

of the fifth pereiopod is proportionally longer in the male of each species than that of the female. The basis extends to the posterior portion of the second abdominal somite in the male, and extends only midway to the second abdominal somite of the female. The sexual determinations by Feldmann and Zinsmeister (1984b) were not supported by these criteria, and are possibly in error. However, definite sex assignments may not be made at this time.

The hard-part preservation of individual specimens of *Lyreidus antarcticus* from the La Meseta Formation is variable; the extent and detail of preservation of some specimens are exceptional. Preparation and study of specimens have revealed the morphology and ornamentation of the carapace, rostrum, thoracic and cephalic appendages, sternum, and abdomen. One specimen (Fig. 10.1,2) shows a remarkably well-preserved cast of the soft-bodied portion of the cephalothorax. Of the 201 specimens examined, including the type specimens, most are preserved within calcite cemented, fine-grained sandstone concretions. Many of these concretions were exposed at the surface, and were collected as part and counterpart. Typically, part and counterpart display the dorsal aspect of the carapace with replaced integument broken and covering portions of both the internal and external molds. These specimens, generally, do not appear to be crushed, inflated, or otherwise distorted. However, one (Fig. 10.7) shows unusual breakage along the right anterolateral margin.

*Lyreidus*, like other raninids, is a burrowing crab (Bourne, 1922; Glaessner, 1969). The specimen shown in Figure 10.4 consists of a carapace of *L. antarcticus* within a very fine-grained structure which is sinuous and tubular in shape. This fossil might represent a *Lyreidus* fossil preserved in its burrow. *Ophiomorpha*, a trace fossil which has been attributed to burrowing activity of callianassid shrimp, is found in the La Meseta Formation in close association with *Lyreidus antarcticus*. Although fossil callianassids are found in the La Meseta, they typically do not occur in close association with *Ophiomorpha*. Wiedman and Feldmann (this volume) have suggested that the *Ophiomorpha* from the La Meseta Formation might have been produced by the burrowing activity of *Lyreidus antarcticus*.

The right or left merus of the first pereiopod is present and exposed

on nearly every specimen, often with some replaced integument still attached (Fig. 9.10). The carpus of the first pereiopod is preserved less often. Where intact, the claws are commonly held in parallel, with one claw in front of the other, just in front of the rostrum (Fig. 10.3). There is no preferred orientation to this arrangement of the claws; that is, the left claw is not more commonly in front of the right claw. The remaining thoracic appendages are typically held beneath the body, subperpendicular to the plane of the carapace, and are not exposed on the same surface with the carapace (Figs. 9.5,10,10.5). Paired distal tips of the second through fifth thoracic appendages are frequently exposed along the outside, weathered surface of the concretion (Fig. 10.5,6). Only four prepared specimens (Fig. 9.5,7) show specimens of the second through fifth pereiopods, including the dactyli. These are extremely fragile elements and were probably easily scattered upon the death of the animal.

In several specimens, the abdomen is preserved attached, intact, to the carapace (Fig. 9.8). However, most specimens with preserved abdomina are found in Salter's position. They exhibit the abdomen split from the carapace and projected downward with respect to the body. Although it is commonly assumed that when brachyuran crabs are preserved in Salter's position they represent molts, this manner of preservation may result from other processes (Schäfer, 1951). When found in the fossil record, Salter's position has been interpreted as occurring through molting, decomposition of the animal, or from the action of water or wind currents (Schäfer, 1951). The specimens that possess preserved abdomina, either attached to or detached from the cephalothorax, typically possess equally well-preserved thoracic appendages and ventral aspects. It is possible that sedimentary conditions were such that these animals were buried and preserved so quickly that true molts and non-molts were equally well preserved.

The integument is replaced with calcite in nearly every specimen and is best preserved on the carapace. In the less well-calcified areas, such as the individual elements and joints of the appendages, the fragile integument is usually lost, in some cases due to exposure to weathering. The finest specimens are black in color, and possess very detailed preservation of the carapace and appendage ornamentation such as the fine setal pits, minute spines, and large cardiac groove. One black specimen, encased in an extremely fine-grained and well-cemented concretion, possesses some "geodized" appendages (Fig. 9.11).

Samples of integument, taken from the carapace and appendages of *Lyreidus antarcticus* and a Recent form, *Lysirude nitidus*, were examined by scanning electron microscopy (Fig. 10.8,9). The samples revealed few morphologic differences. Each exhibits the layered integument, typical of decapods, with thin exoskeletal and endoskeletal layers, and an intermediate, thick, prismatic layer. Samples of the integument of *L. antarcticus* even show the morphology of setal pits. The similar structures and thicknesses of these samples suggest that, in this case, the fossil is not a molt.

Of the 190 specimens of *L. antarcticus* collected during the austral summer of 1983–1984, 180 were derived from nine major localities; the remainder were from various miscellaneous or undetermined localities. All of these localities are found stratigraphically in Talm2, 3, and 5 (Sadler, this volume), which correspond to Unit I and Unit II of Elliot et al. (1982). No specimens were collected from the lowermost or uppermost sections of the La Meseta Formation. The localities are listed in Table 1, associated decapods are given therein, and their locations are illustrated on Figure 1. The majority of these specimens were collected from Talm3 and 5, the middle of the La Meseta Formation. *Lyreidus* fossils do not appear to occur commonly in the deeper water facies of the unit, the lowermost portion stratigraphically, nor in the shallow-water facies of the unit, the uppermost portion stratigraphically. *Lyreidus antarcticus* was found in association with a wide variety of fossil animals and plants.

The occurrence of the concretions at Locality 7 is particularly interesting. Most are spherical to ovoid in cross section; occasionally, two

Figure 10. *Lyreidus antarcticus* Feldmann and Zinsmeister, 1 through 7 figured hypotypes; 8 and 9, scanning electron micrographs. 1 and 2, USNM 404890, internal mold of cephalothorax, dorsal and ventral, dorsal view with rostrum, muscle attachment areas; ventral view with oral and sternal areas, coxae of pereiopods 1 through 4. 3, USNM 404891, oblique anterior view, rostrum missing, showing typical juxtaposition of chelae. 4, USNM 404893, dorsal view of central portion of carapace embedded in fine-grained, sinuous-tubular matrix, possible burrow structure. 5 and 6, USNM 404892, dorsal view of cephalothorax with right and left meri of chelae and external view of concretion with weathered paired dactyli of pereiopods 2, 3, and 4 emerging at surface. 7, USNM 404894, dorsal view of cephalothorax with complete rostrum, right and left meri of chelae, showing crushed right anterolateral margin. 8 and 9, Scanning electron micrographs of integument taken from carapace of *L. antarcticus* (8) and from carapace of Recent *L. nitidus* (= *L. bairdii*). Bar scales for 1 through 7 = 1 cm, bar scales for 8 and 9 = 0.1 mm.

ovoid masses coalesce to form a dumbbell shape. The size of the concretions vary from a diameter of about 2 cm to a maximum of 25 cm; the typical size range is 7 to 10 cm. Nearly all the concretions were broken open in the field, perhaps by processes of freezing and thawing. Specimens that had been exposed were subject to abrasion by wind-blown sediment, and the surfaces had the appearance of desert varnish. In 78 cases, both halves of the concretions were found lying within a few centimeters of one another and could be positively identified as representing all the fragments of a single unit. All but two of the concretions were single units; two were doubles. Of the 78 concretions examined on the exposure, only 2 appeared to be totally devoid of organic matter. The overwhelming majority, 64, contained plant debris, primarily in the form of carbonized stem material. Of the 64 concretions containing plant fragments, 11 also contained other fossil material, bryozoans, small bivalves, small gastropods, or burrows. Ten of the concretions contained *Lyreidus antarcticus* as the nucleus. The remaining two concretions were cored—by a bivalve and a gastropod in one case, and by a burrow structure in the other. The megafauna of these concretions was delicately preserved, suggesting that little, if any, transportation had occurred prior to entombment. Therefore, based upon these observations, it can be concluded that *Lyreidus antarcticus* was a significant element in the benthic fauna at this site and that other inhabitants were small bivalves and gastropods along with bryozoans. Furthermore, formation of the concretions was induced by the presence of the organic remains; conversely, preservation of the assemblage was assured by the protective encasement of the concretion. From these occurrences and associations, it is clear that *L. antarcticus* was a part of an extremely diverse, shallow-water, variable-energy marine environment.

Recent species of *Lyreidus* are deep water dwellers. Griffin (1970) recognized and summarized the distribution of five Recent species of *Lyreidus*. *Lyreidus tridentatus*, the type species of the genus, has by far the broadest geographic range and the longest geologic range. This species is found throughout the western and central Pacific in depths ranging from 27 to 425 m; this species has a geologic range of middle Oligocene to Recent (Jenkins, 1972). *Lyreidus brevifrons* is restricted to the Indo-west Pacific and is commonly found in depths ranging from 188 to 440 m. *Lyreidus stenops*, a western Pacific form, is commonly found in depths of 55 to 160 m. As understood by Griffin (1970), the genus *Lyreidus* also included *L. channeri* and *L. nitidus*. However, Goeke (1985) recently reassigned these two species to a closely related new genus, *Lysirude*. *Lysirude channeri* is restricted to the northern Indian and western Pacific oceans and is found in depths of 366 to 820 m (Griffin, 1970). Examination of preserved biological specimens of *Lyreidus* and *Lysirude* in the National Museum of Natural History provided further depth information exceeding Griffin's maxima: *L. tridentatus*, 669 m; *L. brevifrons*, 776 m; *L. stenops*, 503 m; and *Lysirude channeri*, 1,455 m. *Lysirude nitidus* has a geographic range from the coast of Maine to the Gulf of Mexico and a bathymetric range of 119 to 475 m (Griffin, 1970). Powers (1977) listed the geographic range of this species as Massachusetts to Puerto Rico in depths of 119 to 823 meters. Powers (1977) referred to the habitat of *L. nitidus* (= *L. bairdii*) as "soft mud substrates."

Workers including Bourne (1922) and Sakai (1937) have studied the probable life habits of these animals. Such studies have been based on observations regarding functional morphology and on the nature of the sediment dredged up with the crab. Direct observations of these animals in their natural setting have not been documented. However, because we do know the approximate geologic, geographic, and bathymetric limits on each species, we can say that these are, today, deep-dwelling crabs.

Section HETEROTREMATA Guinot, 1977  
Superfamily PORTUNOIDEA Rafinesque, 1815  
Family PORTUNIDAE Rafinesque, 1815  
Subfamily PORTUNINAE Rafinesque, 1815

Genus *Callinectes* Stimpson, 1860

?*Callinectes* sp.

Figures 11.1–3, 12

**Description.** Specimen moderately large, strong, spined, consisting of partial well-preserved merus, carpus, propodus, and dactylus of right cheliped and mold of exterior of carapace fragments.

Carapace fragment appears to be right posterolateral corner with well-defined, smooth border and coarsely punctate surface.

Merus greater than 34 mm long and 8 mm wide. Upper margin angular, defined by row of closely spaced spines with diameters at base of about 1 mm. Outer surface convex with nodes, smaller than spines on upper margin, arranged in poorly defined longitudinal rows. Inner surface nodose near upper margin.

Carpus about 14.5 mm long, 7.5 mm wide. Upper surface triangular, with greatest width at midlength, flattened, ornamented by coarse spines and interspersed pustules. Distal margin finely serrate.

Propodus, including all but distal portion of fixed finger, greater than 37.5 mm long, 16.8 mm high, 9.1 mm wide. Hand generally smoothly convex; outer surface finely granular, with shallow sulcus just below upper margin extending from carpus-propodus joint distally one-half the length of hand; upper surface slightly convex in profile, narrow, ornamented by moderate-sized nodes; inner surface smooth, convex; lower margin slightly sinuous in profile. Fixed finger tapers distally; sulcus with numerous setal pits, near lower margin of outer surface; ovoid cross section. Denticles on occlusal surface low, broad domes.

Dactylus broad proximally, tapering in width and height distally; outer surface with longitudinal, pitted sulcus just above midline; denticles as on fixed finger. Maximum height, 7.0 mm; width, 4.7 mm; length, greater than 10 mm.

**Type.** The sole specimen, USNM 404880, is deposited in the U.S. National Museum of Natural History, Washington, D.C.

**Locality and stratigraphic position.** This specimen was collected from the upper part of the late Eocene La Meseta Formation at Locality 14 (Fig. 1).

**Remarks.** The right arm and claw described above is unquestionably distinct from other decapods collected from the La Meseta Formation. The elements are large, robust, and have relative proportions unlike any of the other species. The most distinctive morphologic characteristics are the great length of the merus and the strength of the ornamentation on the various segments. In most crab genera, the cheliped is carried close to the front in a defensive posture. The merus tends to be relatively short, and the ornamentation becomes more pronounced on the distal elements, the propodus and dactylus. Just the opposite condition is observed on this specimen. The merus is nearly as long as the propodus, and the ornamentation on the merus is composed of coarse tubercles, or possibly spines, whereas ornamentation on the propodus is limited to fine granulations.

Using the general proportions of the various arm elements as the primary basis for identification, the specimen would seem to represent a species within the Portunidae. Many of these swimming crabs have chelipeds with elongate, strongly ornamented meri. More specific identification is difficult, however, owing to the absence of carapace material and the unique combination of characters expressed on the arm. The

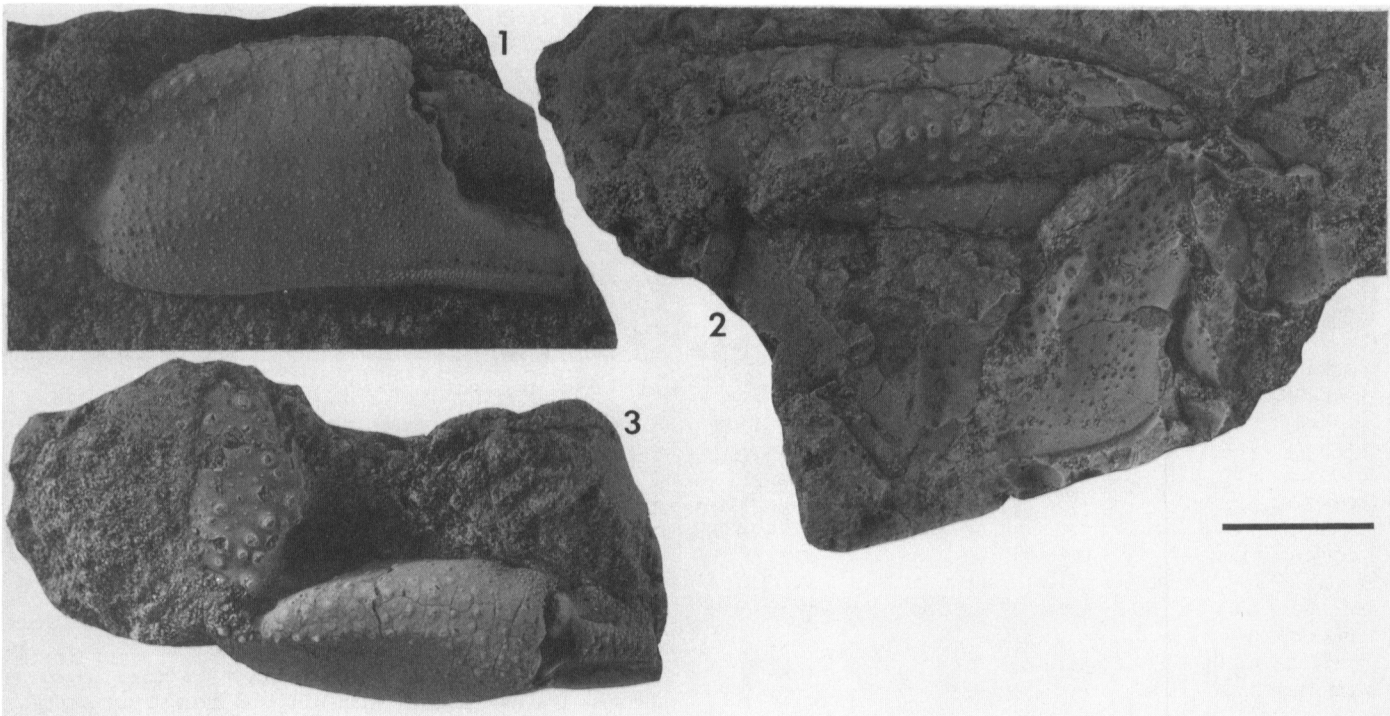


Figure 11. ?*Callinectes* sp., USNM 404880. 1, Outer surface of propodus and dactylus of right cheliped. 2, Upper surface of merus and mold of fragments of carapace. 3, upper surface of carpus, propodus, and dactylus of right cheliped. Bar scale = 1 cm.

specimen is tentatively referred to *Callinectes*, based on the absence of a mesiodistal spine on the carpus (Williams, 1984, p. 355) and coupled with the elongate, well-ornamented merus. However, the propodus on typical *Callinectes* is longitudinally keeled, which is not the case with this specimen. Taken alone, the propodus is more like that seen on Cancridae than on portunids, but the merus is typically short and relatively smooth on the former. Given this uncertainty, it seems most prudent to questionably refer the specimen to *Callinectes* sp.

**Superfamily CALAPPOIDEA de Haan, 1833**

**Family CALAPPIDAE de Haan, 1833**

**Subfamily CALAPPINAE de Haan, 1833**

**Genus *Calappa* Weber, 1795**

***Calappa zinsmeisteri* n. sp.**

Figures 13.1,2, 14

**Description.** Taxon represented by one nearly complete right claw and partial hands of one left and one right cheliped. Right and left claws similar size; strong, thick, with short, stout fingers.

Propodus generally triangular, narrow at articulation with carpus, highest at point of articulation with dactylus. Carpus-propodus joint steeply inclined to long axis of carpus. Upper margin smoothly convex, ornamented with row of more than five prominent spines. Lower margin, including base of fixed finger, straight or slightly downturned when viewed from side. Fixed finger short, about one-fourth the total length of propodus, narrows uniformly distally, occlusal surface intercepts lower

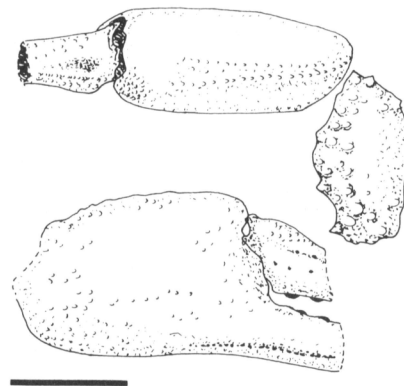


Figure 12. Line drawings showing the interpreted morphology of the carpus, propodus, and dactylus of ?*Callinectes* sp. Bar scale = 1 cm.

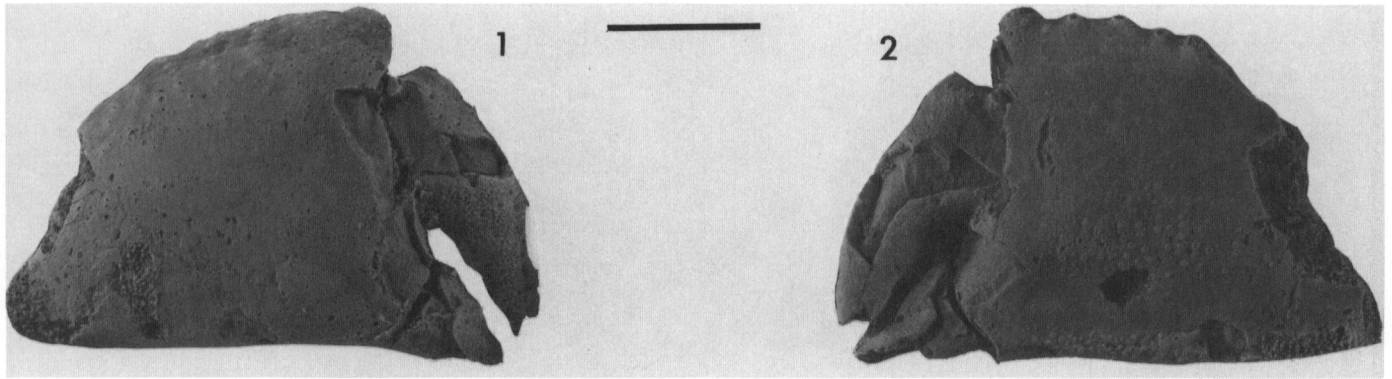


Figure 13. *Calappa zinsmeisteri* n. sp., USNM 404877. 1, Outer surface of propodus and dactylus of right cheliped. 2, Inner surface of propodus and dactylus of right cheliped. Bar scale = 1 cm.

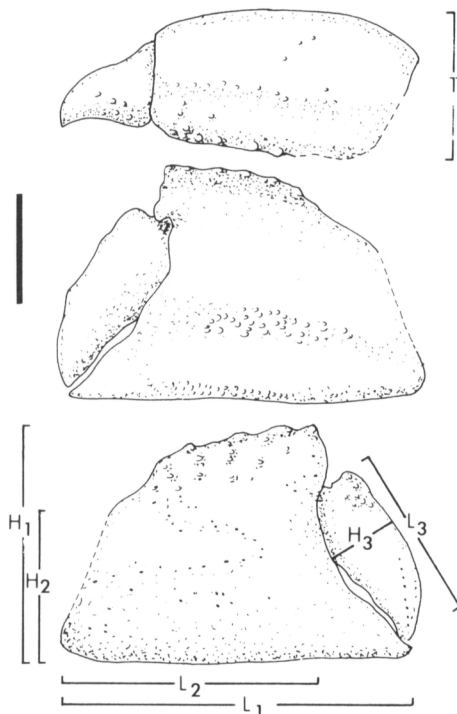


Figure 14. Line drawings showing interpreted morphology of upper, inner, and outer surfaces of the right cheliped of *Calappa zinsmeisteri* and position of measurements. Bar scale = 1 cm.

margin at about  $40^\circ$  angle. Outer surface pustulose; pustules small, some arranged in approximately longitudinal rows from base of hand to approximate level of articulation with dactylus; pustules become larger, less numerous, less systematically arranged above. Inner surface a sinuous curve with hand generally concave near upper and lower margins and thickest and convex mesially. Surface finely pustulose mesially and otherwise smooth. Claws are convex anteriorly when viewed from above.

Dactylus short, stout, pustulose only on proximal portion of upper surface, convex anteriorly when viewed from above. Upper surface gently arched. Occlusal surface of propodus and dactylus apparently with broad, domed denticles. Long axis of dactylus, when closed, makes approximate angle of  $60^\circ$  with base of propodus.

**Measurements.** Measurements, in millimeters, are given in Table 6. All measurements represent minimum dimensions, as none reflects estimates of the amount of material broken or exfoliated.

**Etymology.** The trivial name honors Dr. William J. Zinsmeister, Department of Geosciences, Purdue University, who made it possible to make the collections upon which this study is based.

**Types.** The holotype, USNM 404877, and two paratypes, USNM 404878 and 404879, are deposited in the U.S. National Museum of Natural History, Washington, D.C.

**Locality and stratigraphic position.** Specimens referred to *Calappa zinsmeisteri* were collected from the upper part of the late Eocene La Meseta Formation, at Locality 14 (Fig. 1), Seymour Island, Antarctica.

**Remarks.** Although *Calappa zinsmeisteri* is represented only by cheliped material, placement in the genus can be made with a high degree of certainty. The very strong, triangular hand is smooth and generally concave on the inner surface to conform to the front of the carapace. On its outer surface, the hand is more heavily ornamented on the upper half, and the ornamentation is in the form of rows of nodes. The upper margin projects well above the point of articulation of the dactylus, and it is ornamented by strong spines; the lower margin is smooth. The dactylus rotates downward against the short, stout fixed finger at a steep angle. The base of the fixed finger is not downturned.

This combination of characters is typical of most species of *Calappa*