1840*; *G. lyrica* Blake, 1876; *G. munsteri* (Voltz, 1835)*; *G. oculata* J. Woods, 1957; *G. prestwichi* H. Woods, 1929; *G. pseudoscyllarus* (Schlotheim, 1822)*; *G. regleyana* (Desmarest, 1822); *G. reticulata* Feldmann and Gaździcki, 1997; *G. robusta* Feldmann and McPherson, 1980; *G. rostrata* (Phillips, 1829); *G. squamosa* (Münster, 1839)*; G. *tomesi* Woodward, 1868; *G. udressieri* von Meyer, 1840; *G. vectensis* H. Woods, 1927; *G. willetti* (Woodward, 1878). Those taxa denoted by an asterisk (*) were taken from Glaessner (1929) and have not been verified.

Discussion: *Glyphea* spp. have a bipolar or, perhaps, amphitropical distribution, having been described from Antarctica (Taylor, 1979; Feldmann et al., 1993), New Zealand (Feldmann and Maxwell, 1999), Australia (J. T. Woods, 1957), Europe (H. Woods, 1927; 1929, for example), and North America (Feldmann and McPherson, 1980). None is known from low latitudes. They range in age from the Jurassic to Eocene with certainty (Glaessner, 1969; Feldmann and Maxwell, 1999), and may also occur in the Late Triassic (Glaessner, 1969). However, prior to this notice, only two species have been described from North America; *G. robusta* Feldmann and McPherson, 1980, from the Middle Jurassic of Arctic Canada, and *G. jeletzki* Feldmann and McPherson, 1980, from the Early Cretaceous of Arctic Canada. Therefore, description of this new species from the Eocene of Washington state extends both the geographic and stratigraphic record in North America.

Glyphea micheleae sp. nov.
(Figs. 3, 4)

Material: The holotype, USNM 512151, consists of a carapace with the anterior portion not preserved. Eight paratypes, USNM 512152-512159, include USNM 512152, an incomplete endophragmal skeleton and attached pereiopods; USNM 512153 and USNM 512154, fragments of pereiopods; USNM 512155, a partial carapace, and USNM 512156, abdominal somites 2 and 3.

Etymology: The trivial name honors Dr. Michèle de Saint Laurent, Laboratoire de Zoologie (Arthropodes), Muséum national d'Histoire naturelle, Paris, for her substantial contribution to our understanding of the Glypheidae.

Diagnosis: Typical *Glyphea* with three weakly spinose cephalic keels; cervical groove very deeply impressed; carapace ornamentation nodose between well developed cervical and well developed, complete postcervical groove, elsewhere generally uniformly pustulose.

Description: Cephalothorax average sized for genus. Dorsal margin generally straight throughout; posterior margin straight dorsally and smoothly convex ventrally; ventral thoracic margin very slightly convex, greatest depth at about midpoint; ventral cephalic margin straight, nearly parallel to midline; anterior margin and rostrum not preserved.

Cervical groove nearly straight, inclined about 80 degrees to dorsal midline, deeply impressed, broad. Postcervical groove well defined, continuous, crosses midline at about 70 degree angle, extending anteroventrally at 13 degree angle to midline and abruptly curving posteroventrally to terminate at well defined, convex-upward intercervical groove (Holthuis, 1974, p. 734). Branchiocardiac groove well defined, continuous, crosses midline at 72 degree angle, curving anteroventrally at 24 degree angle to midline to terminate at postcervical groove. Hepatic groove biconvex ventrally, well defined. Hepatic, postcervical, and intercervical grooves define inflated, prominent, bilobed adductor testis muscle insertion area. Inferior groove narrow, deeply impressed, concave anteriorly. Antennar groove a shallowing-anteriorly extension of cer-

vical groove.

Cephalic region with three weakly spinose carinae; supraorbital and orbital carinae somewhat more closely spaced than orbital and antennar carinae. Pair of transversely elongate nodes flank midline. Front of cephalic region and rostrum unknown.

Region between cervical and postcervical grooves with nodose ornamentation. Region between postcervical and branchiocardiac grooves with longitudinal, nodose crest. Branchiostegite and hepatic regions with uniform pustulose ornamentation. Carapace pustules and nodes with apices directed slightly anteriorly. Marginal rim and furrow not observed.

Abdomen of female (?) represented by a single complete somite and small fragments. Tergal surface smooth, bounded on anterior and posteror margins by narrow rim; separated from pleuron by prominent ridge which is steep ventrally and gently sloping dorsally, ridge connecting points of articulation and parallel, deep depression dorsal to ridge. Pleuron generally rectilinear, slightly convex posteriorly, with smoothly arched pustulose ridge extending from anterior articulation to posteroventral corner and subtle, smooth rim with three short, ventrally directed spines along ventral margin.

Pereiopods represented by isolated, broken elements; slender, flattened, bearing fine to moderately coarse, distally directed nodes and spines. Meri about six times as long as high, flattened, bearing two or more rows of granules on outer surface; row of small spines on lower surface; smooth upper surface. Fragments of other elements similarly ornamented.

Measurements: Measurements (in mm) taken on carapace of holotype are illustrated in Fig. 4.

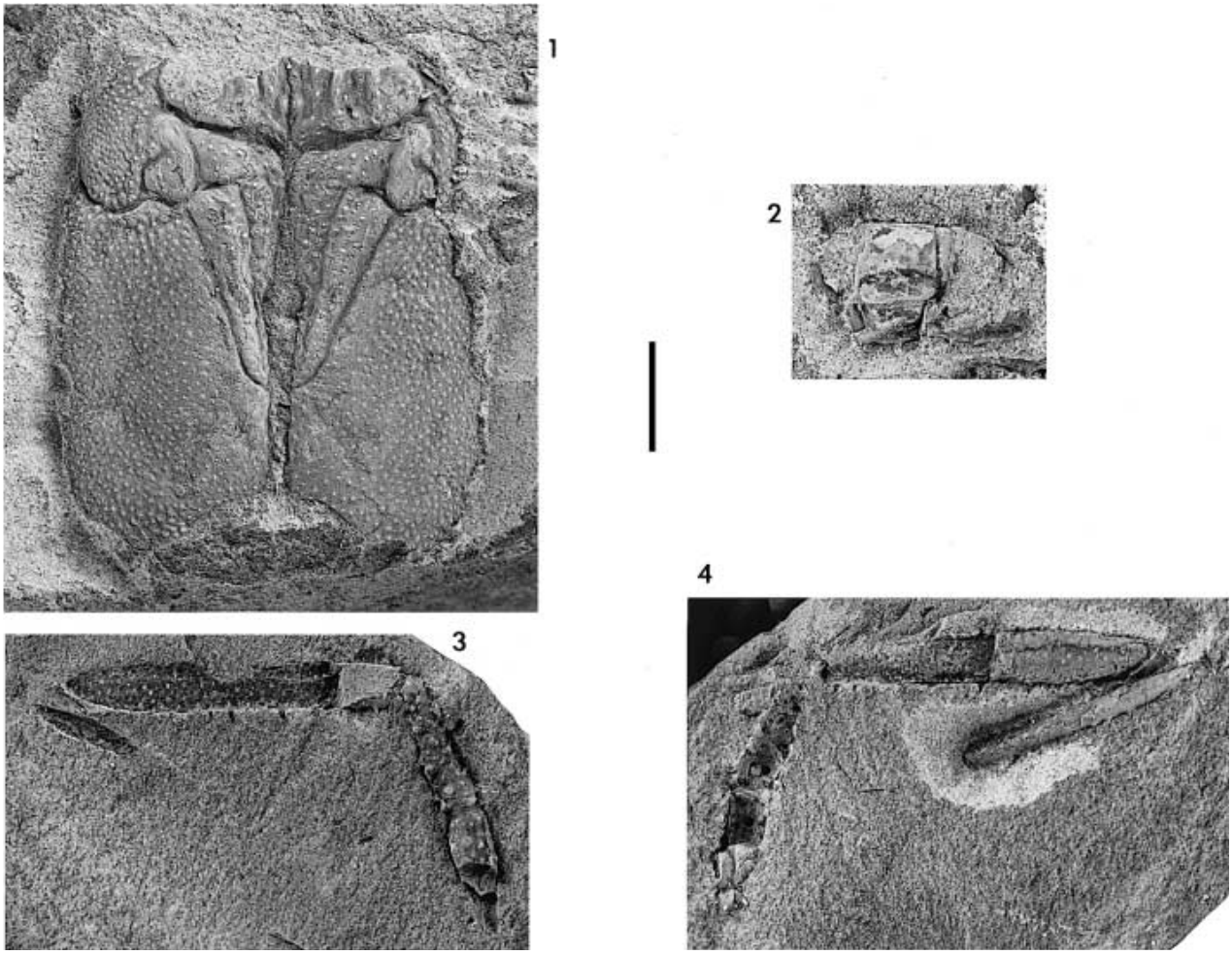


Fig. 3. *Glyphea micheleae* sp. nov. 1, dorsal view of both right and left sides of carapace of holotype, USNM 512151. 2, left lateral view of abdominal somites 2 and 3, of paratype, USNM 52156. 3, 4, part and counterpart of pereiopod of paratype, USNM 512153.. Scale bar equals 1 cm.

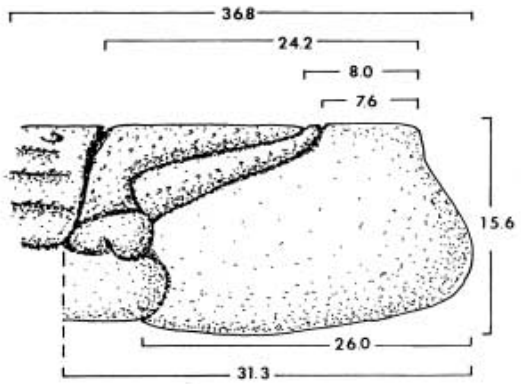


Fig. 4. Line drawing of *Glyphea micheleae* sp. nov., showing the position and values of measurements taken (mm).

Discussion: The specimens can be assigned to *Glyphea* with no reservation. They exhibit a cephalic region with spinose or tuberculate longitudinal keels, a cervical groove that extends across the carapace at an angle between 60-80 degrees, well-developed branchiocardiac and postcervical grooves that converge posteriorly, and an epibranchial region that extends forward on the carapace in advance of the cervical groove (Glaessner, 1969, p. R463).

Species within the genus are distinguished on the basis of a plexus of characters including presence or absence of accessory grooves connecting the postcervical and branchiocardiac grooves, ornamentation between the longitudinal cephalic ridges, number of cephalic ridges, and type and strength of ornamentation over various parts of the thoracic portion of the carapace. In these regards, *Glyphea micheleae* most closely resembles *G. cretacea* McCoy, 1854. Both species exhibit three spinose cephalic ridges, separated from one another by spinose or nodose areas, and complete, and well-developed, postcervical and branchiocardiac grooves that are not connected by accessory grooves. The two species can be distinguished from one another based upon several attributes of the carapace morphology. *Glyphea micheleae* has somewhat finer ornamentation on the branchiostegite than does *G. cretacea*. The new species also has a distinct, nodose ridge that separates the postcervical and branchiocardiac grooves, a feature that appears to be unique in *Glyphea*. An additional unique feature of *G. micheleae* is the bilobed form of the so-called adductor testis muscle area. Typically, this region is ovoid or quadrate and is inflated. That region in *G. micheleae* narrows anteriorly and is distinctly bilobed. This character alone would serve to distinguish the new species from all others.

The specimens representing *Glyphea micheleae* are preserved in attitudes that are unusual for glypheid lobsters. The nearly complete dorsal carapace (holotype, USNM 512151) is preserved in dorsal aspect with the two sides splayed out in a single plane. This specimen probably represents a molted carapace that was preserved in this configuration because the axial furrow was softened and flexible. A second specimen (paratype, USNM 512152) is a partially preserved endophragmal skeleton with attached pereiopods. This represents a molted individual. It has previously been observed that during molting in *Glyphea* the carapace rotates upward around an axis at the anterior of the animal (Feldmann and McPherson, 1980, pl. 2, fig. 9; Feldmann et al., 1993, fig. 12.2). The animal presumably extracted itself first from the dorsal carapace and then from the endophragmal skeleton and pereiopods. Finally, the molting animal extricates itself from the abdomen. The other specimens consist of dissociated fragments of abdomen and appendages, perhaps also molted fragments.

Occurrence: The holotype was collected from the Narizian/Lutetian (Eocene) Aldwell? Formation at locality RB113 of Ross Berglund, N1/2, sec. 18, T26N, R1W, Seabeck 7.5 minute Quadrangle, Pulali Point, Dabob Bay, Hood Canal, Washington. Decapod fossils associated with *Glyphea micheleae* are described in Schweitzer et al. (2000). The paratypes were collected from a sandstone exposure of the Aldwell Formation at locality RB92 of Ross Berglund, at a small waterfall in Browne's Creek about 620 m west and 100 m north of sec. 1, T31N, R14W, Hoko Falls 7.5 minute Quadrangle, Clallam County, Washington. These specimens were associated with only one other decapod taxon, *Branchioplax* cf. *B. hannibalanus*.

Superfamily Nephropoidea Dana, 1852
Family Nephropidae Dana, 1852

Genus *Hoploparia* McCoy, 1849

Type species: *Astacus longimanus* Sowerby, 1826.

Included species: Tshudy (1993) provided a comprehensive list of the 51 named species of *Hoploparia* as well as those specimens simply referred to the genus. To that list can be added *Hoploparia gazdzickii* Feldmann and Crame, 1998, from the early Miocene of Antarctica, *H. miyamotoi* Karasawa, 1998, from the lower Maastrichtian (Upper Cretaceous), Izumi Group, Japan, and *H. kamuy* Karasawa and Hayakawa, 2000, from the Turonian-Santonian (Upper Cretaceous) Upper Yezo Group, Japan.

Diagnosis: "Rostrum long, spinose. Postcervical groove well impressed over most of length; becomes subtler as it extends anteriorly toward cervical groove. Branchiocardiac groove (dorsally) usually present. Ventral extension of branchiocardiac groove typically extends to hepatic groove. Urogastric groove typically absent. Cervical groove well-impressed; extends from level of orbit to junction of hepatic and antennal grooves. Median carina typically absent. Submedian carina present on a few species. Subdorsal carina present. Supraorbital spine present, typically followed by supraorbital carina. Postorbital spine typically present; gastrolateral and hepatic spine typically absent. Antennal carina absent, short or extending to near cervical groove. Thoracic region lacks carinae.

Abdominal terga unornamented, mostly unsculptured; typically with a narrow transverse furrow along posterior margin. Abdominal pleura elongate, typically cordate, ending in a point. Telson surface with a pair of submedian ridges converging posteriorly. Telson without lateral spines but with posterolateral spines. Scaphocerite present. Claws typically unequal; upper and lower surfaces lacking carinae. Exoskeleton generally granulated" (Tshudy, 1993, p. 71).

Discussion: Species of *Hoploparia* have been described from localities ranging throughout temperate and polar regions. None is known from low latitude regions; the distribution is thus amphitropical. The earliest occurrence of the genus is Early Cretaceous (Valanginian) of Europe and the latest occurrence is in the early Miocene of the Antarctic Peninsula. Thus, the species described below does not extend either geographic or geologic ranges.

Hoploparia tshudyi sp. nov.

(Figs. 5, 6)

Material: The holotype, and sole specimen, USNM 512160, is deposited in the United States National Museum of Natural History, Smithsonian Institution, Washington, D.C.

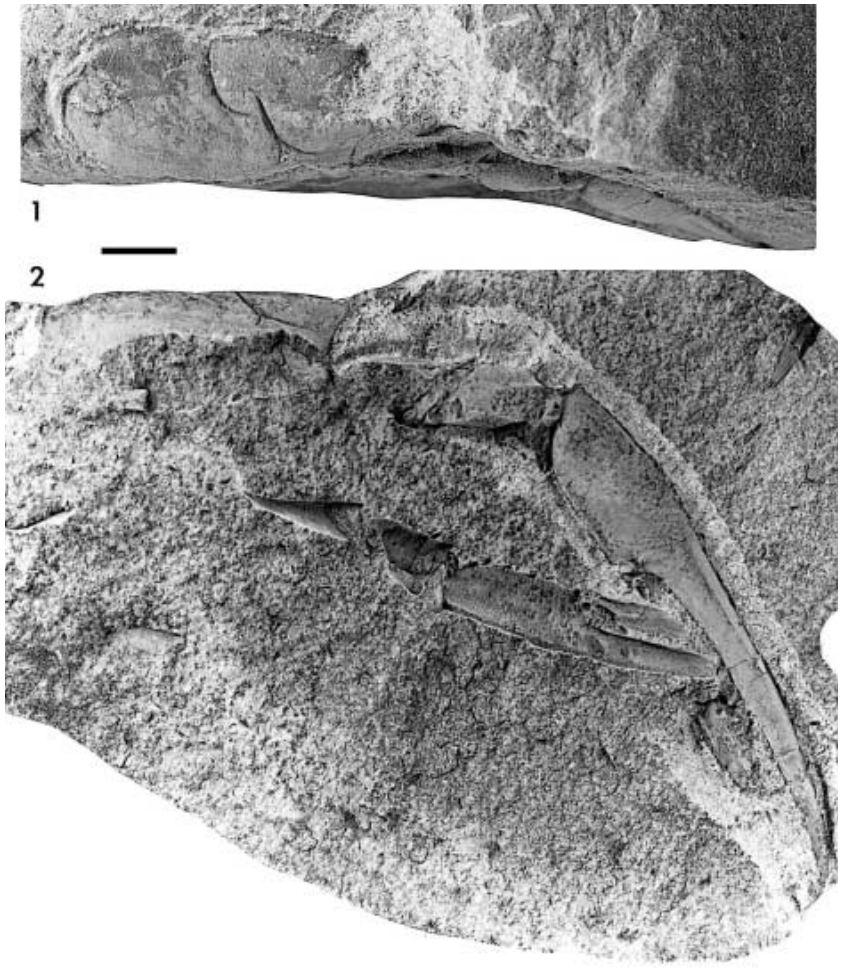


Fig. 5. *Hoploparia tshudyi* sp. nov., holotype, USNM 512160. 1, right lateral view of carapace and oblique view or first right pereiopod. 2, first right pereiopod, the major claw, and a portion of the first left pereiopod, the minor claw. Scale bar equals 1 cm.

Etymology: The trivial name recognizes the contributions of Dr. Dale Tshudy, Edinboro University, Pennsylvania, to our understanding of the genus *Hoploparia*.

Diagnosis: Smooth carapace with reduced subdorsal carina and small supraorbital spine; first pereiopods heterochelate, both claws very slender, fingers of greater claw much longer than hand, finely denticulate occlusal surface.

Description: Moderate sized nephropid, length from base of orbit to posterior margin 38.2 mm, maximum height 20.4mm measured at about midlength; carapace smooth or with very finely reticulate texture throughout; cervical and antennar grooves well developed; postcervical groove well developed dorsally.

Dorsal margin weakly biconvex with shallow depression where postcervical groove crosses midline at right angles to it and just anterior to midlength; posterior margin smoothly convex with broad, prominent marginal rim and furrow; ventral margin incompletely preserved; anterior margin convex ventrally, not preserved at midheight, and with smoothly concave, rimmed orbit. Rostrum not preserved.

Cervical groove nearly straight, arises at approximate level of base of orbital rim, extending anteroventrally at 57 degree angle to midline; antennar groove arises at junction of cervical and hepatic grooves and extends anteroventrally in slightly concave upward curve. Postcervical groove prominent dorsally becoming narrower and shallower in concave forward arc, terminating at midheight and posterior to cervical groove. Branchiocardiac groove expressed as extremely subtle groove arising near postcervical groove, extending in sinuous curve around posterior of weakly inflated adductor testis muscle insertion area, merging with hepatic furrow.

Cephalic region with three small postrostral spines extending on subtle subdorsal carina toward rostrum on either side of midline and gastroorbital node or spine. Branchiostegite entirely smooth.

Abdomen not preserved.

First pereiopods hypertrophied, length of propodus of major chela 191 percent carapace length; heterochelous, minor hand 72 percent length of major hand; morphologically similar. Merus and carpus of both claws slightly longer than high, each bearing long, slender, distally directed spine on distal end of upper surface. Major propodus about twice as long as high, with apparently smooth, convex upper and lower surfaces and weakly scabrous inner surfaces. Fixed and moveable fingers

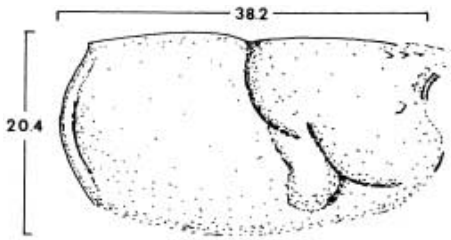


Fig. 6. Line drawing of *Hoploparia tshudyi* sp. nov., showing the position and values of measurements taken (mm).

extremely long, slender, longitudinally sulcate near outer margin, bearing about one sharp, distally directed, alternately long and short, spinose denticle per mm length. Minor claw generally similar but with about five distally directed spines on upper surface of hand.

Measurements: Measurements (in mm) taken on the dorsal carapace are illustrated in Fig. 6. Length of major propodus, 72.8 mm; length of major hand, 24.6 mm; height of major hand, 12.6 mm; length of minor hand, 17.7 mm; height of major hand, 10.4 mm.

Discussion: Assignment of this specimen to *Hoploparia* can be made with confidence. Tshudy (1993, p. 71) provided a definition of the genus from which several aspects of morphology confirm the placement. The cervical groove is well-defined and extends from the level of the orbit to the antennal and hepatic grooves, which are also well defined. The postcervical groove is deeply impressed along its entire length and the branchiocardiac groove extends ventrally to intersect the hepatic groove. This groove pattern is diagnostic of the genus and serves to separate it from *Homarus* Weber, 1795. *Homarus* has a reduced pattern of grooves and the ventral extension of the branchiocardiac groove is absent.

Tshudy (1993) recorded 51 named species of *Hoploparia*, of which most of the species can be readily distinguished from *Hoploparia tshudyi* because this new species has the least ornamentation developed on the cephalic region of the carapace and the longest, and most slender chelipeds of any known species. Most species have several spines near the anterior margin of the carapace and many have well developed carinae. The subdorsal carina, which is the only one present on *H. tshudyi*, is extremely subtle and is recognizable only as a slight elevation connecting the three spines situated upon it. No other carinae are present. In these regards, the two species that seem to be the most similar to *H. tshudyi* are *H. gammaroides* McCoy, 1849, from the early Eocene age London Clay of southern England and *H. riddlensis* Feldmann, 1974, from the

Hauterivian (Early Cretaceous) Days Creek Formation of Oregon. One particular specimen of *Hoploparia gammaroides* illustrated by H. Woods (1931, pl. 27, fig. 1) seems to be devoid of spines and carinae in the cephalic region, except for a subtle subdorsal carina. However, the overall ornamentation is granular, a feature not exhibited on *H. tshudyi*. Another feature these two species have in common is possession of distally directed spines on the upper margin of the hand and extremely long fingers. However, the spines occur only on the minor claw of *H. tshudyi* and the fingers have a distinct sulcus extending the entire length of the fingers near the lower margin of the fixed finger and the upper margin of the moveable finger. No such feature is evident on the fingers of *H. gammaroides*. *Hoploparia riddlensis* has a generally smooth carapace but, in addition to the subdorsal carina, this species has a small supraorbital carina (Feldmann, 1974, pl. 1, fig. 7) and a diminutive axial carina. Additionally, the chelae on this species are more stout than those on *H. tshudyi*. Thus, there should be no problem distinguishing the two species.

Of the two species recently described from Japan (Karasawa, 1998; Karasawa and Hayakawa, 2000), *H. kamuy* would seem to be most similar morphologically to *H. tshudyi*; however, *H. kamuy* has a well developed antennal carina and the hepatic groove is faint or incomplete.

Occurrence: *Hoploparia tshudyi* was collected from the late Albian - late Cenomanian (Late Cretaceous) Moonshine Creek Formation in Contact Gulch, Wrangell Mountains, Lat. 61°29′12″N, Long. 142°18′36″W, Alaska, by J. M. Trop. Well-preserved palynomorphs at this site constrain the age to latest Albian (A. R. Sweet *in* Trop, 2000). Lithofacies analysis (Trop, 2000) suggests deposition on an open marine shelf above storm wave base.

Nephropidae genus indeterminate

(Figs. 7, 8)

Material: The sole specimen, part and counterpart, referred to this taxon, USNM 512161, is deposited in the United States National Museum of Natural History, Smithsonian Institution, Washington, D.C.

Diagnosis: Typical nephropid with very weakly-expressed branchial, intermediate, and lateral carinae of branchiostegite; chelipeds with extremely long, slender fingers bearing needle-like denticles.

Description: Carapace about twice as long as high, convex,

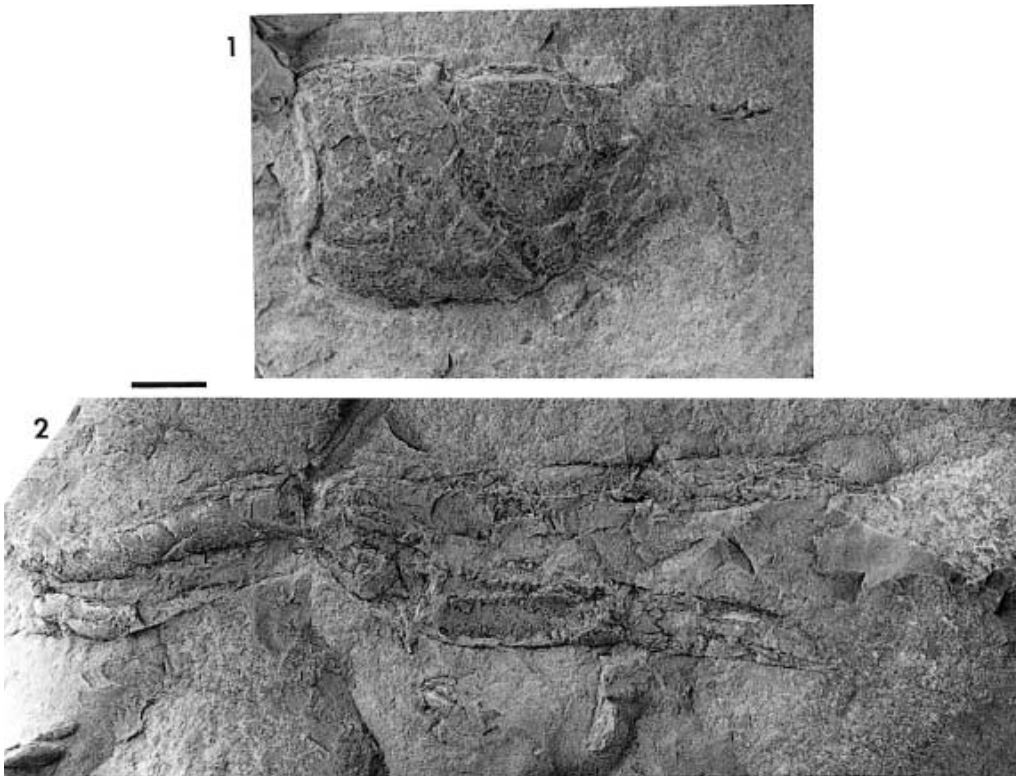


Fig. 7. Nephropidae, genus indeterminate, USNM 512161. 1, right lateral view of carapace. 2, right and left first pereiopods of same specimen. Scale bar equals 1 cm.

weakly ornamented. Rostrum about 33 percent length of carapace, excluding rostrum; slender, slightly upturned to sharp distal spine; bearing at least 2 distally directed dorsal spines; ventral surface smooth. Supraorbital (?) spine large; remainder of cephalic region not well-preserved; surface very finely pustulose where evident.

Postcervical groove well-defined, broad; crosses midline at right angle and extends anteroventrally at about 57 degree angle and curves anteriorly as distinct intercervical groove. Ventral extension of branchiocardiac groove extends anteroventrally from postcervical groove and curves smoothly into well-developed hepatic groove. Cervical groove distinct below level of intercervical groove. Antennar groove preserved only at intersection with hepatic groove.

Branchiostegite with weakly-developed intermediate, branchial, and lateral carinae. Marginal carina and marginal groove well-defined along posterior margin and appear to extend along ventral margin.

Chelipeds extremely long and slender, apparently isochelous. Hand 57 percent total length of propodus, height 38 percent length of hand; ornamented by moderately coarse granules or small spines. Fingers long, slender, turned toward occlusal surface distally, apparently finely dentate. Merus about twice as long as high, widening distally, with long distally-directed spine on outer margin at point of articulation with propodus. Merus long and slender, about 35 percent as high as long, widening distally. Other elements unknown.

Measurements: Measurements taken on this specimen are given in Fig. 8.

Discussion: One specimen, part and counterpart, forms the basis for the above description. It consists of a carapace which has been laterally compressed so that the right side and a part of the left side of the carapace lie in a single plane. Within the same concretion, part of the ischium, as well as the merus, carpus, propodus, and dactylus of both chelipeds are exposed. The only aspect of morphology that is well enough preserved to interpret in detail is the fingers of one cheliped on which needle-like denticles are evident.

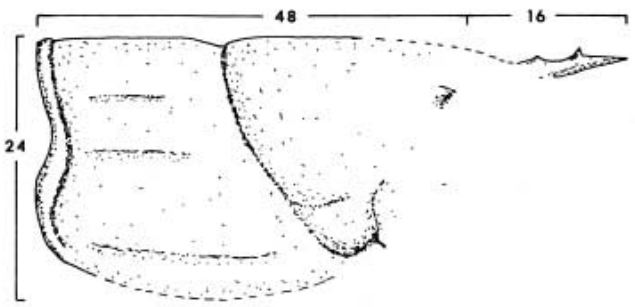


Fig. 8. Line drawing of Nephropidae, genus indeterminate, USNM 512161, showing the position and values of measurements taken (mm).

Too little of the material referred to this indeterminate genus is well enough preserved to permit more specific assignment. It is tempting to assign the material to *Metanephrops* Jenkins, 1972, based upon the possession of intermediate, branchial, and lateral carinae; however, those features are so subtle that it is possible they represent nothing more than the contour developed as the carapace was pressed over the endophragmal skeleton. The carinae are not indicated by any change in surface ornamentation. *Metanephrops* is known in the fossil record only from the Pliocene of New Zealand (Jenkins, 1972a) and the Cretaceous and Paleocene of Antarctica (Feldmann, 1989; Feldmann et al., 1993). No fossils referable to this genus are known from the North Pacific, although modern forms range along the western Pacific margin from New Zealand to Japan.

Complete development of the postcervical groove and ventral extension of the branchiocardiac grooves is suggestive of *Hoploparia*; however, the cervical groove is apparently not developed above the level of the intercervical groove. This observation could be the result of the poor preservation of the cephalic region. Certainly, the rostrum, with a spinose dorsal surface, is also reminiscent of *Hoploparia*. It is difficult to assign the material to *Hoploparia* with confidence because the denticles on the chelipeds appear to be very fine and almost needle-like. This feature is more reminiscent of *Oncopareia* Bosquet, 1854; however, in that genus the hands are strongly heterochelous and the major claw exhibits a short, bulbous hand. Thus, assignment to *Oncopareia* is not reasonable.

Occurrence: The specimen was collected by James L. Goedert, Gig Harbor, Washington, in the intertidal zone approximately 360 m west and 140 m north of the NE corner, sec. 19, T31N, R9W, Twin Rivers 7.5' Quadrangle, Clallam County, Washington. At this locality, the upper Oligocene Pysht Formation crops out as a medium grey, massive but poorly indurated mudstone.

Infraorder Thalassinidea Latreille, 1831
Superfamily Callianassoidea Dana, 1852b
Family Callianassidae Dana, 1852b

Genus *Callianassa sensu lato* Leach, 1814

Callianassa s.l. sp.
(Fig. 9.2)

Material: The best preserved specimen, UAM 2686, and several other specimens, UAM 2580, 2683-2685, 2687-2699, are deposited in the University of Alaska Museum, Fairbanks, Alaska.

Diagnosis: Manus of major cheliped rectangular, narrowing distally, outer surface nearly smooth, with a few tubercles with distally directed setal pits; lower margin bordered by row of tubercles with setal pits; fixed finger with curved tip, sharp spine on fixed finger; cuticle of lower margin of manus and fixed finger with alternating light and dark pillars oriented perpendicular to surface.

Description: Manus of major cheliped longer than high, rectangular, narrowing distally; outer surface nearly smooth, with a few tubercles with distally directed setal pits; outer surface weakly vaulted longitudinally, moderately vaulted transversely; proximal margin nearly straight, with small, blunt indentation at one-quarter the distance vertically from lower corner, upper and lower corners of proximal margin bluntly rounded; lower margin weakly sinuous, bordered by row of tubercles with setal pits; upper margin weakly convex; distal margin nearly straight, oriented at nearly 90 degree angle to upper margin;

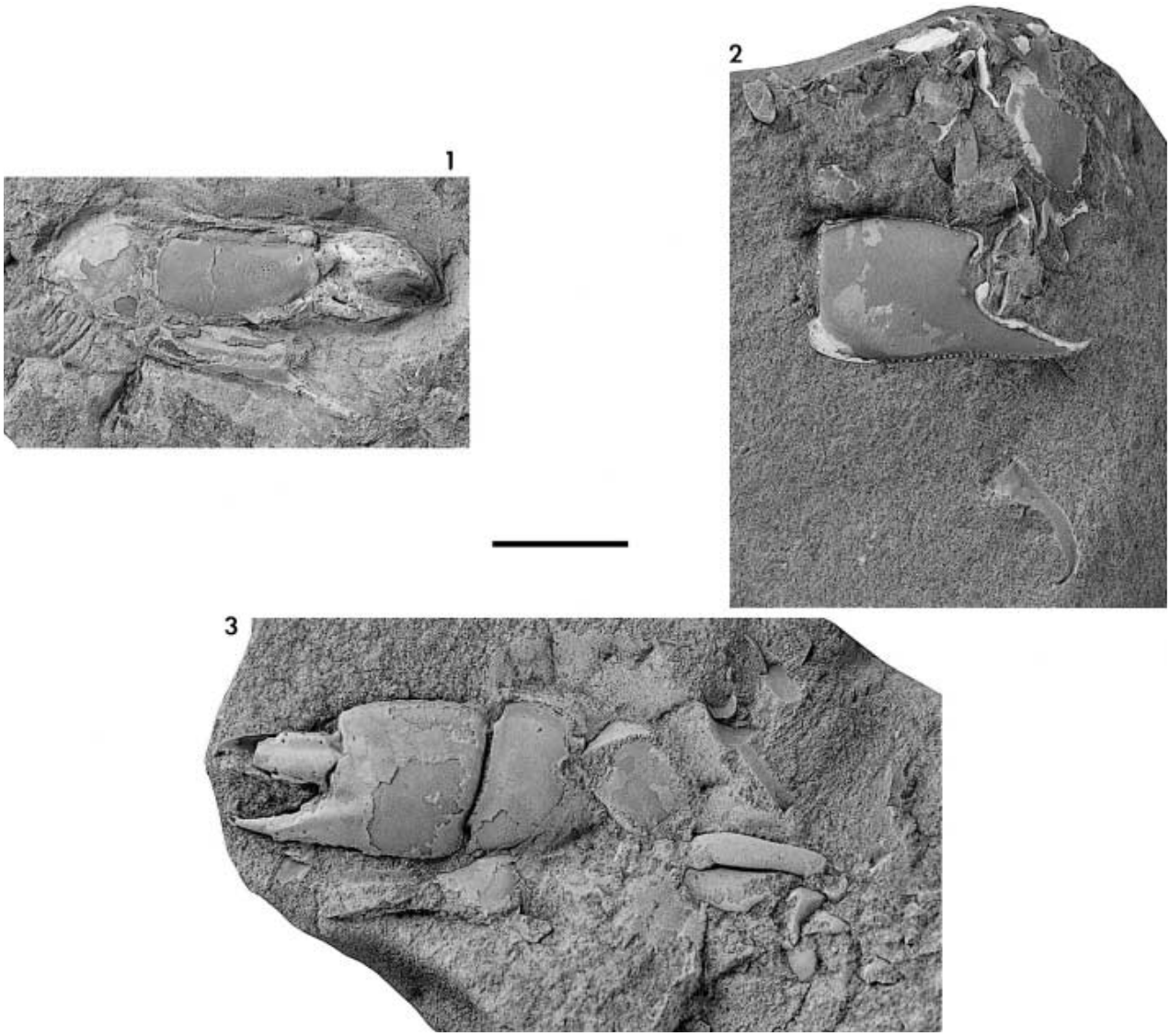


Fig 9. 1, *Brecanclawu rathbunae* gen. nov. and sp. nov., major and minor chelae, holotype, USNM 512170. 2, *Callianassa* s.l. sp., UAM 2686. 3, *Callianopsis* ? *inornatus* sp. nov., holotype, USNM 512168. Scale bar equal to 1 cm.

arcuate depression oriented along distal margin. Fixed finger about 40 percent total length of chela, narrowing distally, with curved tip; sharp, triangular spine positioned about one-third the distance distally on finger. Cuticle about twice as thick along lower margin as along upper margin; cuticle along lower margin with internal pillars, pillars perpendicular to surface of cuticle, alternating in clusters of light and dark pillars, about four or five pillars in each cluster; dark pillars appearing to be less common and possible surrounded by white pillars.

Remainder of elements of carapace and appendages not sufficiently preserved to permit description.

Measurements: Measurements (in mm) taken on UAM 2686, the most complete manus available: length of chela including fixed finger, 20.7; length of chela without fixed finger, 12.3; height of chela, 10.4.

Discussion: The two most complete major chelae are from the right cheliped. The material consists primarily of palms, some with fixed fingers attached. The material does not retain sufficient diagnostic characters to be referred to a genus with certainty; therefore, we have referred the material to *Callianassa* s.l. until more complete material is recovered. The material is superficially similar to specimens assigned to *Callianassa porterensis* Rathbun (Rathbun, 1926; Schweitzer and Feldmann, 1999). Both the new material and *C. porterensis* have relatively smooth outer surfaces; become less high distally; and have setal pits along the lower margin and occlusal surface of the fixed finger. It is thus possible that *Callianassa porterensis* and the new Alaskan specimens are congeneric. *Callianassa porterensis* is known from Oligocene rocks of Washington and Oregon (Rathbun, 1926; Schweitzer and Feldmann, 1999).

Occurrence: Specimens UAM 2683-2689 were collected by Kevin May from the Cretaceous Matanuska Formation, Alaska, as float from a small stream on the south side of Syncline Mountain and the north side of Squaw Creek, at Lat. 61°54′50″N, Long. 147°27′10″W. Specimens UAM 2690-2699 were collected by Kevin May from the Cretaceous Matanuska Formation, Alaska, along the south side of Alfred Creek at the west end of an airstrip, at Lat. 61°56′94″N, Long. 147°30′42″W. UAM 2580 was collected from the upper part of the Matanuska Formation of Cenomanian to early Maastrichtian age.

Family ? Callianassidae Dana, 1852b

Genus *Brecanclawu* gen. nov.

Type species: *Brecanclawu rathbunae* sp. nov., by original designation.

Etymology: The generic name is derived from the Anglo-Saxon words "*brecan*," meaning crack, and "*clawu*," meaning claw, in reference to the apparent crushing nature of the claws because of the large, stout movable finger.

Diagnosis: As for species.

Description: As for species.

Discussion: The new material is not referable to any known genus within the Callianassidae, in which it is questionably placed, or within any other decapod family. The general shape of the carpus of the major chela and the mani of the major and minor chelae; the style of preservation; and the lack of other dorsal carapace parts preserved are all typical of thalassinideans, thus suggesting that *Brecanclawu* belongs within that infraorder. The new genus is most similar to several members of the Callianassidae, including *Callichirus* Stimpson, 1866, and *Neocallichirus* K. Sakai, 1988. Both of these genera are characterized by possession of a fixed finger that is large, and often larger than the movable finger, and a large flange on the occlusal surface of the movable finger. However, the manus of *Brecanclawu* is much longer and more slender than that of either *Callichirus* or *Neocallichirus*. The carpus of *Callichirus* is much longer than high, while that of *Brecanclawu* is apparently higher than long. Additionally, the movable finger of neither *Callichirus* nor *Neocallichirus* is as large and stout as that of *Brecanclawu*. *Trypaea* Dana, 1852b, has a large flange on the movable finger, but the flange itself as well as both the movable and fixed fingers of *Trypaea* are much smaller and more slender than those of *Brecanclawu*. Thus, it appears that the large movable finger, the large flange on the movable finger, and the long and slender manus of the major chela are unique features, necessitating the naming of a new genus.

Brecanclawu rathbunae sp. nov.

(Fig. 9.1)

Material: The holotype and sole specimen, USNM 512170, is deposited in the United States National Museum of Natural History, Smithsonian Institution, Washington, D.C.

Etymology: The trivial name honors Mary Jane Rathbun, a pioneer in the study of both Recent and fossil crabs and a personal heroine to both of the authors.

Diagnosis: Carpus of major chela longest along upper margin, much shorter along lower margin; manus longer than high, nearly rectangular; fixed finger downturned, curved; movable finger stout, strongly arched, with broad flange along occlusal surface, flange separated from distal margin of manus by deep, smooth indentation.

Description: Carpus of major chela not well preserved, about as long as high, narrowest along upper margin, appearing to be much narrower along lower margin. Manus of major chela longer than high, nearly rectangular, narrowing slightly distally, appearing to be smooth on the outer surface; proximal margin weakly sinuous; lower margin very weakly sinuous; upper margin slightly convex; distal margin nearly straight, at about 90 degree angle to upper margin.

Fixed finger downturned, at about 170 degree angle to lower margin of manus; curved; lower margin convex, upper margin concave; occlusal surface appearing to be dentate; narrowing distally. Movable finger stout, longer and stouter than fixed finger; strongly arched; with large knob along margin of articulation with distal margin of manus; outer surface with large setal pits; occlusal surface with large triangular flange, flange separated from distal margin of manus by deep, smooth indentation. Minor chela with slender manus, manus much longer than high; fingers long and slender.

Measurements: Measurements (in mm) taken on the sole specimen of *Brecanclawu rathbunae*: length of manus of major chela including fixed finger, 18.2; length of fixed finger, 7.1; length of movable finger, 8.3; maximum height of major chela, 7.2; length of minor chela including fixed finger, 15.8; length of minor chela excluding fixed finger, 10.2; maximum height of minor chela, 3.8.

Discussion: The sole specimen was collected from Eocene rocks of the Olympic Peninsula, Washington, USA, from rocks of the Hoko River Formation. Thalassinidean taxa are quite common in rocks of the Hoko River Formation and the Twin River Group, of which the Hoko River Formation is the lowermost of three units. Other taxa recovered from the Twin River Group include *Callianopsis* ? *inornata* sp. nov. herein from the Hoko River Formation; *Callianopsis clallamensis* (Withers, 1924) from the lower Oligocene Makah Formation; and *Callianopsis clallamensis*, *Callianassa* cf. *C. porterensis*, and *Callianassa* s.l. sp. from the upper Oligocene Pysht Formation (Schweitzer and Feldmann, 1999). The new taxon is easily differentiated from all of these taxa based upon the diagnostic characters discussed above.

Occurrence: The holotype and sole specimen of *Brecanclawu rathbunae*, USNM 512170, was collected from RB32 from the locality register of Ross E. Berglund, Bainbridge Island, Washington, located near Neah Bay, in the SW 1/4, NW1/4, sec. 4, T33N, R15W, Cape Flattery 7.5' Quadrangle, Clallam County, Washington.

Family Ctenochelidae Manning and Felder, 1991

Genus *Ctenocheles* Kishinouye, 1926

Type species: *Ctenocheles balssi* Kishinouye, 1926, by original designation.

Included fossil species: *Ctenocheles* cf. *C. burlensonensis* (Stenzel, 1935); *C. cookei* (Rathbun, 1935); *C. cultellus* (Rathbun, 1935); *C. dentatus* (Rathbun, 1935); *C. hokoensis* sp. nov.; *C. inaequidens* (Pelseneer, 1886); *C. madagascariensis* Secretan, 1964; *C. rupeliensis* (Beurlen, 1939), *C. sujakui* Imaizumi, 1958; *C. victor* Glaessner, 1947; *Ctenocheles* sp. Feldmann, 1991; *Ctenocheles* sp. Chirino-Gálvez, 1993; *Ctenocheles* sp. De Angeli, 1995; Beschin et al., 1996; *Ctenocheles* sp. Feldmann and Duncan, 1992; *Ctenocheles* sp. Jenkins, 1972b; *Ctenocheles* sp. Rasmussen, 1971.

Diagnosis: Manus of major cheliped bulbous, longer than high, narrowing distally; fixed finger long and straight or arcuate; occlusal surface of fixed finger with long, needle-like teeth, teeth of variable size, tips curving proximally. Manus of minor cheliped rectangular; fixed finger long, narrow, straight. The genus is known in the fossil record only from its chelae.

Discussion: Feldmann et al. (1995) summarized the occurrences of *Ctenocheles* known to date, and the species list above is taken primarily from that work. Three genera with superficially similar chelipeds, *Acanthacaris* Bate, 1888, *Oncopareia* Bosquet, 1854, and *Thaumastocheles* Wood-Mason, 1874, have previously been differentiated from *Ctenocheles* (Feldmann et al., 1995; Tshudy and Sorhannus, 2000). Members of the genus *Laurentiella* Le Loeuff and Intes, 1974, have long fixed fingers with numerous teeth similar to those of *Ctenocheles*. However, the fixed finger of species of *Laurentiella* is much more robust than those of *Ctenocheles* and the teeth are triangular and serrate, not needle-like as in *Ctenocheles*. The manus of *Laurentiella* appears to be shorter and less bulbous than that of *Ctenocheles*.

The new taxon is referable to *Ctenocheles* based upon the criteria delineated in Feldmann et al. (1995). Because

of the delicate nature of the cuticle of members of this genus, chelae are almost always the only fossilized portion of *Ctenocheles*. For this reason, many of the occurrences in the fossil record are simply designated as *Ctenocheles* sp. The elongate finger, bulbous hand, and long, proximally curving occlusal teeth of the manus of the new taxon make it clearly referable to *Ctenocheles*. Because this is the first occurrence of the genus on the Pacific coast of North America, the taxon is almost certainly previously undescribed and is therefore designated as a new species.

Although several characters have been judged to unite species of *Ctenocheles*, the widespread geographic occurrences of the genus in the fossil record might suggest that it may in fact be composed of more than one genus, perhaps distinguishable by dorsal carapace features which do not preserve as fossils (Manning and Felder, 1991). Because no information to the contrary is now known, it is most parsimonious to continue to unite the species within one genus based upon the nature of the major cheliped.

The earliest known occurrence of the genus is from late Cretaceous (Cenomanian-Campanian) rocks of Madagascar (Secretan, 1964), and Paleocene specimens have been recovered from Argentina (Feldmann et al., 1995) and Gulf Coastal North America (Rathbun, 1935). Eocene occurrences include Gulf Coastal North America (Rathbun, 1935), western North America (herein), Australia (Glaessner, 1947), Italy (Beschin et al., 1996), Japan (Imaizumi, 1958), and New Zealand (Feldmann, 1991). Oligocene specimens have been collected from Japan (Karasawa, 1997), Europe (Beurlen, 1939) and Australia (Jenkins, 1972b). Miocene fossils have been recovered from Chile (Chirino-Gálvez, 1993) and Australia (Jenkins, 1972b), and Pleistocene specimens have been collected in New Zealand (Glaessner, 1969). Reports of the genus in Danian rocks of Belgium and Maastrichtian rocks of Denmark have not been confirmed (Feldmann et al., 1995). Recent members of the genus have a primarily Pacific and Indo-Pacific distribution but also have been reported from the Atlantic (Glaessner, 1969; Holthuis, 1967; Manning and Felder, 1991). The temporal pattern of occurrences of species of the genus suggest that it may have originated in the middle to high southern latitudes during the Late Cretaceous and subsequently dispersed to numerous southern hemisphere localities via ocean currents, and to Europe and North America via the Tethys Seaway. Dispersal to the North Pacific may have been facilitated by the open Central American Seaway.

Although *Ctenocheles* is currently found in deep water habitats (Holthuis, 1967), fossil evidence suggests that it may have evolved in shallower water, nearshore areas (Feldmann et al., 1995). The new occurrence reported here may support this hypothesis. The widespread dispersal of the genus may have occurred early in its history when it was adapted to shallow-water habitats; shallow water organisms often disperse by locomotion or pelagic larvae. Offshore benthic organisms typically do not have pelagic larvae that could facilitate such wide-spread dispersal. The genus may have subsequently moved offshore into deep water habitats, a pattern displayed in many invertebrate groups and thought to be a response to competition for resources in shallow water areas (Jablonski et al., 1983).

Ctenocheles hokoensis sp. nov.

(Fig. 10)

Ctenocheles sp. Feldmann, Tucker, and Berglund, 1991, p. 357, 360.

Types: The holotype, USNM 512164, and paratypes, USNM 512165-512167 and 512178 are deposited in the United States National Museum of Natural History, Smithsonian Institution, Washington, D.C.

Etymology: The trivial name is taken from the occurrence of the fossils in the late Eocene Hoko River Formation, Olympic Peninsula, Washington.

Diagnosis: Manus of major cheliped bulbous, ovate; fixed finger very long, arcuate, sinuous; finger deflexed at about 160 degree angle to lower margin of manus; occlusal surface with numerous long teeth; minor chela rectilinear, nearly straight.

Description: Manus of major cheliped bulbous, obovate, chela longer than high, highest proximally, surface smooth; lower margin convex, smooth; upper margin convex, gently sloping distally; proximal margin with rounded corners, nearly straight between corners; distal margin weakly convex, appearing to be ornamented with a few small granules. Fixed finger very long, over half the combined length of the manus and fixed finger, sinuous, with upturned tip, finger deflexed at angle of about 160 degrees to lower margin of manus; occlusal surface with numerous sharp, needle-like teeth, teeth variable in size, large teeth generally separated by 4 or 5 smaller teeth, teeth weakly curved proximally. Movable finger unknown.

Manus of minor chelae rectilinear; upper and lower margins nearly straight; manus longer than high, highest proximally; surface smooth; proximal margin unknown;

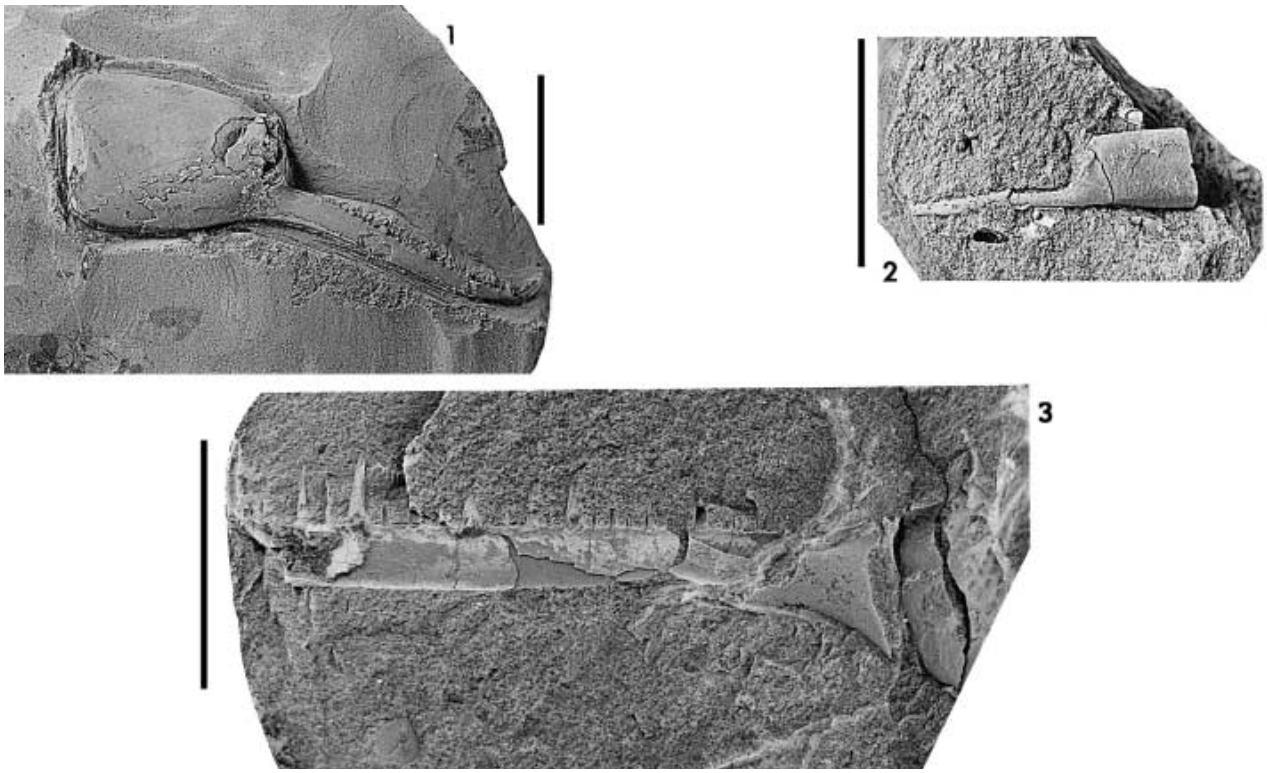


Fig. 10. *Ctenocheles hokoensis* sp. nov. 1, major chela, holotype, USNM 512164. 2, minor chela, paratype, USNM 512165. 3, Close-up of needle-like denticles on occlusal surface of fixed finger of major chela of paratype, USNM 512167. Scale bars equal to 1 cm.

distal margin extending from lower margin at about 75 degree angle. Fixed finger nearly straight, lower margin, forming continuous straight lower margin with manus, narrowing distally; occlusal surface apparently with small teeth.

Remainder of animal unknown.

Measurements: Measurements (in mm) taken on the major chela of the following specimens: USNM 512164, length of manus including fixed finger, 30.6; length of fixed finger, 18.4; height of manus, 10.2. USNM 51266, length of manus including fixed finger, 27.2; length of fixed finger, 14.4; height of manus, 6.6.

Discussion: The specimens are preserved in silty sandstone concretions typical of the Hoko River Formation, and the concretions are littered with organic material. Only the chelipeds are preserved in these specimens; however, USNM 512167 displays delicately preserved occlusal teeth (Fig. 10.3). *Ctenocheles hokoensis* differs from all other species of the genus in having an arcuate, sinuous, fixed finger with very long teeth. *Ctenocheles hokoensis* appears to be most like *C. sujakui* but *C. hokoensis* has longer occlusal teeth and a more arcuate fixed finger. *Ctenocheles* sp. from Danian rocks of Argentina has a much more delicate fixed finger than does *C. hokoensis*. The fixed finger of *Ctenocheles* sp. from the Eocene of Italy is much longer, straighter, and more robust than that of *C. hokoensis*.

Concretions of the Hoko River Formation appear to exhibit downslope mixing of fauna (Feldmann et al., 1991). Both deep-water and shallow-water species are preserved in these rocks, which are thought to have been deposited as deep-sea fans (Feldmann et al., 1991). The large quantity of woody plant material and broken shell material in some of the concretions indicates that they may have formed in near-shore environments and were subsequently transported downslope. The specimens of *Ctenocheles* may have lived in either a shallow or deep water environment, but more likely were incorporated within the concretions at the same time as the wood and shell material.

Occurrence: Two specimens the holotype, USNM 512164, and two paratypes, USNM 512165 and 512178, were collected from RB32 of the locality register of Ross E. Berglund, Bainbridge Island, Washington, located on the south shore of Neah Bay, Strait of Juan de Fuca, in the SW1/4, NW1/4, sec. 4, T33N, R15W, Cape Flattery 7.5'

Quadrangle, Clallam County, Washington. One paratype, USNM 512166, was collected from RB49, in the early Eocene Elkton Formation, located on the bank of the Umpqua River, Basket Point, Douglas County, Oregon, on the Fay Madison Ranch, sec. 30, T24S, R7W, Tyee 15' Quadrangle, Oregon. One paratype, USNM 512167, was collected from RB57, in the Tenmile Member of the early Eocene Lookingglass Formation in a roadcut of a short road connecting Miller Road with Bay Wagon Road, approximately 400 m northwest of Dora, Coos County, Oregon, in the SW1/4, sec. 12, T28S, R11W, Sitkum 15' Quadrangle, Oregon.

Genus *Callianopsis* de Saint Laurent, 1973

Type species: *Callianassa goniophthalma* Rathbun, 1902.

Other species: *Callianopsis clallamensis* (Withers, 1924); *C. elongatodigitata* (Nagao, 1941); *C. muratai* (Nagao, 1932); *C. titaensis* (Nagao, 1941); *Callianopsis* spp., Kato, 1996.

Callianopsis ? *inornatus* sp. nov.

(Figs. 9.3)

Callianassa sp. Feldmann, Tucker, and Berglund, 1991, p. 356, fig. 4B.

Material: The holotype and sole specimen, USNM 512168, is deposited in the United States National Museum of Natural History, Smithsonian Institution, Washington, DC.

Etymology: The trivial name refers to the subdued ornamentation of the manus and fingers, unusual within the genus.

Diagnosis: Manus about as long as high; setal pits border lower margin and base of fixed finger; distal margin initially at about 70 degree angle to lower margin, then straightening to 90 degree angle as it intersects upper margin; weakly bulbous swelling paralleling distal margin; Fixed finger narrowing distally, with setal pits and blunt keel parallel to occlusal surface. Movable finger with two keels and setal pits along upper surface, lower surface appearing to have elongate, uneven ridge of blunt spines.

Description: Ischium of major cheliped much longer than wide, with sinuous upper and lower margins; merus not well enough preserved to permit description. Carpus higher than long, proximal margin appearing to be long and convex; upper margin short, convex; distal margin with concave indentation at upper corner, remainder concave; lower margin with distally directed flange, flange arching distally; outer surface nearly smooth.

Manus of major cheliped about as long as high, narrowing slightly distally; outer surface vaulted transversely, ornamented with setal pits along lower margin and at base of fixed finger; proximal margin slightly convex, angled proximally at about 110 degree angle to lower margin, lower corner bulbous and rounded; upper margin weakly convex; lower margin nearly straight; distal margin initially at about 70 degree angle to lower margin, then straightening to 90 degree angle as it intersects upper margin; weakly bulbous swelling paralleling distal margin.

Fixed finger narrowing distally, with setal pits and blunt keel parallel to occlusal surface. Movable finger with two keels and setal pits along upper surface, lower surface appearing to have elongate, uneven ridge of blunt spines.

Minor chela much smaller than major; manus longer than high, narrowing distally; fingers long, narrowing distally.

Measurements: Measurements (in mm) taken on the sole specimen of *Callianopsis* ? *inornatus*: length of major chela including fixed finger, 17.2, length of major chela excluding fixed finger, 10.3, maximum height of major chela, 11.4; length of minor chela including fixed finger, 13.4; length of minor chela excluding fixed finger, 7.9; maximum height of minor chela, approx. 4.7.

Discussion: The sole specimen consists of portions of a left major chela and the associated right minor chela. The remainder of the elements of the animal were not preserved. The specimen is questionably referred to the genus *Callianopsis* based upon its possession of a carpus with a flange on the lower margin; a fixed finger with a keel and setal pits; a movable finger with two keels on the upper margin; a bulbous swelling parallel to the distal margin of the manus; and a slender minor chela with slender, long fingers. All of these features are typical of species of *Callianopsis*. However, other species of *Callianopsis* possess large tubercles on the outer margin of the manus and on the movable finger of males; a small spine on the distal margin of the manus; and a spine on the fixed finger of males. The specimen described here lacks these characters; however, the distal margin of the manus and occlusal surface of the fixed finger are damaged. Because the specimen possesses some of the diagnostic features of the genus, and because the genus is well-known from the Pacific Northwest of North America (Schweitzer Hopkins and Feldmann, 1997), the specimen is questionably referred to that genus. The subdued ornamentation differentiates the

new species from all other known species of the genus.

Schweitzer Hopkins and Feldmann (1997) described sexual dimorphism for species of *Callianopsis*. The new specimen does not display characters necessary to recognize its gender. For example, the subdued ornamentation of the chela is suggestive of the female morph; however, known females have more developed ornamentation than does *Callianopsis* ? *inornatus*. The fixed finger lacks a spine on the occlusal surface, typical of males, but as mentioned, that region is damaged. The manus has the more rectangular shape typical of males. Thus, it is not possible to determine the gender of the new specimen.

The confirmed occurrence of the taxon in middle Eocene rocks of Washington would extend the geologic range of the genus in North America, having previously been reported from that area from the Oligocene to Recent (Schweitzer Hopkins and Feldmann, 1997). The genus is also known from Eocene-Miocene rocks of Japan, and thus has a North Pacific distribution.

Occurrence: The sole specimen was collected from RB32 from the locality register of Ross E. Berglund, Bainbridge Island, Washington. The specimen was recovered from the late Eocene Hoko River Formation at a site located near Neah Bay, in the SW 1/4, NW1/4, sec. 4, T33N, R15W, Cape Flattery 7.5' Quadrangle, Clallam County, Washington, and was collected and donated by Berglund.

Infraorder Palinura Latreille, 1802
Superfamily Eryonoidea De Haan, 1841
Family Polychelidae Wood-Mason, 1874

Genus *Palaeopentacheles* von Knebel, 1907

Type species: *Eryon röttenbacheri* Münster, 1839.

Included species: *Palaeopentacheles roettenbacher*i (Münster, 1839), *P. starri* sp. nov.

Diagnosis: Carapace longer than wide, front projected beyond deep-set, ovoid orbital indentations; lateral margins convex, dentate; carapace surface with reduced axial keel and faint cervical groove; abdomen with axial spines; first pereiopods long, claws robust, fingers with long, needle-like denticles.

Palaeopentacheles ? starri sp. nov.
(Figs. 11, 12)

Material: The holotype, and sole specimen, USNM 512162, is deposited in the United States National Museum of Natural History, Smithsonian Institution, Washington, D. C.

Etymology: The trivial name honors David Starr, Bellevue, Washington, for the many contributions he has made as an amateur collector to the study of paleontology of the Pacific Northwest of North America.

Diagnosis: Lateral margins only slightly convex, bearing fewer, coarser spines that type species; axial keel nodose.

Description: Carapace large for genus, about 1.2 times as long as wide, widest at midlength, flattened and does not appear to have been vaulted. Lateral margins not well defined. Right lateral margin with more than 7 strong anterolaterally-directed spines spaced about 4.5 spines per cm. Dorsal midline with subtle granular to nodose ridge most strongly developed at midlength and becoming obscure anteriorly and posteriorly. One pair of cardiac(?) spines situated adjacent midline. Abdomen poorly preserved; tapering slightly toward posterior; axis of terga with apparently one prominent spine per somite.

First pereiopods extremely long, slender. Ischium appears to be shorter than merus. Manus shape not discernable. Fingers long, slender, bearing long, curved denticles arrayed about 14 per cm, becoming longer distally.

Measurements: Because of the fragmentary nature of the material, no reliable measurements can be taken. The carapace is at least 31 mm wide and 42 mm long. The abdomen is approximately 26 mm wide. The longest well-defined limb element is the right merus?, 56 mm long. The longest fragment of finger is 13 mm long.

Discussion: As can be discerned from the sketchy description of the specimen, the preservation is poor enough that positive generic identification is not possible. However, there are several aspects of morphology that strongly suggest that the specimen is an eryonoid, probably a polychelid, and possibly *Palaeopentacheles*. The badly fragmented specimen is preserved in its entirety within a concretion and is oriented in such a way as to indicate that the animal came to rest on its ventral surface. This preservational orientation is typical of the eryonoids, among others, because they are dorso-ventrally compressed so that, upon death, the most stable position of repose would be with the venter on the substratum. In addition, eryonoids, including polychelids, have very long first pereiopods that extend outward in an anterolateral orientation. The pereiopods would further ensure that the dead animal would come to rest on its ventral surface. Polychelids exhibit a serrated lateral margin on the carapace,

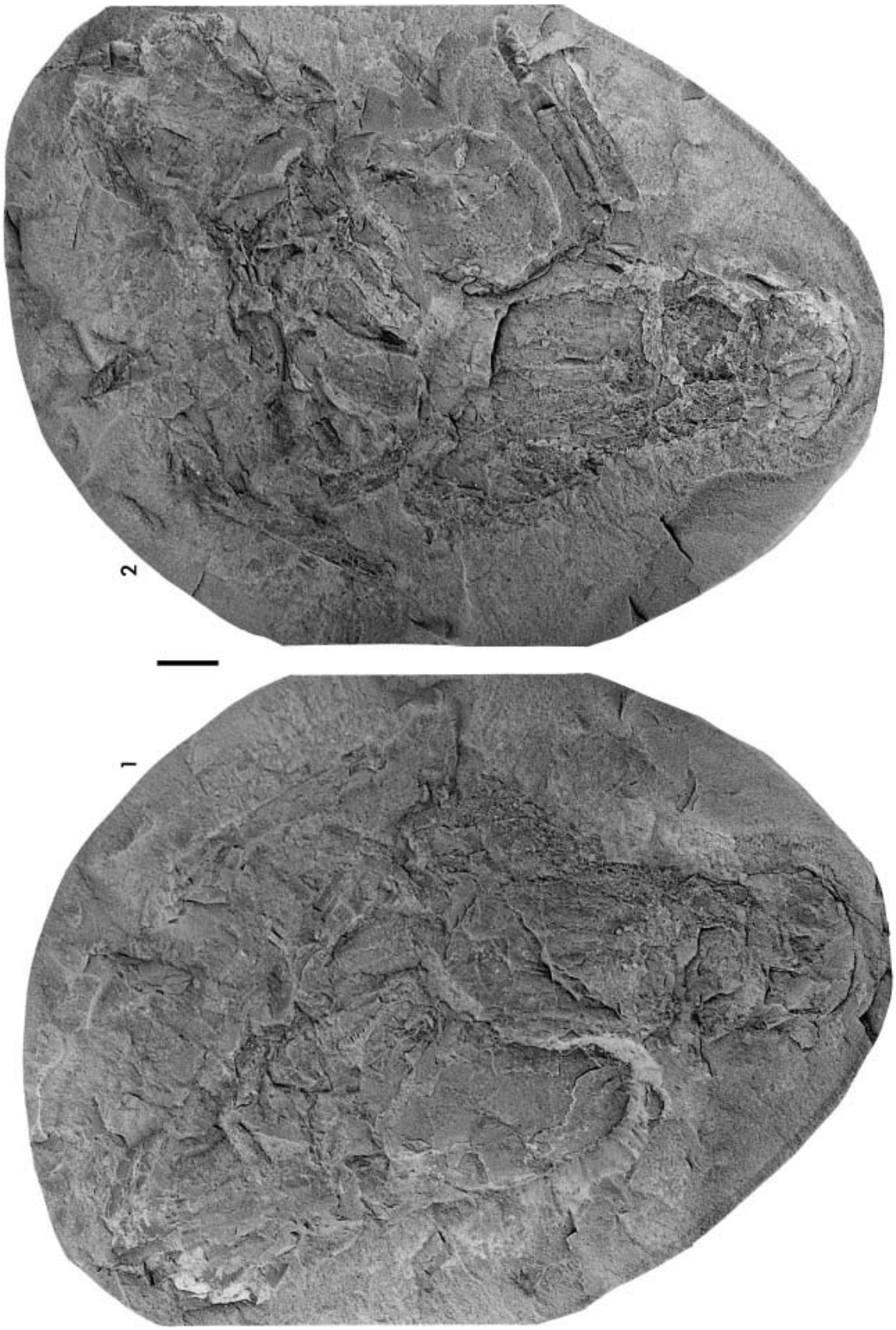


Fig. 11. 1, 2, part and counterpart of *Palaeopentacheles ? starri* sp. nov., holotype, USNM 512162. Scale bar equals 1 cm.

a feature seen on the specimen under consideration. Among the polychelids, the only genus that has strongly denticulate first pereiopods is *Paleopentacheles*.

To our knowledge, the only other known species of this genus is the type species, *P. roettenbacheri* (Münster, 1839) from the Upper Jurassic Solnhofen Limestone near Eichstädt and Solnhofen, Germany (Van Straelen, 1924 [1925]). Thus, discovery of a specimen referrable to this genus in the Oligocene of Washington greatly expands the geographic and stratigraphic range of the taxon. It is partly for this reason that the generic identity is questioned.

Occurrence: The specimen was collected by David Starr, Bellevue, Washington, from the intertidal zone at Shipwreck Point, east of Neah Bay, NE1/4, sec. 36, T33N, R14W, Clallam Bay 15' Quadrangle, Clallam County, Washington, from a concretion in deepwater siltstones of the early Oligocene Makah Formation.

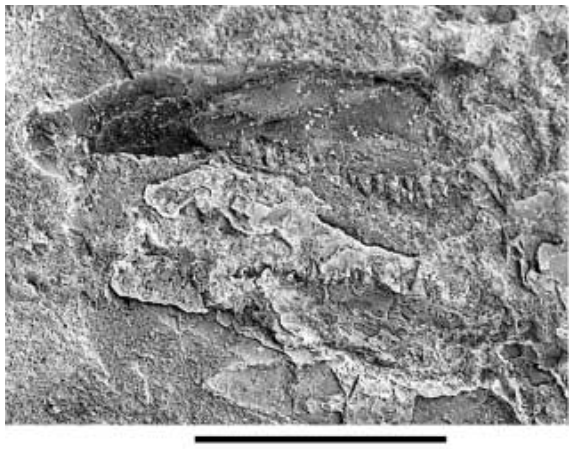


Fig. 12. Enlargement of a portion of *Palaeopentacheles* ? *starri* sp. nov., holotype, USNM 512162, showing the elongate denticles on the fixed and moveable fingers of one of the first pereiopods. Scale bar equals 1 cm.

Infraorder Anomura MacLeay, 1838

Superfamily Paguroidea Latreille, 1802

Discussion: The Paguroidea as currently known in the fossil record is in need of revision, because most fossil taxa are typically referred to only two families, the Diogenidae Ortmann, 1892, and the Paguridae Latreille, 1802, within the superfamily, and only a few of the numerous existing genera within those families, including among others *Pagurus* Fabricius, 1775, *Paguristes* Dana, 1851, *Dardanus* Paulson, 1875, and *Petrochirus* Stimpson, 1859. Assignment of fossil material within the Paguroidea is relatively straight-forward at the family level because family-level classification is based in part upon characters of the major and minor chelae, the most commonly preserved portion of the organism in fossil specimens. Members of the Diogenidae are diagnosed by possession of equal, subequal, or very unequal chelipeds; in the cases in which the chelipeds are very unequal, the left is the largest (Forest and de Saint Laurent, 1967). Members of both the Paguridae and the Parapaguridae Smith, 1882, have very strong right chelae; however, the chelae of the Parapaguridae may be differentiated from those of the Paguridae by several means. Among the Parapaguridae, members are typified by possession of a manus of the major chela that becomes highest distally and that can be quite convex along the upper and especially the lower margins. The movable finger is typically oriented in a strongly deflexed manner, such that it articulates with the very short fixed finger at a steep angle. The movable finger is often strongly arched. The parapagurids are also typified by a minor chela that is more slender and more poorly ornamented than the major chela (Lemaitre, 1989, 1990). Among the Paguridae, members are characterized by possession of a long carpus, a manus that maintains an approximately equal height along its length, and long, weakly arched or nearly straight fingers. Members of the Pylochelidae Bate, 1888, have symmetrical chelae (Forest, 1987). The lower margin of the manus of the major cheliped is strongly convex in many members of the Pylochelidae, and the fixed finger is weakly or strongly deflexed upward. The movable finger is usually shorter than the fixed finger, and the fingers articulate such that they touch only at the tips. The upper margin of the manus of many members is ornamented with long, stout, spines. Members of the Coenobitidae Dana, 1851, are terrestrial and thus less likely to be found fossilized. They are characterized by a manus of the major chela that is very much larger than the other articles of the cheliped and that has an extremely convex lower margin; a very high, stout fixed finger; and short fingers. Taxa within the Lithodidae Samouelle, 1819, have a strong right chela and chelae with a triangular cross-section, while hermit crabs typically have chelae with a circular cross-section (Vega et al., 2001). Lithodids are not hermit crabs, and as free-living forms, might be expected to be found associated with their well-calcified dorsal carapaces.

Although classification at the family level is straightforward, assignment at the generic level is much more difficult because most of the generic level characters are fea-

tures of the dorsal carapace, mouthparts, and appendages that rarely fossilize. Thus, assignment at the generic level must be accomplished by placing fossil taxa within a genus that can best accommodate the morphology of the chelipeds. Almost all fossil occurrences of hermit crabs known from the fossil record are based solely upon mani, propodi, dactyls, or some combination of these; thus, generic assignments are made based only upon those articles and are by nature imprecise. The two new taxa described here are remarkable for their level of preservation, and in both cases, include articles of the major cheliped other than the chela and portions of the minor cheliped including the chela. Thus, the fossil taxa herein were assigned at the generic level using not only the major chela but also the carpus and manus of the major cheliped as well as features of the minor cheliped.

Family Diogenidae Ortmann, 1892

Discussion: Members of the Diogenidae are diagnosed by possession of equal, subequal, or very unequal chelipeds; in the cases in which the chelipeds are very unequal, the left is the largest (Forest and de Saint Laurent, 1967). In the new species to be described here, the claws are subequal in size, with the right being slightly larger than the left. Because of its subequal chelae, the new taxon is placed within the Diogenidae. It cannot be accommodated within the Paguridae or Parapaguridae, because members of those families have very unequal chela, with the right being the strongest (Forest and de Saint Laurent, 1967; Lemaitre, 1989). Members of the Parapaguridae often live in association with corals or in gastropod shells infested by corals or sponges and sometimes demonstrate an abandonment of the shell-inhabiting habit (Lemaitre, 1989, 1990, 1998). Additionally, parapagurids are often found in outer sublittoral environments. These habits are not congruent with the gastropod and plant material-rich, coral-deficient, siliciclastic shallow water deposits in which these fossils were collected. Members of the Coenobitidae live in terrestrial habitats, not congruent with the marine deposits in which the material was found. Members of the Pylochelidae have symmetrical chelae (Forest, 1987), thus excluding the new material from that family.

Genus *Paguristes* Dana, 1852

Type species: *Paguristes hirtus* Dana, 1852, by subsequent designation of Stimpson, 1858.

Discussion: Generic placement of the new material is difficult because only the major and minor chelipeds are preserved. However, the material is most easily embraced within the genus *Paguristes* for several reasons. Members of *Paguristes* are diagnosed by possession of subequal pereiopods, which characterizes the new material as well. The carpus of members of *Paguristes* is short; highest distally; has a concave, arcuate lower margin; and is ornamented with spines and nodes; all of these are also features of the new material. The manus of members of *Paguristes* is short; shortest along the upper margin; and ornamented with numerous large tubercles and spines. The fixed finger is stout and very high proximally as are the fixed fingers in the new material. Because the features of the chelipeds of the fossil material are more similar to members of *Paguristes* than any other known genus, the new material is placed within *Paguristes*.

Rathbun (1926) described *Dardanus subaequalis* from Eocene rocks of California. She reported that the claws were subequal, and the left was described as the major chela (Rathbun, 1926). Members of *Dardanus* are characterized by having a left cheliped that is much larger than the right and do not usually have subequal chela (Rathbun, 1926; Forest and de Saint Laurent, 1967). Because the chelipeds are almost identical in size in *Dardanus subaequalis*, and because that taxon is very similar to the new material described herein, *Dardanus subaequalis* is herein placed within *Paguristes*. Thus, *Paguristes* is now known from Eocene rocks of California and Washington, U.S.A. Rathbun (1926) reported *Paguristes* sp. from Miocene rocks of California, but the specimen is very poorly preserved, and generic placement cannot be confirmed.

Paguristes hokoensis sp. nov.

(Fig. 13)

Material: Twenty-five specimens, USNM 512173, holotype, and USNM 512174-512177; 512179-512197, paratypes, are deposited in the United States National Museum of Natural History, Smithsonian Institution, Washington, D. C.

Etymology: The trivial name is derived from the Hoko River Formation, the rock unit from which all of the type specimens were collected.

Diagnosis: Carpus of major cheliped short, highest distally, with spines along upper margin; manus of major chela short, highest proximally, ornamented with tubercles arranged in two rows on outer surface as well as other random tubercles with distally directed setal pits; fixed

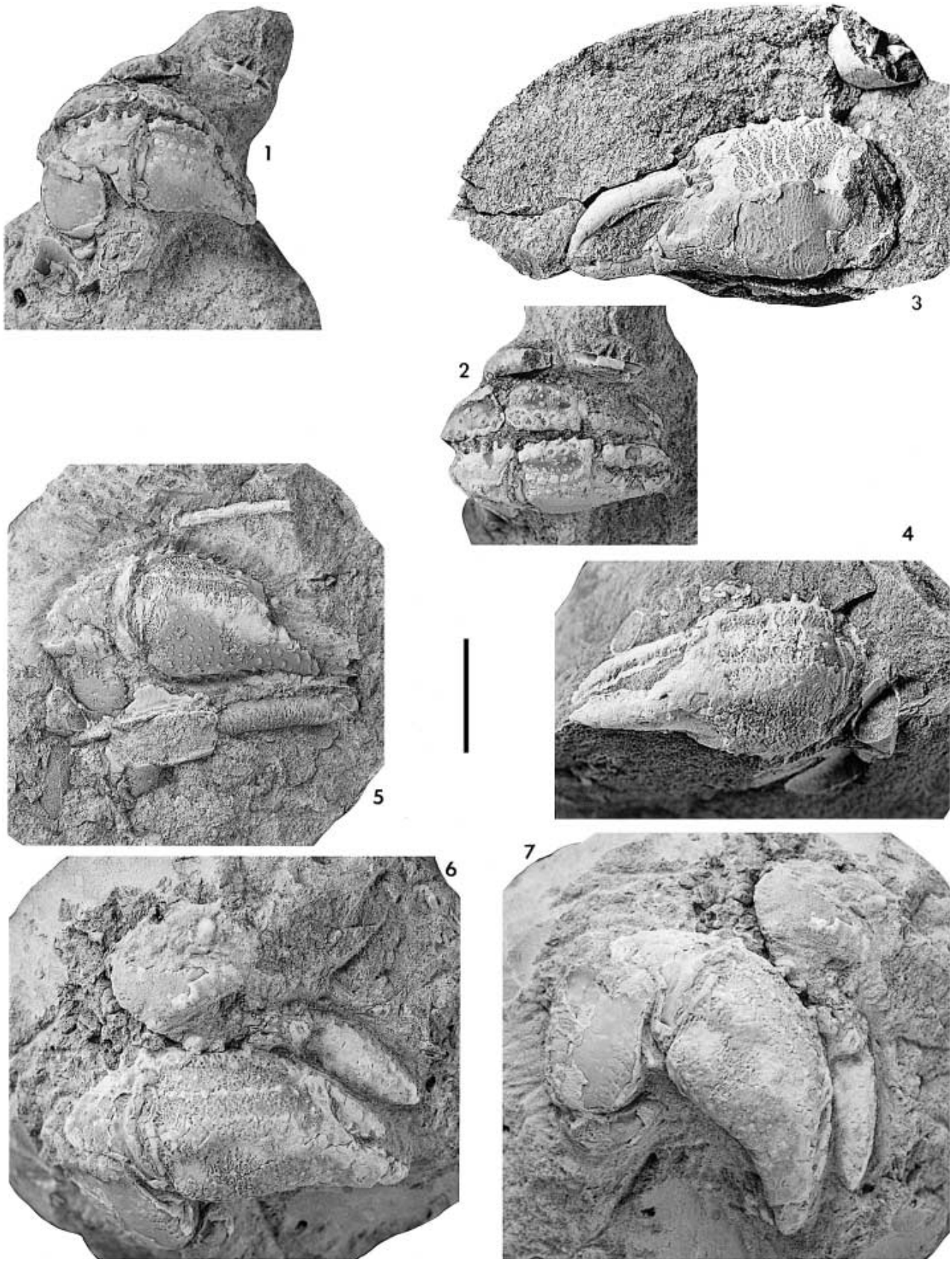


Fig. 13. *Paguristes hokoensis* sp. nov. 1, right major chela of holotype, USNM 512173. 2, view of upper margin of major chela and subequal minor chela, holotype, USNM 512173. 3, inner surface of right major chela, paratype, USNM 512184. 4, left major chela, paratype, USNM 512196. 5, outer surface of manus of right major chela with exceptionally well-preserved ornamentation, paratype, USNM 512185. 6, oblique view of manus of right major chela, paratype 512176. 7, view of manus, carpus, and merus of major chela, paratype, USNM 512176. Scale bar equal to 1 cm.

finger weakly deflexed, stout, highest proximally. Minor chela of same general shape as major but somewhat smaller.

Description: Merus of major cheliped somewhat longer than high; subrectangular; proximal margin convex; lower margin sinuous; upper margin convex; distal margin concave.

Carpus of major cheliped about as long as high, highest along distal margin articulation with manus, narrowing proximally to articulation on upper proximal margin with merus; distal margin weakly concave; upper margin with at least five short, stout spines; outer surface with two weak rows of small tubercles paralleling upper margin.

Manus of major cheliped longer than high, widest proximally and narrowest distally, vaulted outer surface, flattened inner surface; proximal margin nearly straight, with central extension forming articulation with carpus; lower margin nearly straight; upper margin sloping downward distally ornamented with several stout spines; distal margin at about 100 degree angle to upper margin, appearing to have some small, stout spines; outer surface with two rows of spherical tubercles parallel and near to upper margin, remainder of outer surface with distally directed tubercles with setal pits. Fixed finger deflexed weakly, with tubercles with forward directed setal pits; occlusal surface with blunt tubercles; finger narrowing distally. Movable finger strongly arched, narrowing distally with blunt tubercles on occlusal surface.

Minor cheliped smaller than major but not considerably so. Carpus of minor cheliped ornamented with large, stout tubercles on outer and lower margins. Manus of minor cheliped ornamented with large tubercles on outer and lower margins; fingers appearing to be ornamented with tubercles.

Remainder of carapace and appendages not sufficiently preserved to permit description.

Measurements: Measurements (in mm) taken on the major chela of specimens of *Paguristes hokoensis* are listed in Table 1. Measurements (in mm) taken on the carpus of the major cheliped are listed in Table 2. Measurements (in mm) taken on the merus of the major cheliped: USNM 512173, maximum length, 7.7; maximum height, 6.6; USNM 512176, maximum length, 14.2; maximum height, 11.0. Measurements (in mm) taken on the manus of the minor chela: USNM 512173, maximum length including fixed finger, 14.2; length excluding fixed finger, 7.9; maximum height, >5.2; length of movable finger, 8.4.

Discussion: *Paguristes hokoensis* sp. nov. is represented by numerous specimens, most of which retain only the major chela, some with fragments of other pereiopod articles. The holotype, USNM 512173, has the most completely preserved major and minor chelae. Most of the specimens retain cuticle, but in most it is badly damaged. USNM 512185 has exceptionally well-preserved ornamentation, in which the forward-directed setal pits can be observed within the tubercles. All of the specimens were preserved in concretions.

Paguristes hokoensis sp. nov. is similar to *Paguristes subaequalis* (Rathbun, 1926) comb. nov. but differs from it in several ways. *Paguristes subaequalis* has three rows of tubercles on the outer surface of the major chela, while *P. hokoensis* has only two, and the ornamentation on *P. subaequalis* is more subdued than that of *P. hokoensis*.

Paguristes ouachitaensis Rathbun, 1935, is poorly preserved and has much finer ornamentation than does *P. hokoensis*.

Table 1. Measurements (in mm) taken on the manus of the major cheliped of specimens of *Paguristes hokoensis* sp. nov.

Specimen Number	Length Including Fixed Finger	Length Excluding Fixed Finger	Height	Length of Movable Finger
USNM 512173	15.2	7.9	> 5.2	8.4
USNM 512184	27.6	16.6	14.2	12.9
USNM 512185	18.8	12.9	11.2	N/A
USNM 512176	27.2	18.3	14.3	N/A
USNM 512196	23.3	14.8	13.7	12.2
USNM 512180	31.6	17.7	14.0	17.8
USNM 512179	> 17.7	12.0	10.5	> 8.2
USNM 512181	N/A	12.5	11.9	N/A

Table 2. Measurements (in mm) taken on the carpus of the major cheliped of *Paguristes hokoensis* sp. nov.

Specimen Number	Maximum Length	Maximum Height
USNM 512173	7.1	8.0
USNM 512185	9.2	10.2
USNM 512176	10.9	12.0
USNM 512179	8.8	9.5
USNM 512181	7.3	11.2

Paguristes johnsoni Rathbun, 1935, lacks the two rows of tubercles on the outer surface of the manus of the major chela as seen on that of *P. hokoensis*. *Paguristes chipolensis* Rathbun, 1935 is represented only by dactyls and propodi and is thus not sufficiently preserved to permit comparison with *P. hokoensis*. The manus of the major chela is much shorter and the tubercles are much larger on *P. cserhatensis* Müller, 1984, than on *P. hokoensis*. The manus of the major chela of *P. florae* Collins, Fraaye, and Jagt, 1995, has a much more rounded, convex lower margin and a rim of very small granules, differentiating that species from *P. hokoensis*. Collins and Portell (1998) described *Paguristes* sp. from the Pliocene of Jamaica; however, that species is known only from a dactyl which is characterized by much larger teeth on the occlusal surface than are known in *P. hokoensis*. *Paguristes oligotuberculatus* Müller and Collins, 1991, has a much higher and stouter fixed finger and a much shorter manus of the major chela than does *P. hokoensis*.

Karasawa (1993, 1997) illustrated several genera and species of paguroid decapods, but most, including "*Dardanus*" *mulleri* Karasawa and Inoue, 1992, and *Pagurus* sp. Karasawa, 1993, are differentiated from *Paguristes hokoensis* by generic level characters. Six species belonging to either the Diogenidae or the Paguridae were illustrated by Kato and Karasawa (1998), but these species belong to genera other than *Paguristes* and are thus differentiated from it by generic level characters.

Occurrence: Fifteen specimens, USNM 512183-512197, were collected from the RB32 locality, described above, from the late Eocene Hoko River Formation. Four specimens, USNM 512179-512182, were collected from RB33, also located in the late Eocene Hoko River Formation, in the W1/2, N1/2, sec. 4, T33N, R15W, Cape Flattery 15' Quadrangle, near West Kydikabbit, Washington. Five specimens, USNM 512173-512177, were collected from unknown localities within the Hoko River Formation.

Family Paguridae Latreille, 1802

Discussion: Members of the Paguridae and Parapaguridae are diagnosed by having strongly unequal chelae, with the right always being the largest. The new taxon to be described below is characterized by possession of very large right chelae and very much smaller left chelae. Thus, it cannot be placed within the Diogenidae, which is characterized by equal, subequal, or unequal chelae with the left being the larger (Forest and de Saint Laurent, 1967). The Coenobitidae embraces terrestrial forms, and the Pylochelidae includes those paguroids with symmetrical chelae, thus neither family can embrace the new taxon.

The new material has major chelae typical of the Paguridae, not the Parapaguridae, as defined above, and the habit and ecology of members of the parapagurids is not congruent with the nature of the deposits and fauna associated with the new fossils. Thus, the new material is excluded from the Parapaguridae and placed within the Paguridae.

Genus *Pagurus* Fabricius, 1775

Type species: *Cancer bernhardus* Linnaeus, 1758.

Discussion: Placement of the new material within a genus is difficult because of the incomplete nature of the material, composed of portions of a major and minor chela in the holotype, and portions of a major chela and two pereiopods in the paratype. The new material shares several features with extant members of *Pagurus*, which is widely acknowledged to most likely be an amalgamation of several taxa. Because the new material has a long carpus of the major chela; a manus that maintains its height along its entire length; nearly straight fingers; and well-developed, dense tuberculate ornamentation, we have taken the most conservative approach and placed the material within *Pagurus*. Numerous fossil taxa have been assigned to *Pagurus*; however, that taxon as known in the fossil record is badly in need of revision.

Pagurus malloryi sp. nov.

(Fig. 14)

Material: The holotype, USNM 512171, and a paratype, USNM 512172, are deposited in the United States Museum of Natural History, Smithsonian Institution, Washington, D. C.

Etymology: The trivial name honors Dr. V. Standish Mallory, who served for many years as the Curator of Invertebrates at the Thomas Burke Memorial Washington State Museum, Seattle, Washington.

Diagnosis: Carpus of major cheliped longer than high, densely ornamented with tubercles; manus of major cheliped somewhat longer than high, ornamented on outer surface with densely spaced, long tubercles; fixed finger short; movable finger nearly straight; minor chela of similar shape and ornamentation as major except smaller and somewhat more slender.

Description: Merus of major cheliped longer than high, becoming higher distally, lower margin smoothly convex, upper margin weakly convex, distal margin nearly straight along articulation with carpus, ornamented on outer surface with densely spaced tubercles. Carpus of major cheliped longer than high, becoming higher distally; proximal margin at about 50 degree angle to upper margin, angled distally;

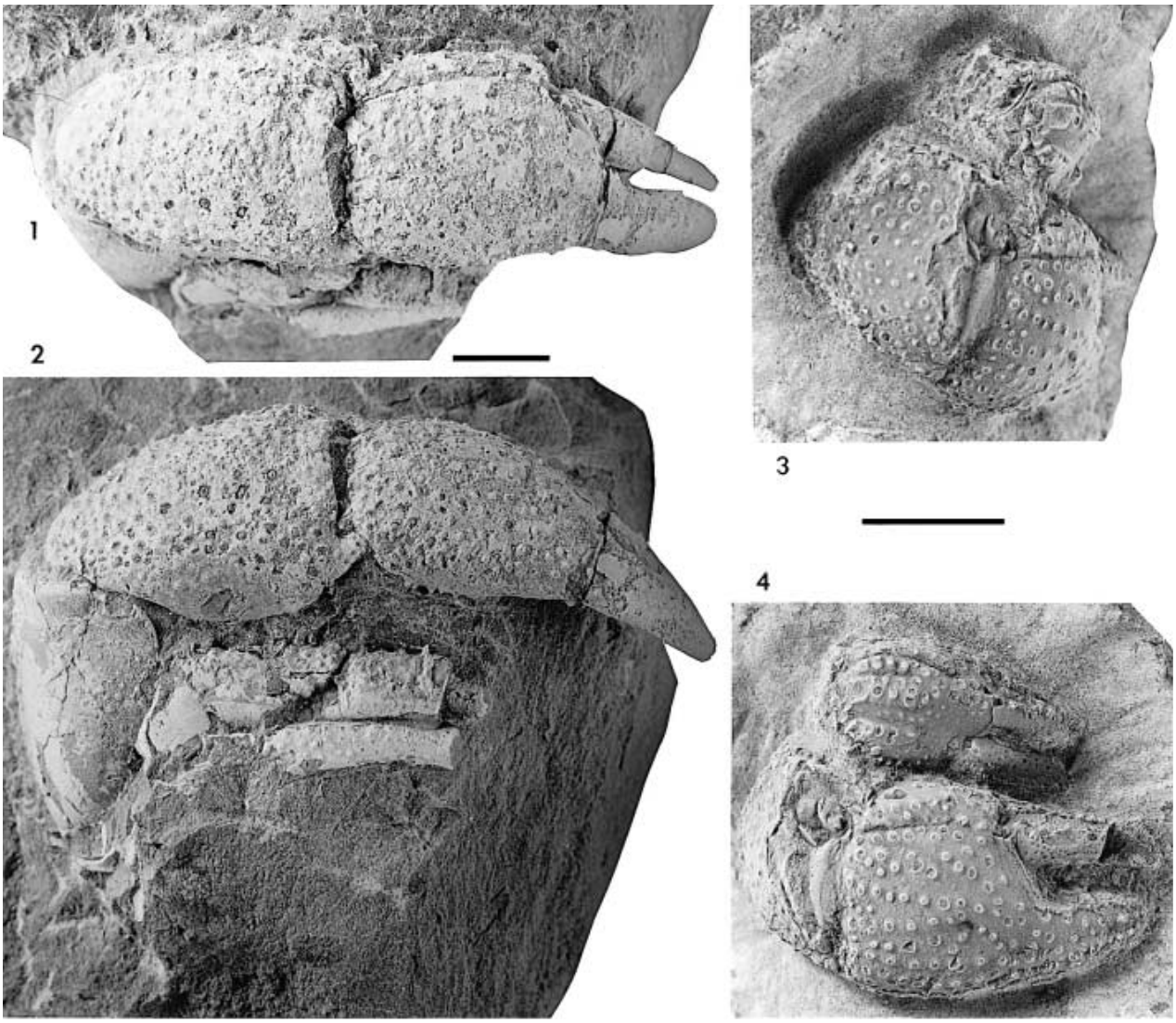


Fig. 14. *Pagurus malloryi* sp. nov. 1, manus and carpus of right major cheliped, paratype, USNM 512172. 2, oblique view showing second and third pereiopods and right major cheliped, paratype, USNM 512172. 3, partially preserved carpus of right major cheliped, holotype, USNM 512171. 4, holotype showing right major chela and markedly smaller left minor chelae, USNM 512172. Scale bars equal to 1 cm.

lower margin short, weakly convex; upper margin long, weakly convex; distal margin nearly straight along articulation with manus, with large, blunt spine at lowermost articulation with manus. Manus longer than high, decreasing in height distally; ornamented on outer surface with long tubercles roughly arrayed in rows, tubercles appearing as circular pits when broken; proximal margin with central flange at articulation with carpus; lower margin convex, with tubercles; upper margin with tubercles, weakly convex; distal margin nearly straight, at 130 degree angle to upper margin. Fixed finger curved, stout, rounded; ornamented with rounded, high tubercles. Movable finger more slender than fixed finger, nearly straight with curved tip; occlusal surface with blunt tubercles; upper margin apparently with tubercles.

Minor chela much smaller than major chela; bulbous, outer surface ornamented with poorly developed rows of tubercles, smoother near bases of fingers; upper, lower, and proximal margins convex; distal margin at 130 degree angle to upper margin; fingers ornamented with tubercles, appearing to be nearly straight.

Articles of second and third pereiopods ornamented with tubercles. Remainder of articles insufficiently preserved to permit description.

Measurements: Measurements (in mm) taken on specimens of *Pagurus malloryi*: major chela, USNM 512171, length of manus including fixed finger, 25.1; length of fixed finger, 9.5; length of movable finger, 12.6; height of manus. 15.9. Minor chela, USNM 512171, length of manus including fixed finger, 18.8; length of fixed finger, 7.6; length of movable finger, 9.5; height of manus, 9.0. Major chela, USNM 512172, length of manus including fixed finger, 43.1; length of fixed finger, 17.7; length of movable finger, 25.5; height of manus, 22.6. Carpus of major cheliped, USNM 512172, length, 35.6; height, 24.6. Merus of major cheliped, USNM 512172, length of merus, 29.2; height of merus, 21.3.

Discussion: The two specimens assigned to this species have very different types of preservation. The holotype, USNM 512171, was preserved in a concretion, and the cuticle is preserved as a brownish substance that breaks with a conchoidal fracture. The paratype, USNM 512172, was not preserved in a concretion, and the cuticle is poorly preserved as a powdery, white substance. The two specimens were collected from different localities within the same formation. This differential preservation of the material suggests that taphonomic processes and/or environmental conditions varied during the time of deposition of the Makah Formation.

Several species of *Pagurus* have previously been reported from the fossil record. *Pagurus latidactylus* Müller and Collins, 1991, and *P. marceti* Via, 1959, have a shorter manus and smaller, less spine-like tubercles on the manus of the major chela than does *P. malloryi*. The tubercles of the manus of the major chela of *P. mezi* Lörenthey, 1909, are much finer, more widely spaced, and less spine-like than those of *P. malloryi*. *Pagurus concavus* Müller, 1979, has very fine tubercles and a longitudinal keel on the outer surface of the major chela, which *P. malloryi* lacks. *Pagurus rakosensis* Müller, 1979, has a longitudinal ridge of tubercles on the outer surface of the manus, which *P. malloryi* lacks. *Pagurus albus* Müller, 1979, is similar to *P. malloryi* in the shape of the manus and fixed finger of the major chela but has coarser and less-densely spaced ornamentation than does *P. malloryi*. ? *Pagurus turcus* Müller, 1984, has a much more ovoid manus and coarser and more densely-spaced ornamentation than does *P. malloryi*. The overall shape of the manus of the major chela and the markedly arched shape of the movable finger of *P. banderensis* Rathbun, 1935, differentiate it from *P. malloryi*. The shape of the manus and fingers of *P. banderensis* suggests that it may in fact be referrable to the Parapaguridae. *Pagurus alabamensis* Rathbun, 1935, is similar in the nature of the ornamentation and the shape of the manus of the major chela to *P. malloryi*; however, the movable finger is nearly straight in *P. malloryi* while it is strongly arched in *P. alabamensis*. *Pagurus* sp. Karasawa, 1993, has much coarser and more broadly spaced tubercles than does *P. malloryi*. Four species illustrated by Kato and Karasawa (1998) differ from *P. malloryi* because *P. malloryi* possesses coarser and less closely spaced ornamentation than do the Japanese species. The remainder of the Japanese paguroid material as listed previously is differentiated from *P. malloryi* by generic-level characters.

Occurrence: The holotype, USNM 512171, was collected from the RB62 locality of Ross E. Berglund, along the Strait of Juan de Fuca, near the northwest tip of the Olympic Peninsula, 3 miles west via Highway 112 from the mouth of Jansen Creek, SW1/4, sec. 22, T33N, R14W, Cape Flattery 15' Quadrangle, Clallam County, Washington, from rocks of the Jansen Creek Member of the lower Oligocene Makah Formation. The paratype, USNM 512172, was collected from the Jansen Creek Member of the lower Oligocene Makah Formation, about 1 km west of

the mouth of Jansen Creek, in SE1/4, SE1/4, sec. 26, T33N, R14W, Clallam Bay 15' Quadrangle, Clallam County, Washington.

Infraorder Brachyura Latreille, 1802
Section Podotremata Guinot, 1977
Family Raninidae de Haan, 1841
Subfamily Notopocorystinae Lörenthey *in* Lörenthey and Beurlen, 1929

Genus *Eucorystes* Bell, 1863

Included species: *Eucorystes carteri* (McCoy, 1854); *E. eichhorni* Bishop, 1983; *E. harveyi* (Woodward, 1896), *E. intermedius* Nagao, 1931; *E. oxtedensis* Wright and Collins, 1972; *E. platys* sp. nov.

Discussion: Both Tucker (1995) and Collins (1996) have recently discussed the generic status of *Notopocorystes* McCoy, 1849 (=*Palaeocorystes* Bell, 1863), *Eucorystes*, and *Cretacoranina* Mertin, 1941. Glaessner (1969) considered *Eucorystes* to be a synonym of *Notopocorystes* and *Cretacoranina* to be a subgenus of *Notopocorystes*. Wright and Collins (1972) reinstated *Eucorystes* as a separate taxon and considered both *Eucorystes* and *Cretacoranina* to be subgenera of *Notopocorystes*. They argued that the differences in ornamentation and other features among the three genera were gradational and that they were thus best designated as subgenera of *Notopocorystes*. Collins (1996) concurred with his and Wright's earlier conclusion. Tucker (1995) argued that the subgenera of *Notopocorystes* should be elevated to generic status, thus rendering *Notopocorystes*, *Eucorystes* and *Cretacoranina* separate genera. We concur with Tucker (1995) and consider the three genera as distinct. They are in fact readily differentiated based upon the degree of ornamentation on the dorsal carapace. Members of *Cretacoranina* have no strap-like or nodose ornamentation on the dorsal carapace; species of *Eucorystes* have strap-like ornamentation anteriorly on the carapace; and members of *Notopocorystes* have ridges and nodes developed on the carapace. Additionally, members of *Cretacoranina* appear to have more and better developed orbital and anterolateral spines than either *Eucorystes* or *Notopocorystes*, and the frontal margin of *Notopocorystes* is somewhat narrower than that of either *Eucorystes* or *Cretacoranina*. We have followed Tucker (1995) and Collins (1996) in assignment of species to *Eucorystes*; however, we have also placed *Palaeocorystes harveyi*, named by Woodward (1896) for material collected from the Cretaceous of Vancouver Island, British Columbia, within *Eucorystes*. Both Collins (1996) and Tucker (1995) placed that species within *Cretacoranina*; however, the clearly exhibited strap-like ornamentation (see Rathbun, 1926, pl. 20, fig. 4) places this species within *Eucorystes*.

Species within *Eucorystes* are known from Cretaceous rocks of Japan (Collins, Kanie, and Karasawa, 1993), Britain (Wright and Collins, 1972), the western Interior of the United States (Bishop, 1983b), Vancouver Island, British Columbia (Woodward, 1896) and Oregon (herein). The earliest occurrences are in Albian rocks of Britain and Oregon, while the Japanese and other North American occurrences are in younger rocks of the Santonian-Campanian. This pattern suggests that the genus dispersed via a north polar route, either from Britain or northwestern North America to the remainder of its range. Numerous other Cretaceous and Paleocene genera display such a dispersal pattern as will be discussed below.

Eucorystes platys sp. nov.
(Figs. 15, 16)

Types: The holotype and sole specimen, USNM 512163, is deposited in the United States National Museum of Natural History, Smithsonian Institution, Washington, D. C.

Etymology: The trivial name is taken from the Greek word "platys," meaning broad, in reference to the broadness of

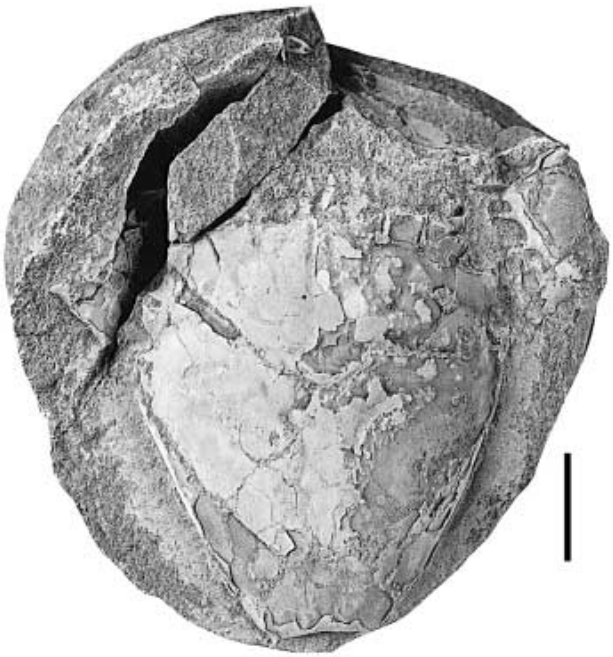


Fig. 15. *Eucorystes platys* sp. nov., dorsal carapace, holotype, USNM 512163. Scale bar equal to 1 cm.

the anterior portion of the dorsal carapace.

Diagnosis: Carapace longer than wide; ornamented with strap-like ornamentation; rostrum bifid; orbital margins long, sinuous, with two nearly closed fissures, terminating in outer-orbital spine; anterolateral margin short, with two spines; posterolateral margin long, smooth; strap-like ornamentation forming straight and parallel sided epibranchial ridge.

Description: Carapace longer than wide, W/L about 0.75, widest at position of second anterolateral spine, about one-third the distance posteriorly on carapace; regions poorly defined; gastric and anterior branchial regions ornamented with strap-like ornamentation, straps raised slightly above remainder of surface, finely granular. Carapace moderately vaulted transversely and longitudinally.

Rostrum projected well beyond orbits, bifurcate, each bifurcation a needle-like, triangular spine. Orbits extremely broad; orbital width to maximum width equal to about 0.30; fronto-orbital width to maximum width about 0.65; orbital margin weakly sinuous, with two nearly closed fissures of about the same length; outer edge of margin terminating in broad, short, triangular spine. Anterolateral margin short, with two spines; first spine broadest, longest, directed slightly anterolaterally; second spine shorter, directed anterolaterally. Posterolateral margin long, smooth, weakly convex anteriorly and straighter posteriorly. Posterior margin narrow, concave, about 30 percent maximum width.

Protogastric regions with granular strap-like ornamentation, about as broad as long; hepatic regions small, triangular, with raised granular ornamentation; mesogastric region with long anterior process, widening and triangular posteriorly, lateral margins nearly straight, posterior margin convex. Urogastric and cardiac regions confluent, elongate, with sinuous lateral margins, cardiac area bounded by relatively deep branchiocardiac groove. Intestinal region not differentiated. Branchial regions not well differentiated; ornamented anteriorly with strap-like ornamentation; ornamentation forming an epibranchial ridge with straight, parallel sides, directed slightly posterolaterally from base of urogastric area; additional strap-like ornamentation posterior to epibranchial ridge; remainder of region apparently mostly smooth.

First pereiopod with short carpus, with long, distally directed spines on upper margin. Chela narrowing proximally, with at least three distally directed spines on upper and lower margins. Fixed finger directed weakly downward, triangular, narrowing distally. Movable finger narrower than fixed finger.

Venter unknown.

Measurements: Measurements (in mm) taken on the dorsal carapace of *Eucorystes platys*: maximum width (W1), 33.1; maximum length (L1), 41.9; fronto-orbital width (W2), 26.4; orbital width (W3), 11.8; posterior width (W4), 9.7. Position and orientation of measurements taken are illustrated in Fig. 16.

Discussion: The new species is based upon one specimen which retains some cuticular material but is broken and sheared in some places. Fortunately, the most important diagnostic features, the rostrum, orbits, and ornamentation, are relatively well-preserved. Haj and Feldmann (in press) demonstrated that some taxa within the Notopocorystinae exhibit a unique type of hexagonal prismatic cuticular structure; however, this structure was not observable in the cuticle remaining on the sole specimen of *Eucorystes platys* described here. Other specimens apparently referable to *Eucorystes* from the Cretaceous of Oregon do exhibit hexagonal prismatic plates (T. Nyborg, pers. commun.).

The strap-like ornamentation on the new species is not prominent but is clearly observable, especially under magnification, indicating that the new species is referable to *Eucorystes*. *Eucorystes platys* appears to be most similar to *E. harveyi* and *E. intermedius*. However, *E. platys* differs from *E. harveyi* because the former has a much greater frontal width, smaller spines, and better developed strap-like ornamentation than does *E. harveyi*. *Eucorystes*

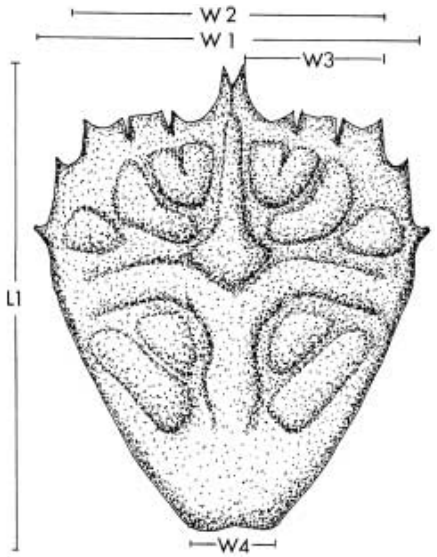


Fig. 16. Line drawing of *Eucorystes platys* sp. nov., showing the position and orientation of measurements taken.

platys differs from *E. intermedius* because *E. intermedius* is narrower overall and has frontal margins that are angled posteriorly, while those of *Eucorystes platys* are nearly parallel to one another. The strap-like ornamentation of the British species is much better developed and much more elevated above the carapace surface than that of *Eucorystes platys*. The new species differs from *E. eichhorni* because *E. eichhorni* has much better developed ornamentation and is narrower anteriorly than is *E. platys*.

The discovery of a new species of *Eucorystes* from Albian rocks of Oregon does not greatly extend the geographic range, because the genus had previously been reported from British Columbia and Montana. However, the new species occurs in considerably older rocks than either the Canadian or Western Interior species, extending the geologic range of the genus in the area.

Occurrence: The sole specimen was collected from the Albian Hudspeth Formation, 300 m east of Mud Creek, 3 miles west of Mitchell, Oregon, 1 mile south along Gable Creek Road from U.S. Highway 26, NE1/4, Sec. 33, T11S, R21E, Mitchell, Oregon 7.5' Quadrangle. The material was collected by G. J. Retallack.

Section Heterotremata Guinot, 1977

Superfamily Retroplumoidea Gill, 1894

Family Retroplumidae Gill, 1894

Diagnosis: Carapace rectilinear or ovoid, wider than long, ornamented with three transverse ridges, usually positioned on protogastric, epibranchial, and mesobranchial regions. Front narrow, downturned, axially sulcate; orbits broad, margins sinuous, often with blunt projection at midlength; orbits terminating in sharp spine. Sternum with transverse ridges mimicing those on the dorsal carapace.

Discussion: The Retroplumidae has been assigned by some authors to the Thoracotremata (Guinot, 1977; Vega and Feldmann, 1992). Herein we follow Saint Laurent (1989) and Guinot and Richer de Forges (1997) in placing the family within the Heterotremata based upon the nature of the gonopores. Saint Laurent (1989) suggested that the family be divided into two families, the Retroplumidae and the Costacoplumidae; further, she suggested removal of *Archaeopus* Rathbun, 1908, and *Cristipluma* Bishop, 1983a, from the family. Vega and Feldmann (1992) discussed the Retroplumidae at length and included the genera *Retropluma* Gill, 1894; *Archaeopus*, *Bathypluma* Saint Laurent, 1989; *Costacopluma* Collins and Morris, 1975; and *Cristipluma*. They endorsed placement of all five genera within one family based upon possession of flattened, rectilinear to ovoid carapaces and distinctive transverse carinae on the dorsal carapace. We concur with Vega and Feldmann (1992) that all five genera must be contained within one family. To that family must be added *Loerenthopluma* Beschin, Busulini, De Angeli, and Tessier, 1996, described from Eocene rocks of Italy. In addition to the other diagnostic features listed above, the retroplumids display transverse, granular ridges on the sternum which mimic those seen on the dorsal carapace. These sternal ridges are known in all taxa in which the sternum is preserved. This further suggests that these genera should be united within one family.

Vega and Feldmann (1992) suggested that the family may have originated during the Cretaceous in North America based upon the occurrence of three retroplumid genera in that area in Late Cretaceous rocks. They further suggested that the family subsequently dispersed eastward to Eurafrica and the Indo-Pacific by the Late Cretaceous, where modern members now live (Vega and Feldmann, 1992). The occurrence of *Archaeopus ezoensis* (Nagao, 1941) in Late Cretaceous rocks of Japan suggests either that dispersal occurred in a westward direction as well or alternatively that the family evolved in Japan and subsequently dispersed eastward to North America and the Atlantic Ocean.

Genus *Archaeopus* Rathbun, 1908

Type species: *Archaeopus antennatus* Rathbun, 1908.

Other species: *Archaeopus ezoensis* (Nagao, 1941); *A. lunicarina* sp. nov.; *A. vancouverensis* (Woodward, 1896).

Material: A specimen referable to *Archaeopus vancouverensis* (Woodward, 1896), collected by an anonymous collector from Upper Cretaceous rocks of Hornby Island, British Columbia, Canada, has been deposited in the United States National Museum of Natural History, Smithsonian Institution, Washington, D.C., under specimen number USNM 512169. Other specimens referable to the two new species are listed below.

Diagnosis: Carapace subquadrate, somewhat wider than long, moderately vaulted longitudinally and transversely; front narrow, produced beyond orbits, downturned, axially sulcate; orbits very wide, sinuous, terminating in sharp, anterolaterally directed post-orbital spine; protogastric regions with straight or arcuate ridge; epibranchial regions with ovoid swellings; mesogastric regions with transverse ridges; cardiac region broad, with

lobate swellings along lateral margins, transverse ridge on level with ridges of mesogastric regions; sterna with granular transverse ridges.

Discussion: Species of *Archaeopus* are united in possessing three discontinuous transverse carapace ridges; broad orbits, a narrow, sulcate front; a quadrate or subcircular carapace that is not much wider than long; lobate swellings on the cardiac region; and well-developed carapace regions. However, many of the dorsal carapace features within the genus exhibit a broad range of variation. The development of the transverse carapace ridges is quite variable, ranging from well-developed and nearly continuous in *A. vancouverensis* (Fig. 19, USNM 512169) to inconspicuous as in *A. ezoensis* (Collins et al., 1993, figs. 5.1-5.5). Additionally, the shape of the carapace ranges from quadrate in *A. lunicarina* sp. nov. to markedly wider than long in *A. antennatus* (Rathbun, 1926, pl. 4, figs. 4-7, pl. 5). The size, shape and number of swellings on the carapace also varies among species. For example, *A. vancouverensis* possesses a transverse swelling just posterior to the orbit (Fig. 19), whereas *A. lunicarina* sp. nov. has spherical swellings in that area and *A. ezoensis* lacks a swelling in that area altogether.

Species of *Archaeopus* possess transverse carapace ridges that are more poorly developed and more discontinuous than those seen in other retroplumids. Additionally, species of *Archaeopus* have better developed regions than other retroplumids. Modern retroplumids have ill-defined regions and very distinctive carapace ridges. Because *Archaeopus* is one of the oldest known retroplumid genera, discontinuous, poorly developed ridges and well-developed regions may be primitive character states within the family.

Most members of the genus are known from North America. *Archaeopus antennatus* is known from Coniacian-Maastrichtian rocks of California, and *A. vancouverensis* was reported from Late Cretaceous rocks of Canada. The new species, *A. lunicarina*, is known from Late Cretaceous rocks of Alaska. The only non-North American species is *Archaeopus ezoensis*, described from Turonian to Maastrichtian rocks of Japan. *Archaeopus rathbunae* Beurlen, 1965, is not a retroplumid and may be a carcineretid (Vega and Feldmann, 1992). This suggests that the genus may have evolved in Japan with subsequent dispersal to North America via the North Pacific or that it originated in North America with subsequent dispersal to Japan. In either case, it appears that *Archaeopus* is a North Pacific form, since its occurrences are restricted to the Pacific coast of North America and to Japan. These findings may corroborate Vega and Feldmann's (1992) hypothesis, which did not take into account *A. ezoensis* from Japan, that the Retroplumidae may have originated in the Americas and subsequently dispersed to Eurafrica and the Indo-Pacific. Alternatively, the family may have originated in the north-western Pacific Ocean and subsequently dispersed eastward to the Americas and westward to the Indo-Pacific and Eurafrica. These dispersal pathways would have been easily accommodated during the high sealevels and proximity of the continents to one another during the Late Cretaceous.

Archaeopus lunicarina sp. nov.
(Figs. 17, 18)

Material: The holotype, UAM-2574a and b, and paratypes, UAM-2575-UAM-2580, are deposited in the University of Alaska Museum, Fairbanks, Alaska.

Etymology: The trivial name is derived from the Latin words "*carina*", meaning ridge or keel, and "*luna*", meaning to bend into a crescent, describing the crescent-shaped concave ridges on the protogastric regions that are diagnostic for the species.

Diagnosis: Carapace quadrate, slightly wider than long, regions separated by distinct grooves, regions granular; rostrum projected well in advance of orbits, axially sulcate and axially notched; orbits broad, orbital margin sinuous, post-orbital spine sharp, directed anterolaterally; ridges on protogastric region concave forward, crescent-shaped; ridges on branchial and cardiac regions discontinuous, poorly developed.

Description: Small crab for genus, quadrate outline, slightly wider than long, L/W about 0.90; moderately vaulted longitudinally and transversely; carapace regions generally well-defined by distinct grooves, elevated areas on regions ornamented by fine granules.

Rostrum projected well in advance of orbital margin, axially notched, downturned, axially sulcate. Orbital margins long, each about one-third carapace width, bearing minor protuberances at about mid length, without obvious fissures, terminating laterally in prominent anterolaterally directed, sharp, needle-like spines; fronto-orbital width about three-quarters maximum width. Lateral margins slightly convex, maximum width attained about three-quarters the distance posteriorly on carapace. Posterolateral margins converge sharply to posterior margin which is straight and about one fifth maximum width.

Protogastric regions each with prominent concave-forward granular ridge extending nearly from midline to hepatic regions, small transverse swelling just posterior to orbit. Hepatic regions reduced, with small longitudinal elevation. Mesogastric region slightly elevated; bearing elongate, granular elevation just posterior to rostral sulcus and transverse granular ridge extending across widest part of region; narrow anteriorly and widest posteriorly, posterior margin convex. Urogastric region short, shortest axially and widest distally, upper margin concave, lower margin nearly straight. Cardiac region widest of all axial regions, nearly one half carapace width, generally triangular with lobose lateral swellings and convex forward transverse ridge at level of maximum width. Intestinal regions flattened, poorly developed. Cervical groove distinct laterally, concave forward, indistinct across axis. Epibranchial region with two ovoid, granular swellings. Mesobranchial region with transverse granular swelling at same level as ridge on cardiac region, forming discontinuous transverse carapace ridge. Metabranchial regions with granulated, swollen areas.

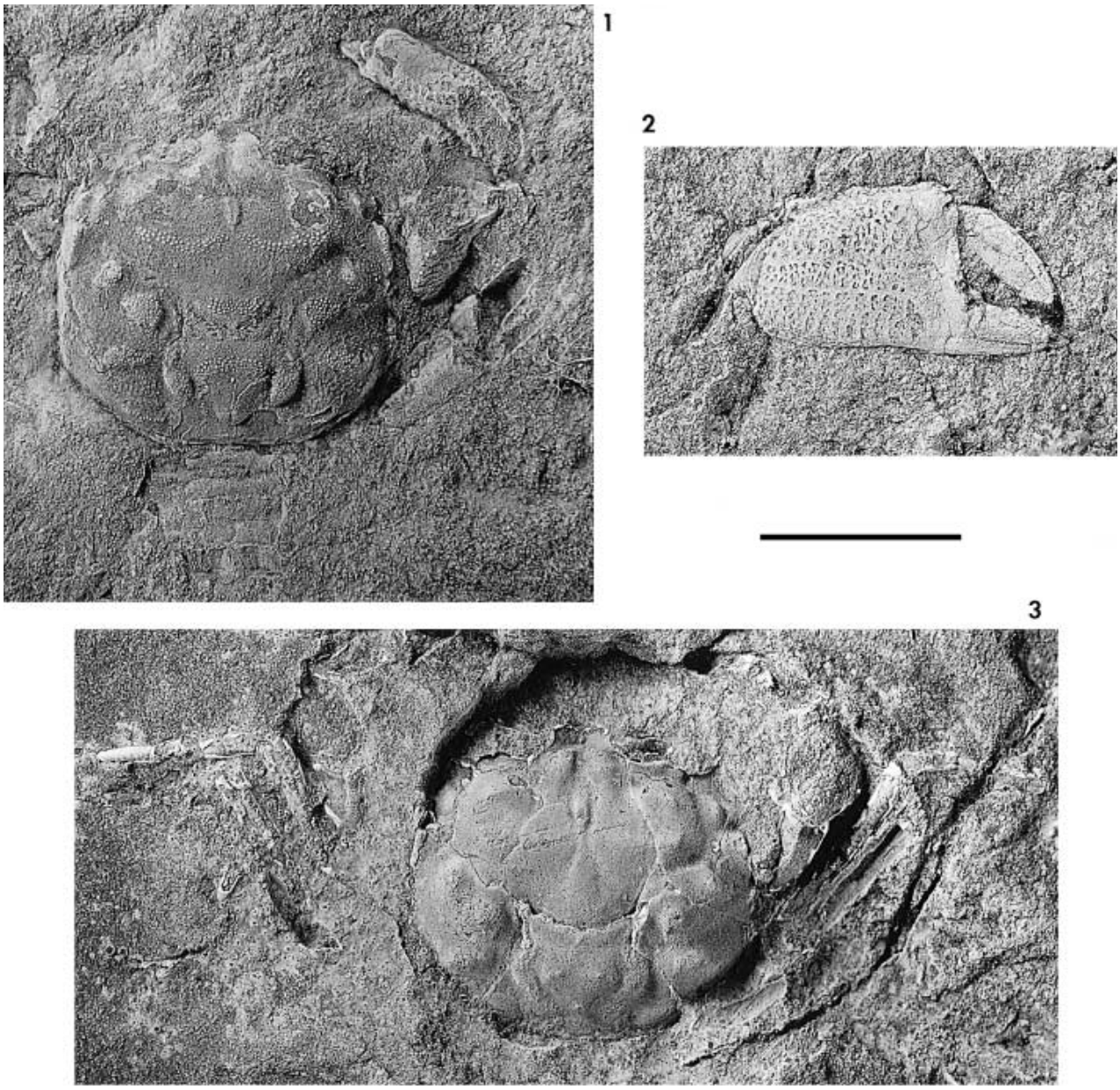


Fig. 17. *Archaeopus lunicarina* sp. nov. 1, dorsal carapace, holotype, UAM2574a. 2, chela, paratype, UAM2576. 3, dorsal carapace, rounded morphology, paratype, UAM2581. Scale bar equal to 1 cm.

Abdominal somites insufficiently preserved to permit description.

Right cheliped about twice as long as high, stout; hand about two-thirds total length. Fixed finger stout, tapering abruptly distally. Dactylus longer, upper surface smoothly arcuate, apparently transversely flattened. Occlusal surfaces with relatively large, domal denticles. Outer surface of hand with two or three subtle, longitudinal markings on a generally reticulate surface pattern.

Measurements: Measurements taken on the dorsal carapace of specimens of *Archaeopus lunicarina* are presented in Table 3. Position and orientation of measurements taken are illustrated in Fig. 18.

Discussion: Most of the specimens of *Archaeopus lunicarina* are corpses, exhibiting portions of the appendages or abdomen. The shape of the dorsal carapace ranges from subquadrate to ovoid, suggesting either that the carapace was deformed during burial in some specimens or that sexual dimorphism existed in this species. Interestingly, other species of *Archaeopus*, most notably *A. ezoensis* display a similar phenomenon. However, the lack of preserved sterna and abdomina make it impossible to determine if the shape variations are due to individual variation, deformation, or sexual dimorphism.

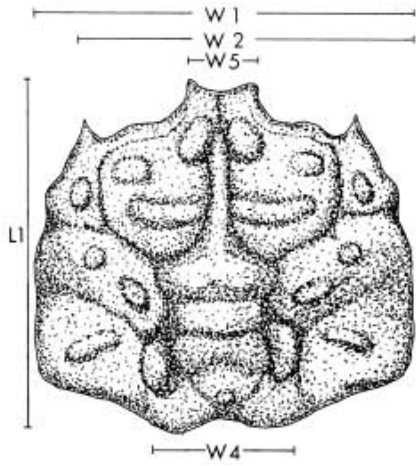


Fig. 18. Line drawing of *Archaeopus lunicarina* sp. nov., showing the position and orientation of measurements taken.

Archaeopus lunicarina differs from *A. antennatus* and *A. vancouverensis* in possessing concave forward, crescent shaped ridges on the protogastric regions and in having generally poorly developed and discontinuous transverse ridges on the dorsal carapace. Additionally, *A. lunicarina* does not narrow markedly anteriorly as seen in those two species. *Archaeopus lunicarina* is most similar to *A. ezoensis* but differs from it in possessing better developed ridges and a more quadrate carapace.

The occurrence of *Archaeopus* in Cretaceous rocks of Alaska extends the geographic range of the genus but does not extend its geologic range. The proximity of Alaska to Japan may explain the similarity between *A. lunicarina* and *A. ezoensis*.

Occurrence: The specimens were collected from the upper part of the Matanuska Formation, Late Campanian to Maastrichtian in age. The Matanuska Formation is part of the Peninsular Terrane of the Wrangellia Composite Terrane in south central Alaska (Plafker and Berg, 1994).

Palaeobiogeograhy

Palaeobiogeographic patterns within the Decapoda have previously been summarized (Feldmann et al., 1995, 1997, 1998; Feldmann and Maxwell, 1990; Feldmann and McLay, 1993; Karasawa, 1993; 2000; Schweitzer and Feldmann, 1999; Schweitzer, 2001). Several previously undescribed patterns were documented by Schweitzer (2001), and the distribution patterns of several of the taxa discussed herein corroborate those findings.

Table 3. Measurements (in mm) taken on the dorsal carapace of specimens of *Archaeopus lunicarina* sp. nov. W1, maximum width; W2, fronto-orbital width; W5, frontal width; W4, posterior width; L1, maximum length.

Specimen Number	W 1	W 2	W 5	W 4	L 1
UAM 2574a	16.7	14.0	3.1	7.2	15.3
UAM 2579	18.8	13.6	3.7	8.7	17.7
UAM 2575	17.7	12.5	3.2	9.3	16.5
UAM 2578	15.0	12.0	3.0	6.5	12.9
UAM 2581	16.6	12.2	3.7	7.9	14.6

Schweitzer (2001) discussed several taxa that appeared to have north polar distributions, and two taxa discussed herein, *Eucorystes* and *Palaeopentacheles*, appear have a north polar distribution as well. Marincovich et al. (1990) supported open Arctic passages at least until the latest Cretaceous, and the north polar area was known to be ice free during the Cretaceous (Kauffman, pers. commun.). Previously reported paleontological evidence supports such a connection (Cvancara, 1966; Jeletzky, 1971; Feldmann, 1972, 1974; Schweitzer, 2001). Other raninid taxa are known to have had a north polar, south polar, or bipolar distribution in the Cretaceous and early Tertiary. *Macroacaena* Tucker, 1998 and *Rogueus* Berglund and Feldmann, 1989 each had north polar distributions in the Cretaceous and Paleocene (Schweitzer, in press). *Lyreidus* had a south polar distribution in the Tertiary and retains a primarily southern hemisphere distribution in the Recent (Feldmann, 1992; Tucker, 1995). The polar distributions of raninid taxa are probably due to their tolerance of cold or deep water habitats.

Numerous amphitropical or bipolar taxa are known from Cretaceous and Tertiary deposits of the North Pacific (Schweitzer, 2001). Both *Glyphaea* and *Palaeastacus* have bipolar or amphitropical distributions, adding to the growing list of amphitropical decapods. Schweitzer (2001) described the presence of a distinctive North Pacific fauna beginning during the Cretaceous and extending into the Recent, and the distribution of *Archaeopus* places it into the category of North Pacific fauna. Schweitzer Hopkins and Feldmann (1997) and Schweitzer (2001) reported the earliest known occurrence of *Callianopsis* as being from the Eocene of Japan; however, the new species described herein is from the Eocene of Washington, USA. Thus, it is now uncertain as to exactly where along the Pacific Rim that the genus evolved, but it remains certain that the genus is in fact of North Pacific origin.

The genus *Palaeopentacheles* was previously known only from the Jurassic of Germany (Glaessner, 1969); the occurrence reported herein from western North America extends the range of the genus into the Oligocene. Members of the family to which *Palaeopentacheles* belongs, the Polychelidae, are cosmopolitan in Recent oceans, but fossils until now have only been reported from the Jurassic of Europe. The new Oligocene occurrence suggests that members of the family began dispersing to other areas at least by the Oligocene and in part via a North Polar route.

Acknowledgments

Specimens for this study were collected and/or donated

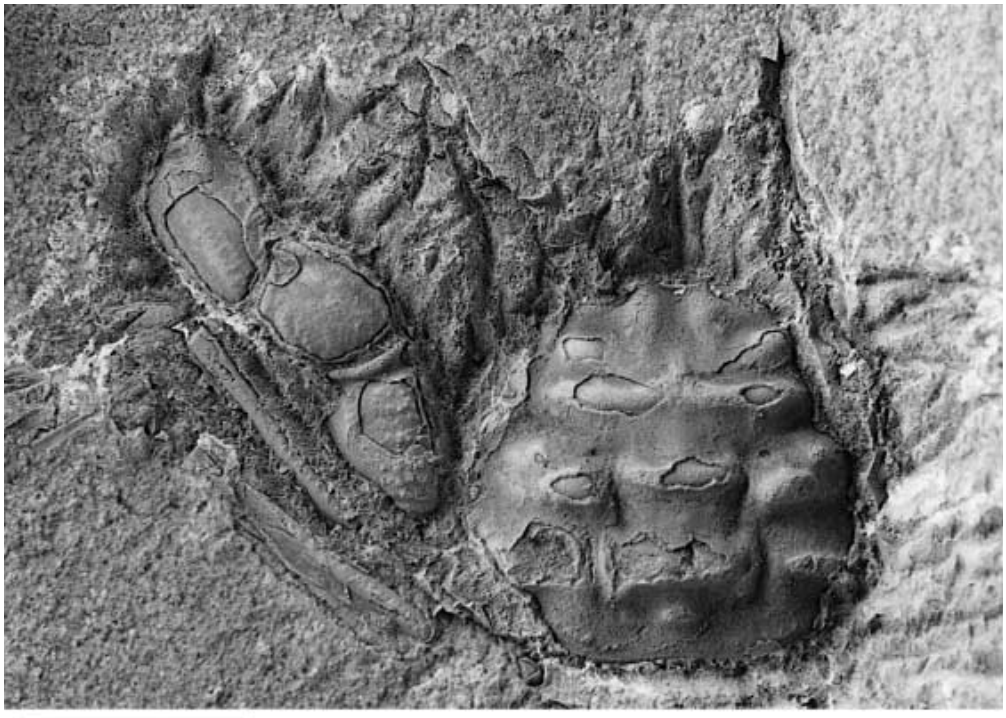


Fig. 19. *Archaeopus vancouverensis* (Woodward, 1896), dorsal carapace, USNM 512169. Scale bar equal to 1 cm.

for study by Ross E. Berglund, Bainbridge Island, Washington; J. L. and G. Goedert, Gig Harbor, Washington; David Starr, Washington; G. Retallack; University of Oregon, Eugene, Oregon; and R. Gangloff, University of Alaska Museum, Fairbanks, Alaska. Gangloff supplied locality information for *Callianassa* s.l. sp. and *Archaeopus lunicarina*. Travel for examination of specimens housed in Japan and in Great Britain was funded by National Geographic Society Grant 6265-98 to the authors.

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