

Ostracoda as indicators of vertebrate environments in the Middle Eocene Guys Hill Formation of Jamaica

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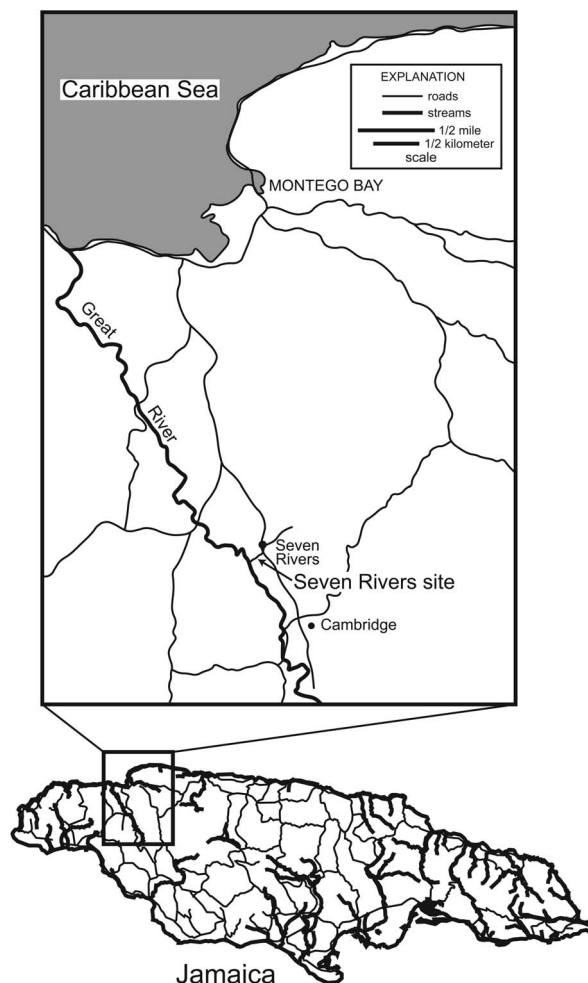
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ABSTRACT: Samples collected from the Guys Hill Formation (Yellow Limestone Group, middle Eocene) in the Seven Rivers region of northwestern Jamaica yielded a rich ostracode fauna, including eight new species. The samples were collected to determine the environment of deposition for the strata that contain both fully-terrestrial and marine vertebrates, including seacows in the transition between land- and sea-faring morphologies. Adult and juvenile and male and female ostracode specimens were recognized, indicating an autochthonous thanatocoenosis. The dominance of cytherideid ostracodes, particularly the presence of significant numbers of noded cytherideids, indicates brackish conditions, at least during part of the chronostratigraphic interval, and marine taxa, such as *Orionina* and *Hemicythere*, indicate fluctuating paleoenvironmental conditions, which is consistent with the range of vertebrate fossil faunas collected from the site. New species include *Cytherelloidea nebuloreticulata*, *Paracytheridea jamaicaensis*, *P. inflata*, *Cythereis? iturraldei*, *Quadracythere robusta*, *Quadracythere polycosta*, *Hemicythere elongata*, and *Orionina anteroexposita*.

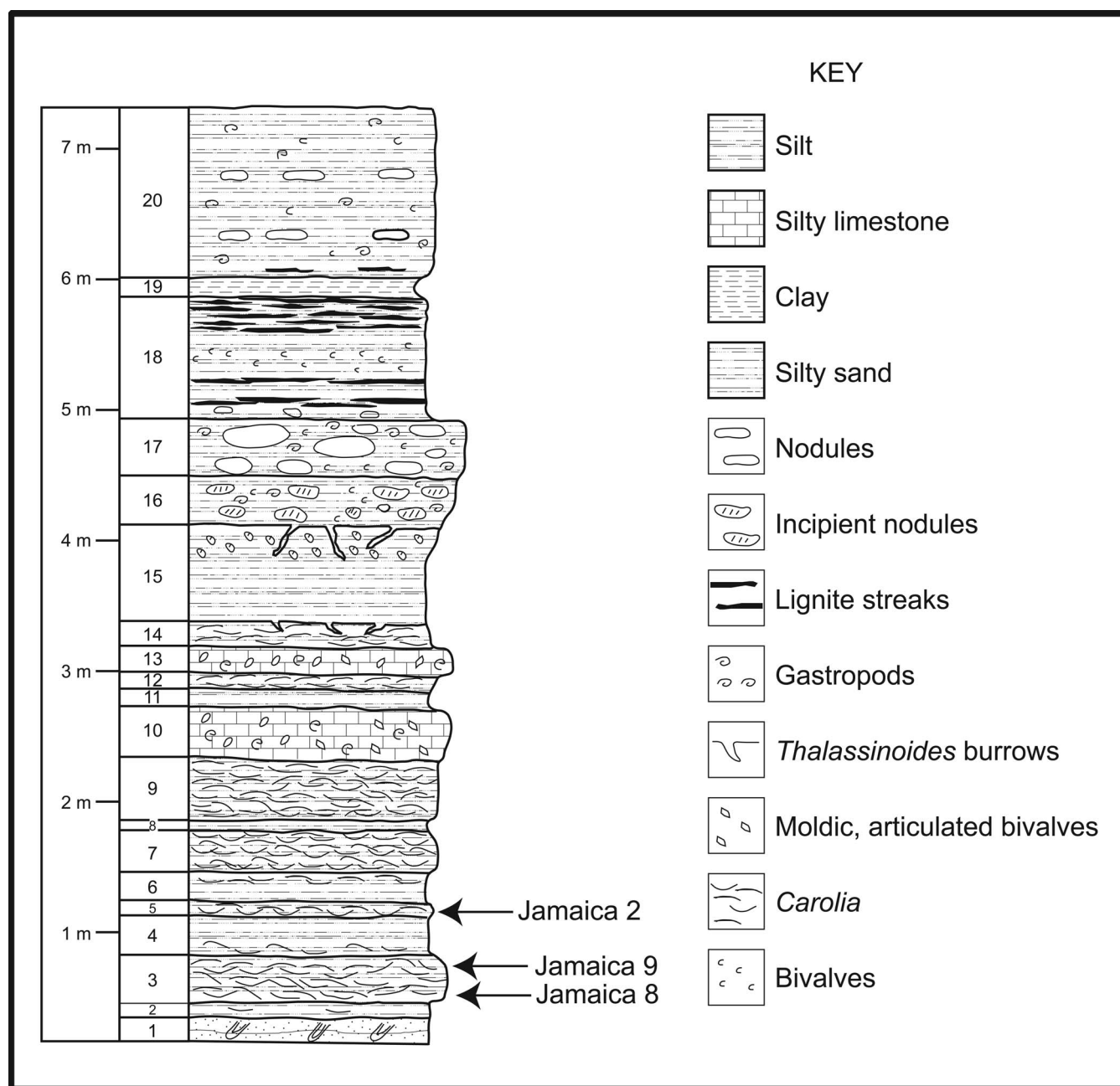
INTRODUCTION

The early Middle Eocene Yellow Limestone Group has yielded important vertebrate fossils, particularly with regard to the evolutionary transition from land- to ocean-dwelling vertebrates and the paleobiogeography of the Caribbean and Central American region. At one site, the Seven Rivers locality in northwestern Jamaica (text-figs. 1 and 2), aquatic and amphibious fossils of chondrichthyan and osteichthyan fishes, a crocodilian, a side-necked turtle, and the early remains of seacows (sirenians) have been recovered; in addition, the fauna also includes the remains of terrestrial animals such as a primitive rhinoceros, an iguanian lizard, and possibly a primitive primate (Donovan et al. 1990; Domning 2001a; 2001c; Portell et al. 2001), in addition to numerous invertebrates. Particularly important in these deposits are the remains of the evolutionarily transitional land-to ocean-dwelling sirenians. Samples were collected from this site during July, 2000, by Manuel Iturralde-Vinent of the Museo Nacional de Historia Natural, Havana, Cuba, nine of which were kindly sent to the author for study of the ostracodes for use as a tool in collecting evidence for the reconstruction of the environments in which the Eocene evolution of this fauna occurred. The sampling, therefore, represents a reconnaissance survey, rather than a comprehensive study. Three samples yielded abundant ostracodes, which are the focus of the present study. The samples also included new species, which are described herein.

Ostracodes, which are bivalved crustaceans, are among the most useful groups of microfossils for use in paleoenvironmental analyses, principally because specific types are restricted to specific paleoenvironments (for example, the Darwinuloidea and Cypridoidea occur in freshwater environments, the Cytheroidea typically dominate in nearshore environments, and the Bairdioidea and Platycopida are exclusively marine), which is a trend that can be observed in ostracode assemblages for millions of years (collections of studies of ostracode paleoenvironmental analyses include (Oertli 1971; Maddocks 1983; Boomer et al. 2003)). Being arthropods, ostracodes grow in a series of molts (typically 9 instars in a se-



TEXT-FIGURE 1
Map of the Seven Rivers area of northwestern Jamaica where samples were collected for this study.



TEXT-FIGURE 2
Measured section and sample horizons (from Simon Mitchell, with permission).

ries). The degree of sorting by water currents can be assessed by quantifying the ratios of juvenile and adult carapaces. Boomer et al. (2003) described criteria for recognizing biocoenoses (life assemblages), autochthonous thanatocoenoses (indigenous populations with the juveniles removed or dissolved) and allochthonous thanatocoenoses (predominantly juvenile specimens that have been transported into a low-energy environment) based on juvenile/adult ratios. Analysis of the ostracodes can, therefore, be of significant value in interpreting paleoenvironments.

STRATIGRAPHY

The samples analyzed for this study were collected from the Seven Rivers paleontological site, which is in the Parish of Saint James, south of Montego Bay, in northwestern Jamaica. The outcrop is located in a small tributary to Browns River that extends parallel to the road between the towns of Anchovy and Cambridge. The stratigraphy of the units in this area (text-fig. 3) includes the Lower to Middle Eocene Yellow Limestone Group, which is separated from the underlying Cretaceous strata by an unconformity (Robinson and Mitchell 1999). The Yellow

Ma	System	Larger Benthic Foraminiferal Fossil Zones ¹		Lithostratigraphic Units ¹	
				Northwestern Clarendon Block	Clarendon Block
35	Upper Eocene	Assemblage 10	Zone 5	Montpelier Formation	
		Assemblage 9	Zone 4		
		Assemblage 8	Zone 3		
		Assemblage 7			
	Middle Eocene	Assemblage 6	Zone 2B	Yellow Limestone Group (undifferentiated)	Chapelton Formation
40		Assemblage 5			
		Assemblage 4			
		Assemblage 3	Zone 2A		— — — — —
45		Assemblage 2			
		Assemblage 1b	Zone 1		— — — — —
	Assemblage 1a	Stettin Formation			
50	Lower Eocene				
	Cretaceous				

1 = based on Robinson and Mitchell (1999).

TEXT-FIGURE 3

Lithostratigraphy and biostratigraphy of the Eocene of northwestern Jamaica (from Robinson and Mitchell 1999).

Limestone Group is comprised of three formations, which are, in ascending stratigraphic order, the Stettin, Guys Hill, and Chapelton Formations. The Middle to Upper Eocene Montpelier Formation overlies the Yellow Limestone Group. The ages of the formations are based on “larger” benthic foraminiferal assemblage zones (Robinson and Mitchell 1999) and molluscs and the primitive rhinoceros, *Hyrachyus* (Domning 2001a).

At this locality, the lower part of the Middle Eocene Yellow Limestone Group is represented by shallow-water limestones underlain by sands and clays that are equivalent to the Guys Hill Formation (Robinson and Mitchell 1999). The ostracodes studied herein were picked from samples collected from the Guys Hill Formation. The stratigraphy was described (Iturralde-Vinent, personal communication) as dark brown to dark gray sandy clays bearing oysters and the anomid bivalve *Carolia*, approximately 2-3 m thick, which contain abundant fossil remains of marine vertebrates. Laterally, the unit is laminated and includes some intercalated layers of lignitic black clays. Roots casts are locally preserved, as well as some oval calcareous-clayey concretions up to 15 cm in diameter. These sediments indicate deposition in a marginal marine setting.

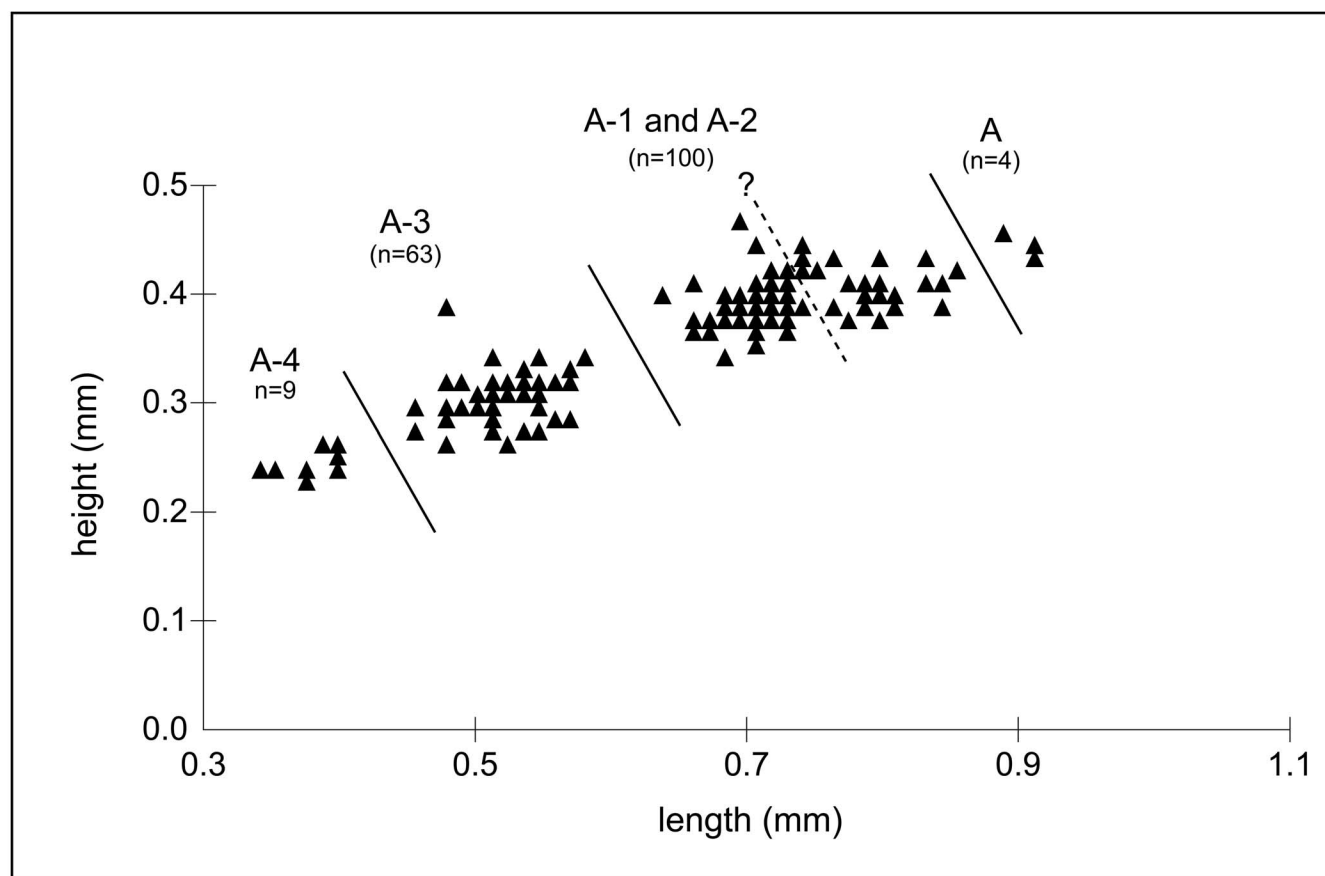
METHODS

The samples were heated to approximately 80°C overnight, soaked in a 3% solution of hydrogen peroxide, and sieved through a 180µm sieve. Due to the indurated nature of the material, most samples required one or even two additional washings using the same technique. Some of the samples sent to the author were composed of indurated limestone and could not be disaggregated. Samples that contained ostracodes were placed in a glass jar, submerged with water, and placed in an ultrasonic bath, also containing water. The samples were then

subjected to ultrasonic cleaning for approximately 5 to 10 minutes. To obtain counts of the relative percentage of species, the samples were split several times until a small amount of material remained; this fraction was then picked entirely. This process was repeated until approximately 300 specimens were picked. The species were then sorted, identified and tabulated. The unpicked portion of the samples was scanned for the rarer species. Specimens were again placed in a test tube filled with water and immersed again in an ultrasonic bath for brief bursts (~10 seconds) to clean off any remaining debris on the test. Specimens were mounted on aluminum stubs using double-sided carbon tape and coated with gold using a sputter coater. Photomicrographs were made using a Philips XL 30 electron microscope. All of the images were digital and saved in .tif format. The images were then imported into Adobe Photoshop®, where all of the plates were prepared. The brightness and contrast of the photomicrographs were often enhanced, similar to techniques used in a darkroom, and a sharpening function was applied to some photomicrographs. The images were not otherwise altered. The plates were then printed on a HP Photosmart C3100 series printer on glossy paper. The length and width of the specimens were measured using an ocular micrometer with a Meiji EMZ-TR binocular microscope.

PALEOECOLOGY

Ostracodes are useful for paleoenvironmental analysis for several reasons, as summarized in Whatley (1983) and Boomer et al. (2003). As mentioned, the relative proportions of the instars can indicate the degree of sedimentary sorting, post-mortem transport, and degree of mixing among adjacent environments. Analysis of the relative proportions of the instars is an important first step to indicate the fidelity of the ostracode assemblage to the original environment of deposition. As can be seen on the



TEXT-FIGURE 4

Length/height plots of adult and instar stages of "*Cyprideis*" sp. aff. *V. howei*.

length/width plot (text-fig. 4) for 172 individuals of "*Cyprideis*" sp. aff. *V. howei* from sample Jamaica 2, three and possibly four of the latest instars (adult, A-1, A-2, A-3, and possibly A-4) can be observed, ranging in size from slightly more than 0.3 mm to more than 0.9 mm. Text-figure 5 is a plot of the relative proportions of the instars. According to the taphonomic scheme of Boomer et al. (2003), this proportion indicates a moderate energy autochthonous thanatocoenosis. Therefore, the ostracode assemblage recovered from sample Jamaica 2 represents the assemblage that was living in the area at the time of deposition, although the smallest valves have been removed.

The next level of paleoenvironmental analysis involves the diversity and evenness of species in the assemblages. Random counts of 300 individuals have long been accepted as a reasonable number to pick to determine species diversity, and were used herein as the basis for calculations of diversity (Dennison and Hay 1967; Patterson and Fishbein 1989; Buzas 1990). Counts of 300 individuals are required to determine with 0.95 probability the occurrence of at least one individual of a species with a proportion of 0.01. Slight variances from the counts of 300 individuals resulted because the final sample splits did not include the exact numbers of individuals to bring the total to 300. In general, samples that are diverse (that is, include a relatively large number of species that are represented by a small number of individuals) are typical of stable environments, such as normal marine below wave base, whereas low diversity samples reflect some environmental stresses or fluctuating condi-

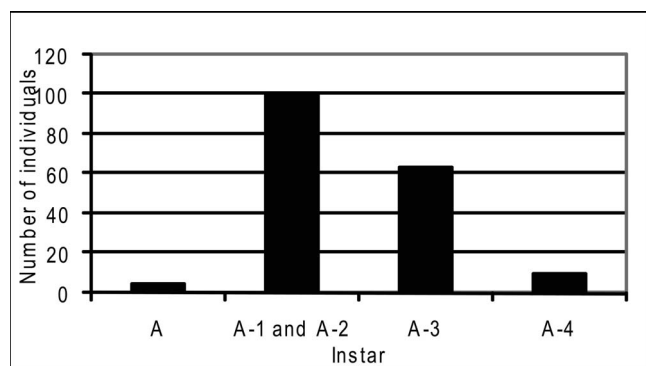
tions that exclude most species but enables relatively few species to reproduce in large numbers.

The samples studied herein are generally comprised of high-dominance, low-diversity assemblages with characteristics of being deposited under fluctuating ecological conditions ranging from normal marine to brackish environments. Three samples (Jamaica 2, 8 and 9) contained sufficient numbers of ostracodes for paleoenvironmental analysis. The table of the approximately 300 specimens counted from these samples is presented below (Table 1). The software package Multi-Variate Statistical Package (MVSP) version 3.13 by Kovach Computing Services was used to perform the calculations. The calculated values of paleoenvironmental parameters is presented in Table 2.

Dominance is calculated by the equation:

$$D = \sum \left(\frac{n_i}{n} \right)^2$$

where D is dominance, n_i is the numbers of individuals of the i th species, and n is the number of species. Dominance ranges theoretically from 0 (all taxa are equally present) to 1 (one taxon completely dominates the assemblage). Thus, the higher the calculated dominance value, the greater the dominance. Diversity was calculated using the Shannon-Weiner function, which is particularly well suited for numerical data and is calculated us-



TEXT-FIGURE 5

Histogram of the number of valves of each instar of “*Cyprideis*” sp. aff. *V. howei* from sample Jamaica 2.

ing the equation:

$$H = -\sum_{i=1}^S (p_i)(\log_2 p_i)$$

where

H = the information content, or species diversity

S = the number of species

p_i = the proportion of the sample belonging to the i th species.

Evenness is calculated by the equation:

$$E = \frac{H}{H_{\max}}$$

where

E = equitability

H = calculated diversity (the Shannon-Weiner information function)

H_{\max} = maximum species diversity

The maximum species diversity is calculated by the equation:

$$H_{\max} = \log_2 S$$

where

H_{\max} = species diversity under conditions of maximum equitability

S = number of species in the community

Calculated values for diversity and evenness are primarily useful for the comparison of samples. It is important when comparing sample diversities to make comparisons of values calculated by the same indices. Graphical representations of the relative percentages of the various taxa in the three samples (text-fig. 6) corroborate the calculated paleoecological indices. The sample with the largest number of species (Jamaica 2) also has the highest values of Shannon's information index and evenness and the lowest value of dominance. Jamaica 8, which has the fewest numbers of species, also has the lowest values of Shannon's index and evenness and the highest dominance value.

A final level of paleoenvironmental analysis is a uniformitarian approach that uses information from ostracodes in modern en-

TABLE 1

Species occurrences in samples from the Guys Hill Formation of Jamaica.

Species	Jamaica 2	Jamaica 8	Jamaica 9
<i>Cytherella</i> spp.	112	7	35
<i>Cytherelloidea nebuloreticulata</i>	3	1	4
<i>Bairdia</i> sp.	9	0	0
<i>Cyprideis</i> ? sp. aff. <i>C. howei</i>	86	269	241
<i>Paracytheridea inflata</i>	43	13	6
<i>Paracytheridea jamaicaensis</i>	0	0	12
<i>Cythereis</i> ? <i>iturradlei</i>	6	0	0
<i>Orionina anteroexposita</i>	14	1	0
<i>Hemicythere elongata</i>	14	0	0
<i>Occultocythereis</i> sp.	4	0	0
<i>Quadracythere robusta</i>	3	0	2
large cytheroid indet.	0	1	0
	294	292	300

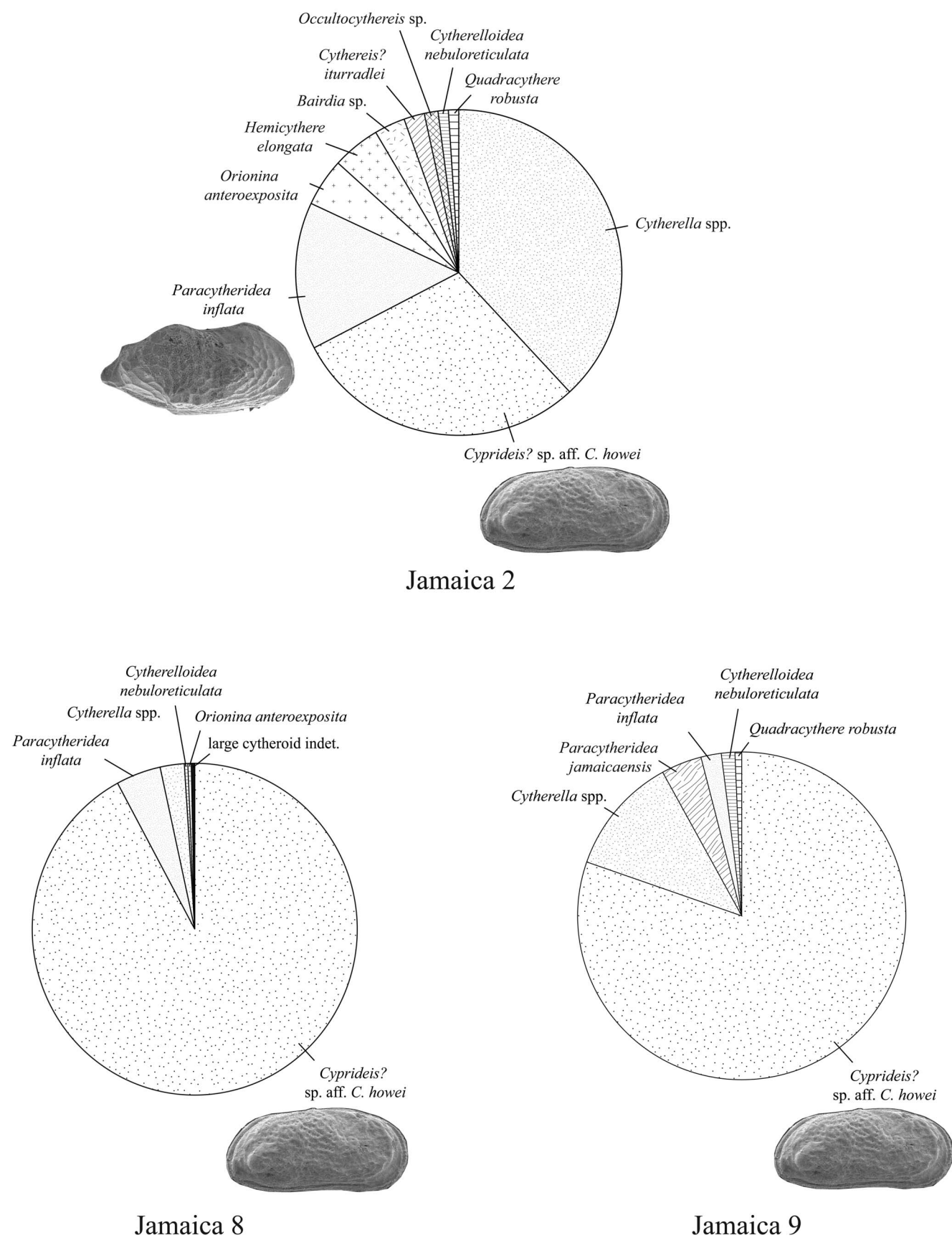
TABLE 2

Calculated values of paleoenvironmental parameters of ostracodes in the Guys Hill Formation.

	Jamaica 2	Jamaica 8	Jamaica 9
Number of taxa	10	5	6
Number of individuals	294	291	300
Dominance	0.258	0.857	0.661
Shannon's index	2.361	0.522	1.045
Evenness	0.711	0.202	0.404

vironments to interpret the preferred conditions of their ancestors. In many cases, large groups of ostracodes are known to have inhabited the same environments for millions of years; for example, the Suborder Darwinulocopina have lived in freshwater environments for hundreds of millions of years.

Not surprisingly, sample Jamaica 2, which is the most diverse sample, includes ostracode taxa that are generally considered to indicate normal marine conditions, an interpretation supported by lithologies and associated macro- and microfossils. Genera most common in marine environments include *Orionina* (van



TEXT-FIGURE 6
Pie diagrams showing the relative percentages of taxa of ostracodes from selected samples.

den Bold 1963a; Cronin and Schmidt 1988), *Hemicythere* (Hazel 1967), and other genera such as *Bairdia*, *Quadracythere*, *Cythereis*, and *Occultocythereis*, as indicated by many references of van den Bold from the Cenozoic of the Caribbean region (van den Bold 1946; 1950a; 1950b; 1961; 1963b; 1963a; 1966; 1968; 1977a; 1977b; 1986) and many other references. Alternatively, taxa within the Cytherideidae have long been known to inhabit nearshore, brackish environments (Benson 1961; Sandberg 1964; Hazel 1971).

Species of the cytherideids are known to become nodose or “torose,” that is, develop large nodes on the carapace, in response to salinities much less than normal marine (Howe 1971; van Harten 2000; Keyser and Aladin, 2004; Keyser, 2005). Van Harten (2000), based on experimental data, determined that nodding on the cytherideid species *Cyprideis torosa* was related to salinities generally less than 4‰, but that some other unknown factor (“factor X”), perhaps in combination with low salinity, was also causally related. Keyser and Aladin (2004) and Keyser (2005) determined that nodding in *Cyprideis torosa* is related to problems with osmoregulation during or very shortly after molting. During molting, an ostracode must increase its volume to accommodate the formation of a larger carapace. The increase in volume is accomplished by absorbing water from the environment, but if the salinity is below a certain threshold (<6‰), the increased osmotic pressure may cause water to be absorbed at a rate faster than can be accurately regulated by the ostracode. If the internal pressure becomes too great, some of the connections holding the cells of the inner and outer epidermal layers tear apart, causing the outer epidermal layer to bulge, forming a node. In any case, nodding in cytherideid ostracodes indicates greatly reduced salinities and the influx of fresh water, as occurs along marginal marine environments. Some of the samples, particularly Jamaica 2, include a diverse fauna that indicate more open marine conditions (such as abundant *Orionina*, *Hemicythere*, *Quadracythere* and *Cythereis*?), but also include very abundant “*Cyprideis*”, including “torose” types. This faunal composition suggests some type of post-depositional mixture of environments, such as bioturbation, reworking during storm activity, or some other mechanism. The overall signal from the ostracode fauna indicates the relatively close proximity of nearshore and open marine paleoenvironments, an interpretation that is consistent with the variety of invertebrate and vertebrate fossils collected from these deposits.

SYSTEMATIC PALEONTOLOGY

The taxonomic hierarchy of Horne et al. (2002) is followed herein.

Class OSTRACODA Latreille 1806
Subclass PODOCOPIDA Müller 1894
Order PLATYCOPINA Sars 1866
Suborder PLATYCOPINA Sars 1866
Genus *Cytherelloidea* Alexander 1929

Cytherelloidea nebuloreticulata Puckett n. sp.
Plate 1, figure 9-10, 12-13

Type Specimens: USNM 534042 (holotype, LV; plate 1, figures 10, 12-13, sample Jamaica 2); USNM 534043 (paratype, carapace, sample Jamaica 2).

Etymology: *nebulosus*, Latin for cloud, and *reticulatus*, Latin for netted or net-like, referring to the faint reticulate pattern observed on portions of the carapace.

Diagnosis: Species of *Cytherelloidea* characterized by a faint reticulate pattern between costae and by distinct reticulation along the anterior margin.

Description: Carapace robust, elongate, evenly rounded along anterior and posterior margins; dorsal margin with concavity at approximately one-third length, very broad concavity along ventral margin. Sharply defined costa extends along dorsal margin at approximately two-thirds length anteriorly just below dorsal margin and along anterior, ventral, and posterior margins; another costa extends from posterodorsal margin toward anteroventral margin, curving ventrally and becoming thinner just posterior to mid-length, then anteriorly just above lower costa, and disappears at approximately quarter-length; another costa extends anteriorly just below -height from near posterior margin to approximately quarter length. Lateral portion of carapace faintly reticulate between costae, but strongly reticulate between anterior costa and margin of carapace.

Measurements:

<i>Cytherelloidea nebuloreticulata</i>	Length (mm)		Height (mm)	
	LV	RV	LV	RV
	0.49	0.53	0.23	0.26
	0.53	0.55	0.31	0.33
	0.54	0.53	0.33	0.31
		0.53		0.30
Averages	0.52	0.54	0.29	0.30

Order PODOCOPINA Sars 1866
Suborder CYTHEROCOPINA Baird 1850
Superfamily CYTHEROIDEA Sars 1925
Family CYTHERIDEIDAE Sars 1925
Tribe CYTHERIDEINI Kollmann 1960
Genus *Cyprideis* Jones 1857

Cyprideis? sp. aff. *C. howei* (Stephenson)
Plate 2, figures 1-14

Description: Carapace displays considerable variability, ranging from nearly smooth, subreniform morphologies to highly nodose (with large knobs) reticulated and pitted forms. Carapace generally elongate, tapering slightly posteriorly; robust. Greatest anterior protuberance at or slightly dorsal to mid-height, greatest posterior protuberance slightly above ventral margin; dorsal margin very broadly arched, with greatest height at approximately quarter length; ventral margin concave slightly anterior to mid-length. Left valve overlaps right valve around entire margin. Anterior margin compressed; in nodose forms, a ridge occurs along anterior margin just posterior to anterior compressed zone; nodose forms display four well-developed nodes, one at mid-height anterior to mid-length, two nodes occur slightly posterior to mid-length (one dorsal and one ventral), and one node near posteroventral angle, which can be attenuated into a spine; some specimens display a fifth, less well-developed node near the anterodorsal angle; most specimens display an arcuate (concave up) depression extending from near mid-length along dorsal margin to point near mid-height at position below anterodorsal angle. Some specimens display a nearly smooth carapace, whereas other speci-

mens display subtle, irregular reticulation or pitting. Hinge of right valve consists of a positive anterior crenulate tooth, subjacent nearly smooth subdued bar, and posterior crenulate tooth; left valve complements that of right valve, with thickening of the valve immediately ventral to anterior crenulate socket. Muscle scars not observed.

Remarks: This species is by far the most common among the samples analyzed for this study. The nodose forms have long been known to indicate lagoonal or brackish water conditions (Sandberg 1964; Howe 1971; van Harten 2000). The presence of abundant nodose specimens in the samples indicates that the environment of deposition of the sediments was in a lagoon or brackish-water environment along the Eocene paleoshoreline of Jamaica.

The taxonomy and identification of these species is problematical because almost all of the specimens are articulated, thus critical taxonomic features such as the details of the hinge, the muscle scar pattern, and the nature of the marginal pore canals cannot be well observed. This species is very close morphologically to *Cyprideis*, and is questionably placed in this genus. *Cyprideis* is, however, considered to occur only from the Miocene to the Recent (Benson 1961; Sandberg 1964; Jiricek and Riha 1993). The taxonomy of this group of ostracodes (the Tribe Cyprideidini, which includes *Cyprideis*, *Miocyprideis*, *Vetustocytheridea*, *Hemicyprideis*, *Cytheridea* and others (Kollmann 1958; Sandberg 1964)) needs further study, as suggested by Jiricek and Riha (1993). Of the genera just listed, none but *Vetustocytheridea* and *Cytheridea* are known to have occurred in the Eocene, and the species described herein clearly does not belong to *Cytheridea*, which has a sloped posterodorsal margin. *Vetustocytheridea* is problematical. Whereas Apostolescu (1956) and Benson (1961) described *Vetustocytheridea* as being distinct from *Cyprideis* on the basis of a thickening of the shell wall just below the anterior socket of the left valve (a feature not observed in the species from the Guys Hill Formation), Sandberg (1964) diagnosed *Vetustocytheridea* on the basis of the mandibular scar, marginal denticulations and hinge morphology. According to the diagnosis of Sandberg, the species described herein could not be assigned to *Vetustocytheridea*.

Jiricek and Riha (1993) noted that the Cyprideidini can generally be separated into two groups, those that display the overall shape of *Cyprideis* (such as the species observed herein that display a broadly rounded posterior margin) and those that are more similar to *Cytheridea*. In this author's opinion, the two morphotypes that have been included in the Tribe Cyprideidini differ considerably and should belong to separate groups. In addition, the morphologies similar to that of *Cyprideis* have been split into an unduly large number of genera and subgenera that make the group challenging taxonomically. A thorough review and revision of the tribe is needed.

Family CYTHERURIDAE G. W. Müller 1894

Genus *Paracytheridea* G. W. Müller 1894

***Paracytheridea jamaicaensis* Puckett n. sp.**
Plate 1, figures 8, 11

Type Specimens: USNM 534044 (holotype, RV, plate 1, figure 8, sample Jamaica 9), USNM 534045 (paratype, carapace, sample Jamaica 9).

Etymology: Named after Jamaica, to which this species is endemic as currently known.

Diagnosis: This species is characterized by a reticulate carapace, a costa that extends along mid-height from anterior margin to approximately one-third length, and pronounced alae that terminate in a blunt spine.

Description: Carapace robust and elongate, with greatest posterior protuberance slightly below mid-height and greatest height at anterodorsal angle. Anterior margin broadly rounded, with greatest anterior protuberance slightly below mid-height, ventral margin very slightly convex, with gentle undulations; posteroventral margin gently concave, extending to near mid-height at distinct, bluntly pointed posterior margin; short, nearly straight posterodorsal margin; dorsal margin slightly to markedly convex, which corresponds to the presence of a posterodorsal lobe; subdued lobe at anterior terminus of alae. Development of posterodorsal lobe may indicate sexual dimorphism, with females bearing a pronounced lobe and with males displaying a subdued lobe. Very little valve overlap, with left valve only slightly overlapping right along anterior and posterior margins. Carapace evenly and strongly reticulate except along anterior and posterior margins; a single costa extends along mid-height from anterior margin to approximately one-third length, extending along anteroventral swelling; center of carapace appears sunken due to presence of alae near ventral margin and posterodorsal lobe. Hinge straight, simple, with no apparent anterior hinge element, weakly crenulate median bar, and posterior, weakly crenulate tooth in right valve and corresponding socket in left valve. Muscle scars not observed. Anterior and posterior marginal areas with simple, straight pore canals.

Measurements:

<i>Paracytheridea jamaicaensis</i>	Length (mm)		Height (mm)	
	LV	RV	LV	RV
	.48	.53	.22	.23
	.50	.48	.23	.22
	.50	0.38	0.23	0.21
	0.50	0.48	0.24	0.21
	0.50	0.5	0.23	0.21
	0.49	0.48	0.23	0.21
	0.48	0.51	0.23	0.24
	0.50	0.49	0.26	0.24
	0.47	0.52	0.23	0.23
	0.49	0.50	0.23	0.22
Average	0.49	0.49	0.23	0.22

Remarks: *Paracytheridea* is a fairly common genus in the post-Mesozoic strata of the Gulf of Mexico and Caribbean region, particularly the species *P. tschoppi* Bold, *P. altita* Edwards, *P. byramensis* Howe and Law, and *P. bellhavenensis* Howe and Chambers. The species described herein differs from all of the species of the genus principally by the shape (being very pointed posteriorly at mid-height) and the high degree of reticulation across the carapace but the extreme anterior and posterior extremities.

***Paracytheridea inflata* Puckett n. sp.**

Plate 1, figures 1-7

Type Specimens: USNM 534056 (carapace, plate 1, figure 3, sample Jamaica 2), USNM 534057 (LV, sample Jamaica 9).

Etymology: *inflatus*, Latin for puffed up, swollen, in reference to the inflated posterior portion of the carapace.

Diagnosis: Species of *Paracytheridea* characterized by a posteriorly inflated carapace.

Description: Carapace large, robust. Greatest height at anterodorsal angle, greatest length at mid-height. Anterior margin broadly rounded, with greatest anterior protuberance just below mid-height; ventral margin broadly convex; acuminate posterior margin, with greatest posterior protuberance at mid-height; dorsal margin straight, but obscured by posterodorsal swelling. Left valve overlaps right valves very slightly along anterior and posterior margins. Prominent posterodorsal swelling, much less prominent swelling at approximately one-third length below mid-height, slight swelling just anterior to acuminate posterior margin; shallow sulcus anterior to posterodorsal swelling; prominent, blunt alae. Surface ornamentation variable, ranging from smooth or slightly pustulose to reticulate, with evenly distributed reticulae; costae along ventral margin parallel to ventral margin. Hinge lophodont, with crenulate bar. Muscle scars not observed.

Measurements:

<i>Paracytheridea inflata</i>	Length		Height	
	LV	RV	LV	RV
	0.59	0.55	0.30	0.30
	0.56	0.53	0.33	0.29
	0.61	0.57	0.30	0.32
	0.63	0.58	0.31	0.30
	0.58	0.60	0.32	0.32
	0.63	0.56	0.36	0.34
	0.65	0.57	0.32	0.31
	0.58	0.62	0.33	0.28
	0.60	0.60	0.33	0.32
	0.56	0.62	0.33	0.28
Averages	0.60	0.58	0.32	0.31

Remarks: Generic assignment was problematical for this species, as the posterior inflation results in a morphology more characteristic of *Bythoceratina* than *Paracytheridea*. Other features, including hinge type and ornamentation, are characteristic of *Paracytheridea*. Unfortunately, the muscle scars are not visible on the specimens, even single valves, due to diagenetic alteration; the muscle scar pattern could be definitive regarding the generic assignment. In another point of view, with the exception of the posterior inflation, this species is very similar to *P. jamaicensis*, which suggests the possibility of sexual dimorphism, with the *P. inflata* form being the female. However, the species lacks the anterior, longitudinal ridge that occurs on *P. jamaicensis*, and is thus considered to be a separate species.

Family HEMICYTHERIDAE Puri 1953
Genus *Cythereis* Jones 1849

***Cythereis? iturraldei* Puckett n. sp.**

Plate 3, figures 7-8

Type Specimens: USNM 534046 (holotype, carapace, plate 3, figure 7, sample Jamaica 2), USNM 534047 (paratype, carapace, sample Jamaica 2).

Etymology: Named after Manuel Iturralde-Vinent of the Museo Nacional de Historia Natural, Havana, Cuba, who collected the samples studied in this report and has assisted the author in the field in Cuba.

Diagnosis: This species is characterized by a moderately robust carapace, moderately developed reticulation, a ventral costa, and a dorsal costa that ends in a small knob.

Description: Carapace moderately robust, tapering lightly posteriorly. Greatest length slightly below mid-height, where the greatest anterior and posterior protuberances occur. Anterior margin broadly rounded; dorsal margin highest at eyespot, with slight concavity near mid-length, and posterior half of dorsum slightly arched; posterodorsal angle moderately distinct, sloping slightly concavely to posterior protuberance; ventral margin broadly rounded to just anterior of mid-length, where margin is slightly concave. Valves essentially symmetrical, with very little valve overlap. Exterior surface reticulate, with larger reticulae along anterior margin defined by muri normal to anterior margin; reticulae along posteroventral margin also relatively large, defined by muri almost normal to posteroventral margin; ventral costa originating near anteroventral margin, flaring laterally posteriorly to end in small knob or spine at approximately 1/5 length; small knob along dorsal margin directly above posteroventral knob; subdued subcentral tubercle with reduced reticulation; continuous costa around margin; indistinct eyespot. Hinge holamphidont, with terminal teeth at anterior and posterior angles (hinge of right valve observed indistinctly on only one specimen, hinge of left valve not well exposed on single valves). Muscle scars and marginal pore canals not observed.

Remarks: This species is questionably placed in *Cythereis* due to lack of costae and other ornamentation indicative of other genera. The species occurs rarely, and is almost always articulated, thus the important internal characters, such as the details of the hingement and the muscle scar pattern, could not be observed. There is some variation in the development of ornamentation, with some specimens bearing well-defined reticulation and large posterodorsal and posteroventral knobs and other being more subdued. It is uncertain whether this variation is due to sexual dimorphism, ecophenotypy, or preservation.

Measurements:

<i>Cythereis? iturraldei</i>	Length		Height	
	LV	RV	LV	RV
	0.60	0.59	0.37	0.37
	0.52	0.58	0.29	0.37
	0.60	0.55	0.33	0.33
	0.52	0.58	0.33	0.38
	0.59	0.54	0.34	0.33
		0.52		0.30
Averages	0.57	0.56	0.33	0.35

Genus *Quadracythere* Hornibrook 1952

***Quadracythere robusta* Puckett n. sp.**

Plate 4, figures 1-8, 10

Type Specimens: USNM 534048 (holotype, RV, plate 4, figure 1, sample Jamaica 2), USNM 534049 (paratype, carapace, sample Jamaica 2).

Etymology: *robusta*, referring to the robust nature of the carapace.

Diagnosis: This species is characterized by large reticulae and intervening 5-6 ridges angled posterodorsally, a prominent dorsal ridge extending from just below eyespot to mid-dorsum, a prominent ventrolateral carina that bifurcates at approximately mid-length, and a depression along the dorsum just posterior to eyespot.

Description: Carapace robust. Greatest height at dorsal shoulder just posterior to mid-length and at eyespot; greatest length slightly below mid-height; greatest width just posterior to mid-length. Anterior margin broadly rounded, with greatest anterior protuberance slightly below mid-height; dorsal margin with prominent depression just posterior to eyespot, distinctly arched in posterior 2/3 and above eyespot; dorsoventral margin concave; ventral margin with concavity at approximate 1/4 length, broadly rounded in posterior 3/4. Very little to no overlap of left and right valves. Anterolateral surfaces compressed, with 6 fossae separated by straight muri, bordered posteriorly by subdued marginal carina continuous with eyespot; lateral surface with reticulation pattern formed by subcircular fossae and muri forming a ridge system, with ridges angled posterodorsally; scattered foveolae; posterior margin compressed, with three elongate fossae and straight intervening muri; prominent dorsal carina, extending from just below eyespot posterodorsally to just posterior to mid-length, where it forms the highest part of dorsum along the posterodorsal margin, then angles sharply posteroventrally to just below greatest posterior protuberance; the sharp posterodorsal angle produced by the dorsal carina is mirrored by the dorsoventral margin; prominent ventrolateral carina extends from near anteroventral margin to point slightly anterior to posterior termination of dorsal carina, flaring widely posteriorly to almost alate form, bifurcates just above ventral concavity at approximately 1/4 length; distinct eyespot; a few short, blunt denticles along posteroventral margin. Inner margin and line of concrescence nearly coincident, maintaining width along anterior, posterior and ventral margins; hinge amphidont; in right valve with distinct anterior tooth, sub-jacent socket, straight medial hinge element, and large, bulbous posterior tooth at posterodorsal angle; left valve complements that of right; distinct, circular central muscle scar pit; scattered foveolae, linked to exterior of carapace; muscle scars not observed.

Remarks: This species is fairly common in each of the samples studied herein. It is very similar morphologically to *Quadracythere stadnichenkoe* Bold 1961 of Guatemala and *Q. goldenensis* Bold 1961 of Guatemala and Honduras, both from the Lower Eocene. It differs from *Q. goldenensis* in the possession of a distinctive eyespot, a concave posterodorsal margin, a distinctive dorsal carina, and fewer but larger reticulations. It differs from *Q. stadnichenkoe* in being less subquadrate, a more prominent dorsal carina, a more concave posterodorsal margin, and fewer but larger reticulations. *Quadracythere stadnichenkoe* and *Q. goldenensis* are restricted to the upper part of the

Petén Group of Honduras and Guatemala (van den Bold 1961; 1963b).

Measurements:

<i>Quadracythere robusta</i>	Length (mm)		Height (mm)	
	LV	RV	LV	RV
	0.71	0.69	0.39	0.42
	0.73	0.64	0.44	0.34
	0.81	0.80	0.50	0.50
	0.70	0.69	0.42	0.43
	0.71	0.69	0.45	0.42
	0.71	0.71	0.42	0.42
	0.71	0.70	0.42	0.42
	0.76	0.74	0.43	0.43
	0.70	0.71	0.40	0.43
	0.72	0.70	0.42	0.40
	0.73	0.71	0.43	0.42
Averages	0.73	0.71	0.43	0.42

***Quadracythere polycosta* Puckett n. sp.**

Plate 4, figure 9

Type Specimens: USNM 534050 (holotype, carapace, plate 4, figure 9, sample Jamaica 9), USNM 534051 (paratype, carapace, sample Jamaica 9).

Etymology: *poly*, referring to many, and *costa*, referring to ridges, in references to the relatively large number of small costae on the lateral portions of the carapace.

Diagnosis: This species is similar in overall morphology to *Quadracythere robusta* n. sp., but has a greater number of (generally 8) and less robust costae on the lateral margins of the carapace.

Description: Carapace robust. Greatest height slightly posterior to eyespot; greatest anterior protuberance near mid-height, greatest posterior protuberance well below mid-height; greatest width just posterior to mid-length. Anterior margin broadly rounded; dorsal margin with prominent depression just posterior to eyespot, distinctly arched in posterior 2/3; dorsoventral margin concave; ventral margin with concavity at approximate 1/3 length. Very little to no overlap of left and right valves. Anterolateral surfaces compressed, with 5 fossae separated by straight muri, bordered posteriorly by subdued marginal carina continuous with eyespot; lateral surface with reticulation pattern formed by subcircular fossae and muri forming a ridge system, with ridges angled posterodorsally, generally 9 anteroventral-posterodorsal costae; scattered foveolae; posterior margin compressed, with costa paralleling concave posterodorsal margin; prominent dorsal carina, extending from just below eyespot posterodorsally to near posterodorsal margin, then angles sharply posteroventrally to just below greatest posterior protuberance; the sharp posterodorsal angle produced by the dorsal carina is mirrored by the dorsoventral margin; row of fossae parallel to ventral margin; distinct eyespot. Inner margin and line of concrescence nearly coincident, maintaining width along anterior, posterior and ventral margins; hinge amphidont; in right valve with distinct anterior tooth, sub-jacent socket, straight medial hinge element, and large, bulbous posterior tooth at posterodorsal angle; left valve complements that of right; distinct, circular central muscle scar pit; scattered

foveolae, linked to exterior of carapace; muscle scars not observed.

Measurements:

Quadracythere polycosta	Length		Height	
	LV	RV	LV	RV
	0.61	0.61	0.35	0.35
	0.62	0.63	0.36	0.04
	0.61	0.62	0.39	0.33
	0.61	0.61	0.37	0.33
	0.60	0.61	0.34	0.32
	0.64	0.58	0.37	0.34
	0.59	0.59	0.32	0.34
	0.58	0.57	0.31	0.31
	0.54	0.54	0.29	0.29
	0.58	0.57	0.28	0.28
Averages	0.60	0.59	0.34	0.29

Remarks: This species appears to be closely related to *Q. robusta*, based on similarity of morphology and temporal association. This species is not as common as *Q. robusta*.

Genus *Hemicythere* Sars 1925

Hemicythere elongata Puckett n. sp.

Plate 3, figures 9-10

Type Specimens: USNM 534051 (holotype, 534052, carapace, plate 3, figure 9, sample Jamaica 2), USNM 534053 (paratype, RV, sample Jamaica 9).

Etymology: *elongata*, referring to the elongate shape of the carapace.

Diagnosis: This species is distinguished by its elongate shape, regular pattern of reticulation, and anterior marginal zone with large reticulae.

Description: Carapace elongate, robust. Greatest height at eyespot, greatest length just dorsal to posterior margin at posteroventral protuberance. Anterior margin broadly rounded, with greatest anterior protuberance just below mid-height; dorsal margin almost straight, with slight concavity posterior to eyespot; posterodorsal margin sharp and distinct, with dorsal and posterior margins at approximately 80° angle, leading to concave posterior margin; posteroventral margin with subdued caudal process; ventral margin nearly straight, with gentle concavity near mid-length and subdued convexities anterior and posterior to mid-length. Very little valve overlap. Lateral surface regularly reticulate, with muri separating fossae angled slightly posteroventrally below mid-height and slightly posterodorsally above mid-height; anterior margin with muri elongated normal to anterior margin, forming large, elongate fossae; posteroventral margin with two convex-upwardly curved muri extending to slightly anterior to posteroventral angle; reticulation just anterior to center of carapace slightly subdued; slight depression posterior and ventral to eyespot. All specimens articulated (no internal features observed).

Remarks: This species differs from *H. dalli* Howe and Brown 1935 (Howe 1935) in being more reticulate and less smooth; it

differs from *H. phryionia* Howe 1951 (Howe 1951) in lacking the two spines on the posteroventral margin; it differs from *H. lienosa* Howe 1951 in being reticulate rather than pitted; it differs from *H. cribraria* Howe 1951 in being more elongate, having a more elongate posteroventral margin, and no posteroventral projecting costae; it is similar to *H. bellula* Howe 1951, but lacks the ventral ridge and very concave posterodorsal margin; it differs from *H. mota* Howe 1951 in being more elongate and lacking a sharp posterior projection; it differs from *H. aleatoria* Howe 1951 in lacking the fine raised ridge among the reticulae and distinct ventral costa; it differs from *H. lemniscata* Howe 1951 in lacking the ribbon-like longitudinal ribs that pass over the muscle scar swelling; it differs from *H. anterocostata* Butler 1963 (Butler 1963) in lacking the strongly developed ridges in the anterior portion of the carapace; it differs from *H. antillea* Bold 1946 in lacking the very strong costa at the posterodorsal angle; it differs from *H. symmetria* Bold 1946 (van den Bold 1946) in being reticulate; it differs from *H. limbata* (Bosquet 1852) (van den Bold 1946) in being more elongate and with more parallel dorsal and ventral margins; it differs from *H. bichensis* Bold 1963 (van den Bold 1963b) in lacking the distinctive ventral costa, posteroventral and posterodorsal swellings and having different reticulation; it differs from *H. confragosa* Ruggieri 1949 (Ruggieri 1949) in being reticulate rather than punctuate; and it differs from *H. cimbaeformis* Ruggieri 1949 (Ruggieri 1949) in lacking the posterodorsal concavity and having much coarser reticulation.

Genus *Orionina* Puri 1953

Orionina anteroexposita Puckett n. sp.

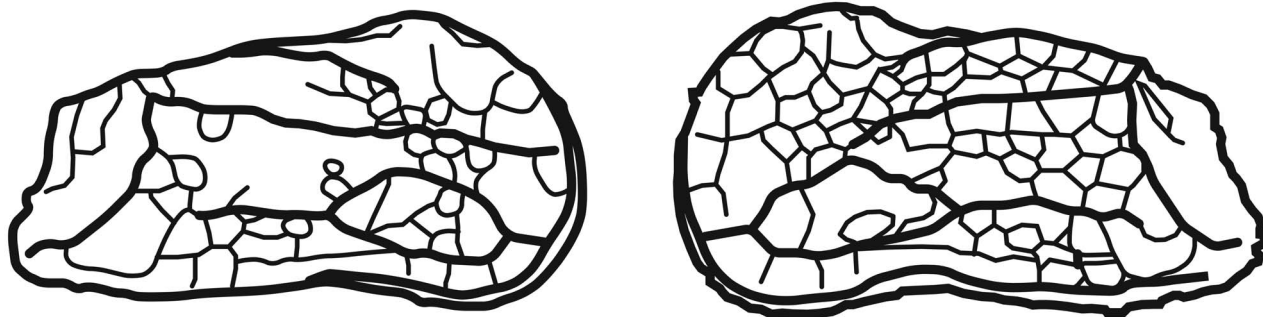
Plate 3, figures 1-6; text-figure 7

Type Specimens: USNM 534054 (holotype, short form (female?), carapace, plate 3, figure 2, sample Jamaica 9), USNM 534055 (paratype, long form (male?), carapace, sample Jamaica 2).

Etymology: *antero*, referring to the anterior portion of the carapace, and *exposita*, referring to the large opening (non-reticulate) in the anterior portion of the carapace.

Diagnosis: This species is characterized by several prominent costae; one that extends from the posteroventral corner, concave up, almost to the posterodorsal margin, then angles sharply to the anteroventral margin; another costa extends from the posteroventral region anterior to approximately mid-length, where it bifurcates, forming a loop, then rejoins to terminate near the anteroventral margin; and a third costa that extends from the sharp angle of the first described costa along the dorsal margin to approximately mid-length, where it angles toward the anteroventral margin, attaching to the loop described for the second costa. In contrast to other species of *Orionina*, the posterior costa does not connect with the ventral costa, being deflected to the posteroventral angle. The anterior region, particularly slightly below mid-height, includes a large area without reticulations.

Description: Carapace elongate, highly ornamented. Greatest height at anterior eyespot, approximately ¼ length from anterior margin, greatest anterior protuberance slightly below mid-height, greatest posterior protuberance near ventral margin. Two ill-defined morphs (see measurements and length/width plot below), a “long” form (>0.60 mm in length) and a “short” form (<0.60 mm in length), that possibly represent sexual dimorphs, although the in-group variation is greater than the be-



TEXT-FIGURE 7

Sketch showing the major ridge systems of *Orionina anteroexposita* n. sp.

tween-group variation. Dorsal margin slightly convex due to elevation of dorsal costa above dorsal margin; anterior margin broadly and evenly rounded continuously around anteroventral margin; ventral margin concave slightly anterior to mid-length, convex in posterior half; posteroventral margin sharp, extending to concave posterior margin; posterodorsal margin with distinct angulation. Very little valve overlap, with only slight overlap of left valve along anterior margin. Several distinct costae (text-figure 7); one extends from posteroventral margin, concave up to dorsal margin in front of posterodorsal angle, then angles sharply toward the anteroventral margin, losing definition at subcentral swelling; another costa originates near cen-

ter of posteroventral quarter of carapace, extending anteriorly to slightly anterior to mid-length, where it bifurcates, forming a loop; costae rejoin to form short costa projecting to near anteroventral margin; another costa extends from near posterodorsal angle along dorsum to approximately $\frac{1}{4}$ length posterior to anterior margin, where it is slightly deflected ventrally under eyespot; carapace reticulate between costae except for large area slightly ventral to mid-height in anterior portion of carapace; reticulations generally sparse in anterior portion of shell. Hinge holamphidont, in LV with anterior socket, tooth, ridge and posterior socket; hinge of RV complements that of LV. Other features of inner portion of carapace not observed.

PLATE 1

RV = right valve, LV = left valve

Figures 1-7 *Paracytheridea inflata* n. sp., scale bars equal 200 μ m.

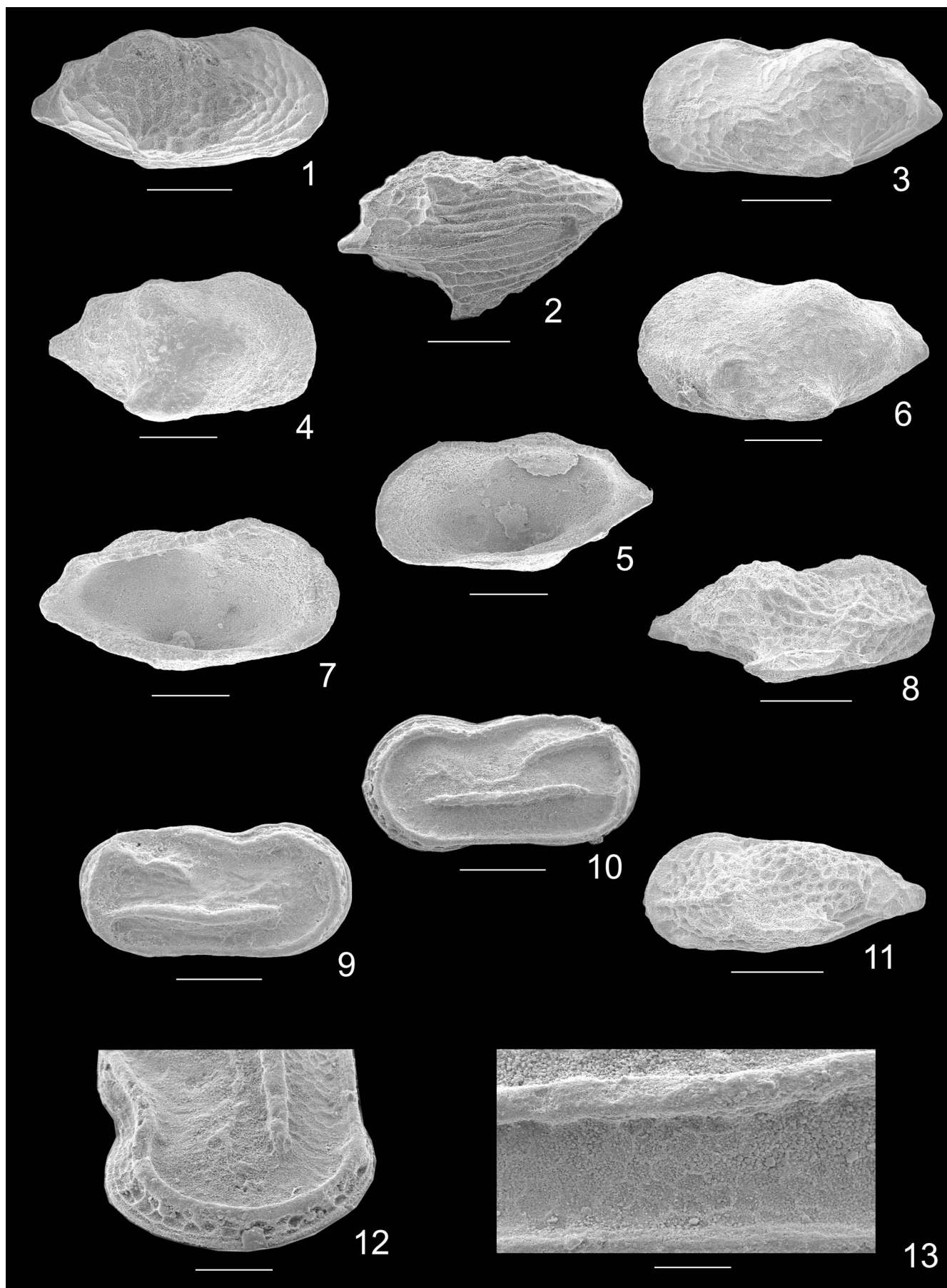
- 1 external view of RV; ventral view of longitudinal costae; specimen from sample Jamaica 2;
- 2 ventral view of longitudinal costae; specimen from sample Jamaica 2;
- 3 holotype (USNM 534056), external view LV; specimen from sample Jamaica 2;
- 4 external view of RV, smooth phenotype; specimen from sample Jamaica 9;
- 5 internal view RV; specimen from sample Jamaica 9;
- 6 external view LV, smooth phenotype; specimen from sample Jamaica 9;
- 7 internal view LV; specimen from sample Jamaica 9.

Figure 8, 11 – *Paracytheridea jamaicaensis* n. sp., scale bars equal 200 μ m, specimens from sample Jamaica 9.

- 8 holotype (USNM 534044), external view RV;
- 11 external view LV.

Figures 9-10, 12-13 *Cytherelloidea nebuloreticulata* n. sp., all specimens from sample Jamaica 2.

- 9 external view RV; scale equals 200 μ m;
- 10 holotype (USNM 574042), external view LV; scale equals 200 μ m;
- 12 holotype (USNM 574042), anterior view showing fine reticulation on anterolateral position of carapace and strongly developed reticulation along anterior marginal area; scale equals 100 μ m;
- 13 holotype (USNM 574042), closeup of faint reticulation on same specimen as figure 10 just below median costa; scale equals 50 μ m.



Measurements:

<i>Orionina aneroexposita</i> (all carapaces)	Length		Height	
	short form	long form	short form	long form
	0.55	0.61	0.33	0.32
	0.56	0.61	0.31	0.34
	0.56	0.61	0.32	0.33
	0.56	0.62	0.32	0.34
	0.57	0.62	0.31	0.33
	0.57	0.63	0.33	0.33
	0.57	0.63	0.31	0.32
	0.58	0.63	0.32	0.34
	0.58	0.63	0.26	0.33
	0.59	0.64	0.32	0.33
	0.59	0.64	0.35	0.34
	0.59	0.65	0.32	0.33
	0.59	0.65	0.27	0.33
	0.59	0.65	0.31	0.35
		0.66		0.33
Averages	0.58	0.63	0.31	

Remarks: This species is similar morphologically to *Orionina vaughani* van den Bold and *O. serrulata* (Brady), but differs from those species in two ways. First, the anterior portion of the carapace is generally open, containing a large, subcircular region just ventral to mid-height that is free of reticulation. Second, the posterior ends of the two lateral costae in *O. anteroexposita* are not connected by a subvertical costa as they are in *O. vaughani* and *O. serrulata*.

CONCLUSIONS AND SUMMARY

The Eocene was a crucial time in the evolution of mammals and other higher vertebrates, when most of the major modern groups are first recognized in the fossil record. A small but

important Eocene vertebrate fauna is recorded from Jamaica and, in particular, from the deposits of the Yellow Limestone Group of the Seven Rivers area. Land-dwelling vertebrates such as crocodiles, an iguanan lizard, a rhinoceros, what may be a primitive primate, and most importantly significant remains of sirenians (sea cows) transitional from terrestrial to aquatic forms, have been described from these deposits as well as a side-necked turtle and fishes from the aquatic realm. These diverse remains suggest a wide range of paleoenvironmental conditions. Studies by Domning (1999; 2000; 2001a; 2001b; 2001c) on specimens collected in the Guys Hill Formation and adjacent stratigraphic units in the Yellow Limestone Group have, in particular, focused on the morphologic changes during the initial aquatic adaptations of the sirenians. For example, the pelvis in the earliest sirenians connected with upright legs, in a structure adapted for walking on land, whereas the hips of later forms were much reduced, as in living sirenians, in an arrangement that was more efficient for swimming. Overall, Domning's work on the Jamaican sirenians provides a dramatic demonstration of tetrapod origins in one major group of modern marine mammals.

Ostracodes (small, bivalved crustaceans) have long been recognized as excellent paleoenvironmental indicators, and they independently support a scenario of shifting marginal environments in the Guys Hill Formation. According to the ostracode data, salinities during that time interval fluctuated from fully marine to nearly freshwater. Specifically, the presence of the genera *Hemicythere* and *Orionina*, based on modern analogues, indicates fully marine conditions, whereas nodose cyprideids indicate salinities no greater than around 4‰. Low-diversity samples are strongly dominated by the cyprideid ostracodes, whereas the more diverse samples generally include more open marine taxa. These marginal marine conditions are ideal for the earliest marine mammals to evolve from land- to sea-dwelling morphologies. The data from the ostracodes and those from vertebrates, therefore, lead to similar conclusions in regard to the environmental conditions associated with this important step in the evolution of early Cenozoic mammals.

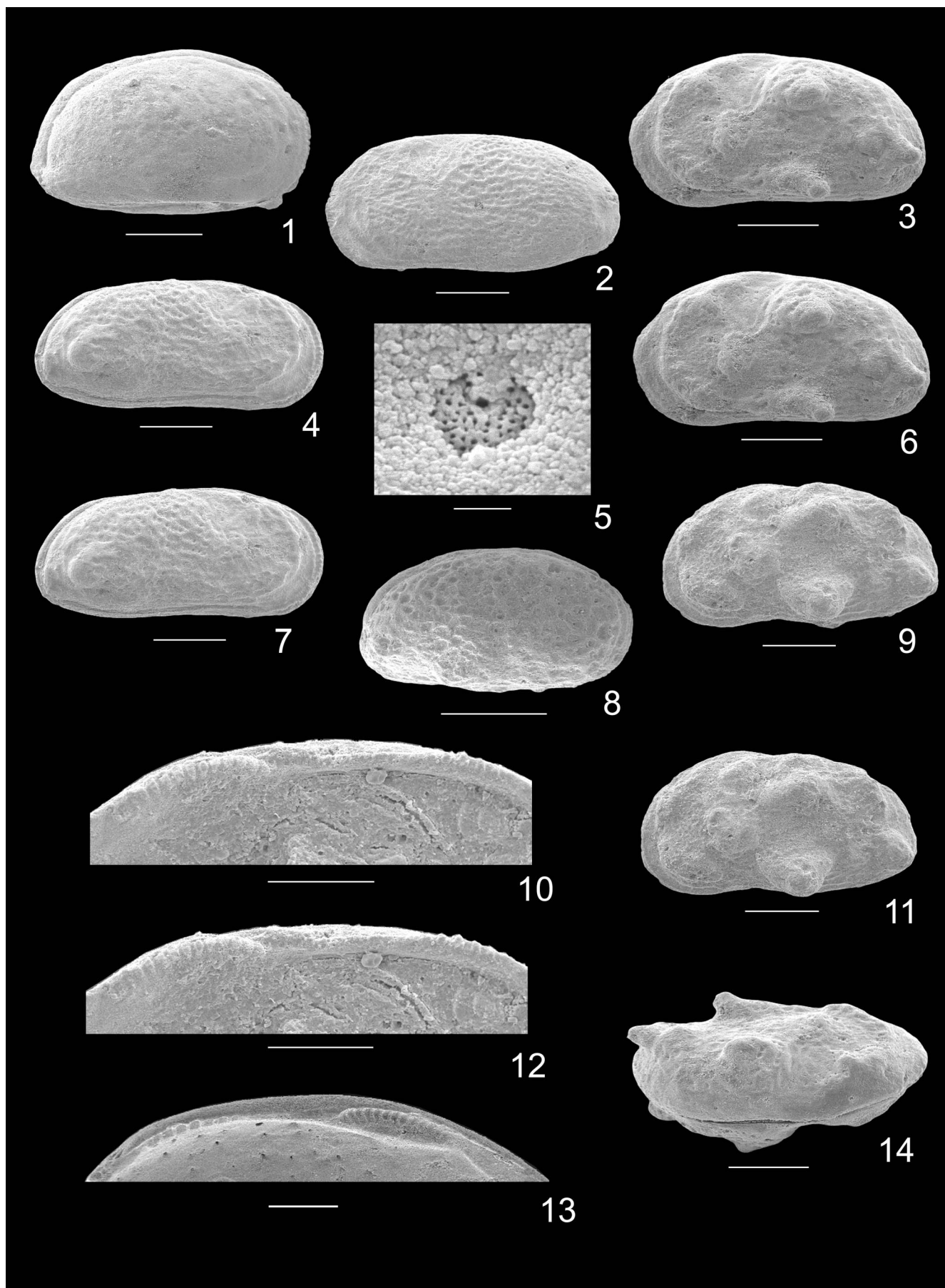
PLATE 2

RV = right valve, LV = left valve

Figures 1-14 – *Cyprideis?* sp. aff. *C. howei* (Stephenson); all specimens from sample Jamaica 2.

- 1 carapace, right view of relatively smooth (non-nodose) individual; note valve overlap; scale bar equals 200µm;
- 2 external view LV; scale bar equals 200µm;
- 3,6 stereopair, carapace, left view, nodose individual; scale bar equals 200µm;
- 4,7 stereopair of carapace, right view, individual with only one (posterior) node; scale bar equals 200µm;

- 5 closeup of sieve pore of specimen on figure 2; scale bar equals 5µm;
- 9,11 stereopair of external view LV, torose individual; scale bar equals 200µm;
- 10,12 stereopair of hinge on RV; scale bar equals 100µm;
- 13 closeup of hinge on LC; scale bar equals 100µm;
- 14 carapace, ventrolateral view, same specimen as figure 3 and 6; scale bar equals 200µm.



ACKNOWLEDGMENTS

Manuel Iturralde-Vinent of the Museo Nacional de Historia Natural in Havana and Ross MacPhee of the American Museum of Natural History in New York are sincerely thanked for sending the samples from the Yellow River Group. Daryl P. Domning, Howard University, is thanked for many helpful discussions regarding the vertebrate fauna and stratigraphy of the Guys Hill Formation. Thomas M. Cronin, US Geological Survey, is thanked for helpful comments on the manuscript. Simon Mitchell, University of the West Indies at Mona, is thanked for permission to publish his measured section of the Seven Rivers area. Richard Fluegeman, Ball State University, is thanked for helpful discussions on the Guys Hill Formation. David J. Horne, University of London, is thanked for helpful comments on an earlier version of this manuscript, particularly regarding ostracode paleoenvironmental analysis and taxonomy.

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PLATE 3

RV = right valve, LV = left valve

Figures 1-6 – *Orionina anteroexposita* n. sp., scale bars equal 200µm.

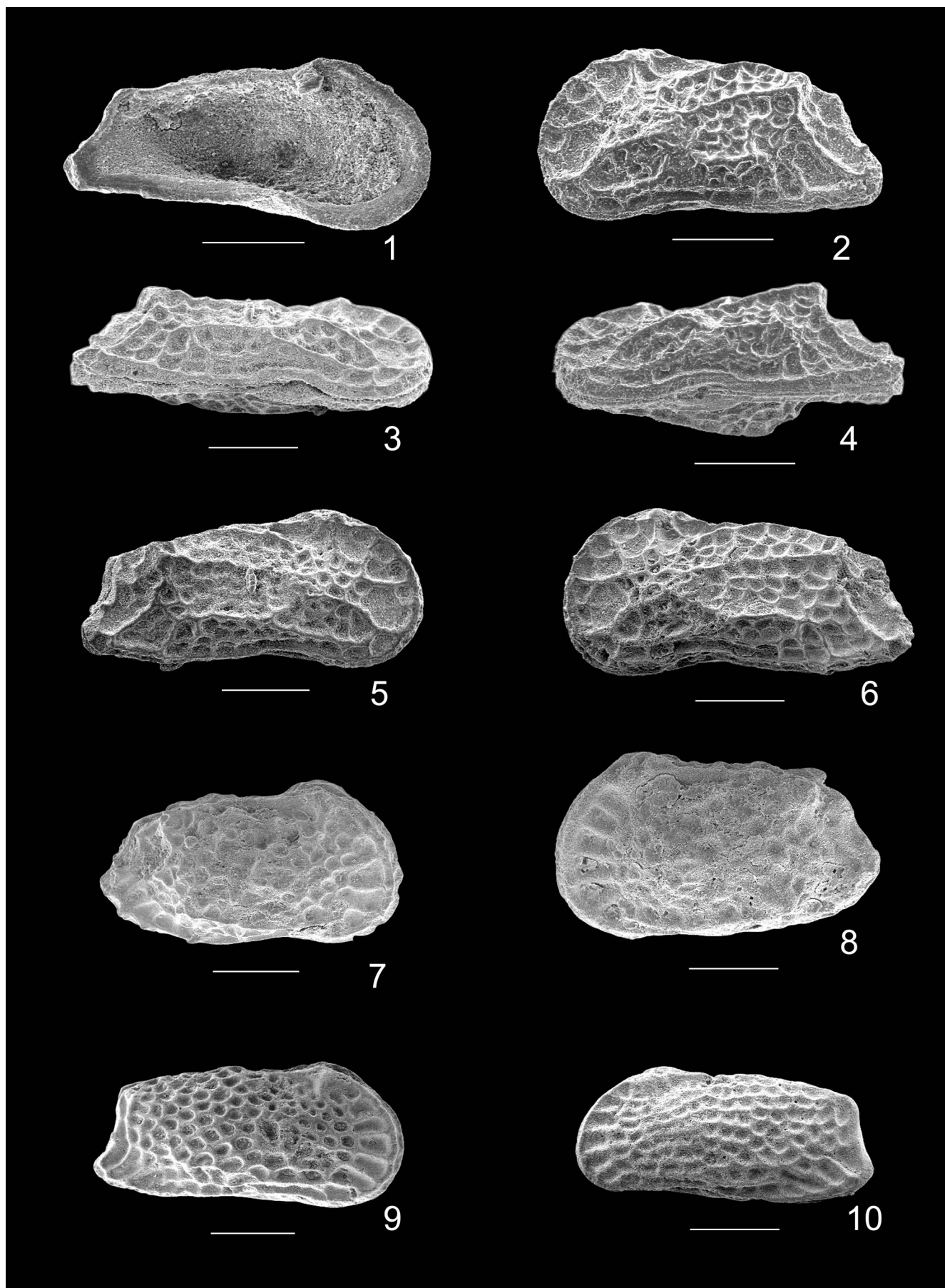
- 1 short form, internal view LV, sample Jamaica 2;
- 2 holotype, (USNM 534054), short form, carapace, left view, sample Jamaica 9;
- 3 long form, carapace, right ventral view, sample Jamaica 8;
- 4 short form, carapace left ventral view, same specimen as figure 2;
- 5 long form, carapace, left view, same specimen as figure 3;
- 6 long form, same specimen as figure 4.

Figures 7 and 8 – *Cythereis? iturraldei* n. sp., scale bars equal 200µm.

- 7 holotype (USNM 534046), carapace, right view, sample Jamaica 2;
- 8 carapace, left view, sample Jamaica 9.

Figures 9 and 10 – *Hemicythere elongata* n. sp., scale bars equal 200µm, both specimens from sample Jamaica 2.

- 9 holotype (USNM 534052) carapace, right view;
- 10 carapace, left view.



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PLATE 4

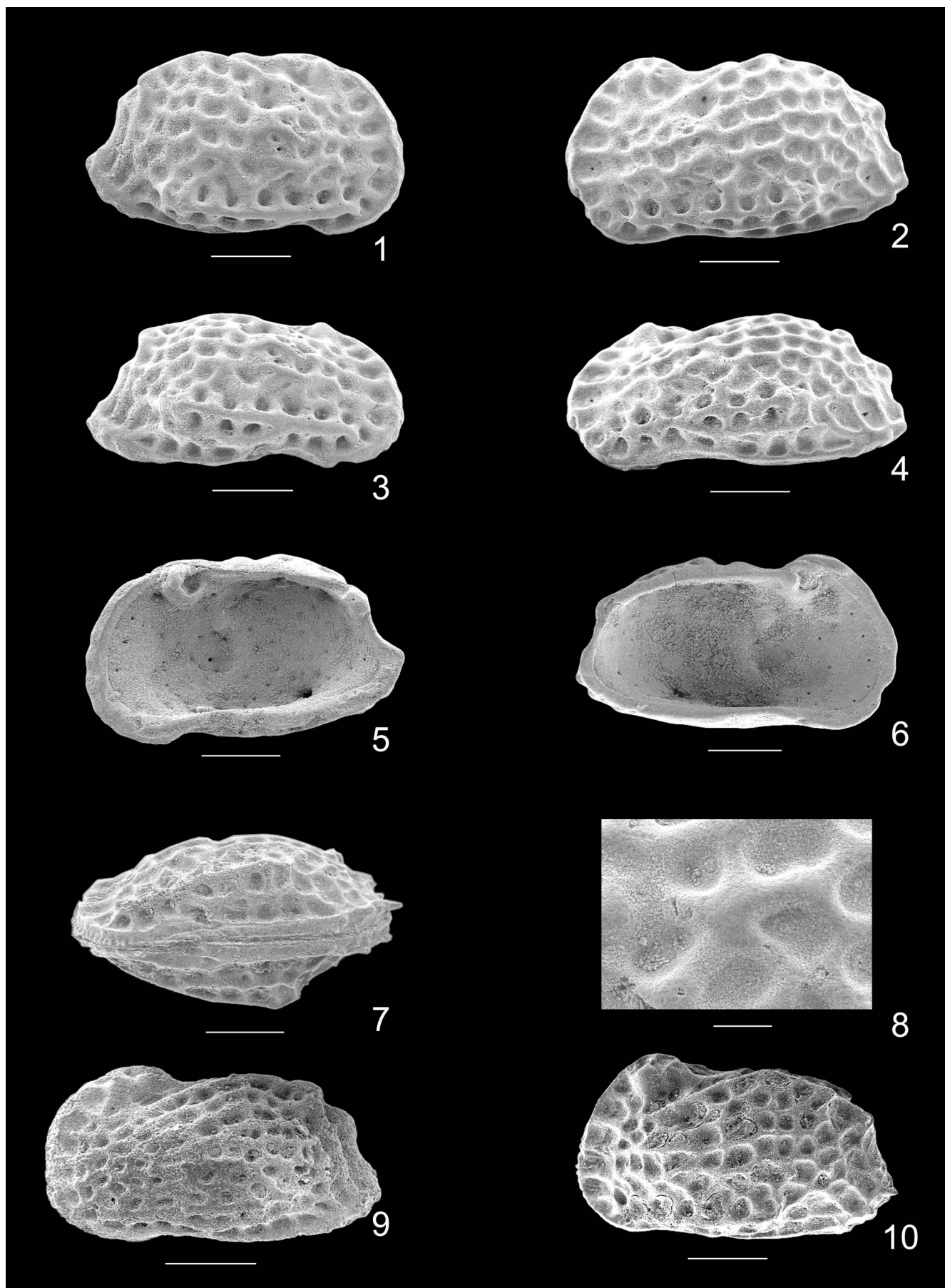
RV = right valve, LV = left valve

Figures 1-8, 10 – *Quadracythere robusta* n. sp., all specimens from sample Jamaica 2.

- 1 holotype (USNM 534048), external view RV; scale bar equals 200µm;
- 2 external view LV; scale bar equals 200µm;
- 3 same specimen as figure 1, right ventral view; scale bar equals 200µm;
- 4 same specimen as figure 2, left ventral view; scale bar equals 200µm;
- 5 same specimen as figure 1, internal view RV; scale bar equals 200µm;

- 6 same specimen as figure 2, internal view, LV; scale bar equals 200µm;
- 7 ventral view of carapace; scale bar equals 200µm;
- 8 closeup of pores on specimen in figure 7; scale bar equals 50µm;
- 10 carapace, left view; scale bar equals 200µm.

9 – *Quadracythere polycosta* n. sp., scale bar equals 200µm, sample Jamaica 9, holotype (USNM 534050), carapace, left view.



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Manuscript received October 14, 2007

Manuscript accepted April 18, 2008