

36. THE CENOZOIC OSTRACODE FAUNAS OF THE SAO PAULO PLATEAU AND THE RIO GRANDE RISE (DSDP LEG 39, SITES 356 AND 357)

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Forty-eight samples were examined from two sites (356 and 357) of DSDP Leg 39 from calcareous layers ranging in age from Maestrichtian (Site 356) and Danian (Site 357) to late Neogene. Ostracodes were found in almost all samples (20 cc in size), with 634 specimens identified. The samples were small and the number of specimens would have been considered less than adequate, except for the ability to compare them with the plentiful and complementary assemblages of Sites 21, 21A, and 22 (Maxwell et al., 1970).

The 28 samples examined from Site 357 had better preserved and more abundant specimens than those of Site 356, possibly due to somewhat shallower conditions or a difference in sediment permeability. The total number of taxa identified from all samples, for the most part to the generic level, is less than 25. In no single sample were there more than 10 species; most samples had 5 or less.

As stated in another recent preliminary report (Benson, 1974), the ostracodes of the deep sea are still in the beginning stages of study. However, in spite of the lagging formal description of many of the new taxa, both morphologic and faunal trends are known (Benson, 1975a; Sylvester-Bradley and Benson, 1971). Several new taxa are described for the first time in this report. Tentative names of yet undescribed taxa are given in quotes. A census of the assemblages follows:

Identification of Ostracode Taxa by Site and Sample		
Site 356 (28° 17.22'S, 41° 05.28'W; 3175 m)		
Sample 2-4, 24-26 cm; Plio-Pleistocene, N19-22:		
<i>Poseidonamicus pinto?</i>	3	
<i>Krithe</i> sp. 1	8	
<i>Henryhowella asperrima</i>	2	
	<hr/>	13
Sample 3-4, 31-33 cm; Plio-Pleistocene, N19-22:		
<i>Krithe</i> sp. 1	3	
" <i>Pelecocythere galitea</i> "?	1	
	<hr/>	4
Sample 4-4, 41-43 cm; Plio-Pleistocene, N19-22:		
<i>Krithe</i> sp. 1	2	
<i>Poseidonamicus major</i>	1	
<i>Henryhowella asperrima</i>	2	
	<hr/>	5
Sample 5-5, 41-43 cm; early Miocene, N4:		
<i>Krithe</i> sp. 1	13	
<i>Poseidonamicus major</i>	3	
<i>Bairdia</i> sp.	5	
<i>Cytherella ovata?</i>	2	
" <i>Thalassocythere</i> " <i>acanthoderma</i> (Brady) (no adults)	7	
<i>Henryhowella asperrima</i>	2	
	<hr/>	32
Sample 6-3, 41-43 cm; Eocene, P12:		
unidentified		<hr/>
		1
Sample 8-2, 41-43 cm? middle Eocene, P10-11:		
<i>Krithe</i> sp.		<hr/>
		4
Sample 9-2, 134-136 cm; middle Eocene, P9-10:		
bythocyprids		2
<i>Krithe</i> sp.		1
<i>Bairdia</i> sp.		2
<i>Cytherella ovata</i>		1
<i>Henryhowella</i> instar		1
	<hr/>	7
Sample 10-3, 46-48 cm; early Eocene, P8-9:		
" <i>Oxycythereis</i> " sp.		<hr/>
		1
Sample 12-2, 40-42 cm; early Eocene, P7:		
<i>Krithe?</i> sp.		<hr/>
		1
Sample 14-1, 143-145 cm; early Eocene, P6-8:		
bythocyprids		<hr/>
		3
Sample 16-2, 82-84 cm; Paleocene-Eocene:		
bythocyprids		<hr/>
		2
Sample 22-3, 87-89 cm; late Paleocene, P4:		
<i>Bairdia</i> instar		<hr/>
		1
Sample 23-3, 64-66 cm; late Paleocene, P3:		
<i>Krithe</i> sp.		4
<i>Phacorhabdotus subtridentus</i> Benson, n. sp.		1
	<hr/>	5
Sample 24-4, 94-96 cm; Danian:		
<i>Macrocypris</i>		5
<i>Phacorhabdotus subtridentus?</i>		2
<i>Cytherella ovata?</i>		2
<i>Bairdia</i> sp.		1
<i>Bythocypris</i> sp.		4
	<hr/>	14
Sample 25-3, 86-88 cm; Danian:		
<i>Atlanticythere murareticulata</i> Benson, n. sp.		1
<i>Bairdia</i> sp.		4
<i>Krithe</i> sp.		2
	<hr/>	7
Sample 26-3, 102-104 cm; Danian:		
<i>Phacorhabdotus texanus</i> Howe and Laurencich		3
<i>Cytherella ovata?</i>		2
bythocyprids		2
	<hr/>	7
Sample 27-3, 89-91 cm; Danian:		
<i>Krithe</i> sp. 2		<hr/>
		6
Sample 28-3, 59-61 cm; Danian:		
<i>Krithe</i> sp.		1
bythocyprid		1

<i>Phacorhabdotus texanus?</i>	1	Sample 9-3, 33-35 cm; early Miocene, N5-6:	
<i>Cytherella ovata</i>	1	<i>Poseidonamicus</i> sp.	1
<i>Bairdia</i> sp.	1	" <i>Thalassocythere</i> " sp.	1
cythereisid instar	1	<i>Krithe</i> sp.	2
	<hr/>		<hr/>
	6		4
Sample 29-3, 21-23 cm; Danian:		Sample 10-2, 33-35 cm; early Miocene, N4-5:	
<i>Macrocypris</i>	13	<i>Poseidonamicus pintoi?</i>	9
<i>Krithe</i> sp.	9	trachyleberid (poorly preserved)	5
cythereisid instar	1	<i>Krithe</i> sp.	7
<i>Bairdia</i> sp.	4	<i>Bradleya dictyon?</i>	3
<i>Rocaleberis?</i>	1	" <i>Pelecocythere</i> " sp.	1
	<hr/>	<i>Henryhowella asperrima?</i>	4
	28	<i>Bairdia</i> sp.	2
Sample 30-3, 84-86 cm; late Maestrichtian:		<i>Acanthocythereis</i> sp.	3
<i>Krithe</i> sp.	1		<hr/>
cythereisid instar	1		34
unidentified	1	Sample 11-2, 33-35 cm; early Miocene, N4:	
	<hr/>	<i>Henryhowella asperrima</i>	11
	3	<i>Acanthocythereis</i> aff. <i>A. subsequenta</i>	1
Site 357 (30°00.25'S, 35°33.59'W; 2086 m)		<i>Poseidonamicus</i>	7
Sample 1-3, 35-37 cm; late Pliocene, N21:		<i>Krithe</i> sp.	7
<i>Krithe</i> sp. 1	2		<hr/>
<i>Krithe</i> sp. 2	5	Sample 12-3, 33-35 cm; early Miocene, N4:	
<i>Poseidonamicus pintoi</i>	13	<i>Poseidonamicus</i> sp.	5
<i>Bradleya dictyon?</i> instar	1	<i>Henryhowella</i> sp.	3
	<hr/>	<i>Krithe</i> sp.	5
	21		<hr/>
Sample 2-3, 33-35 cm; early Pliocene, N19:			13
<i>Krithe</i> sp. 1	4	Sample 13-2, 33-35 cm; early Miocene, N4:	
<i>Poseidonamicus pintoi</i>	7	<i>Poseidonamicus</i> sp.	6
<i>Agrenocythere</i> sp.	1	<i>Krithe</i> sp.	4
<i>Henryhowella dasyderma</i> (Brady)	2	bythocyprid	1
	<hr/>		<hr/>
	14		11
Sample 3-3, 33-35 cm; late Miocene, N17-18:		Sample 14-2, 33-35 cm; early Miocene, N4:	
<i>Bradleya dictyon?</i>	3	broken specimen	1
<i>Poseidonamicus major?</i>	14		<hr/>
" <i>Suhmicythere</i> " sp.	2	Sample 15-2, 33-35 cm; early Miocene, N4:	
<i>Krithe</i> sp.	25	<i>Ambocythere</i> sp.	1
<i>Bairdia</i> sp.	2	<i>Poseidonamicus</i>	2
	<hr/>	<i>Rocaleberis?</i> sp.	2
	46	<i>Krithe</i> sp.	12
Sample 4-4, 33-35 cm; mid Miocene, N15-16:			<hr/>
<i>Bradleya dictyon</i>	1		17
<i>Poseidonamicus major?</i>	3	Sample 16-2, 33-35 cm; late Oligocene, P22 (preservation poor):	
<i>Krithe</i> sp.	5	<i>Krithe</i> sp.	16
<i>Cytheropteron</i> sp. instar	1	<i>Rocaleberis nascens?</i> Bertels	2
<i>Henryhowella asperrima</i>	1	<i>Poseidonamicus</i>	2
	<hr/>	unidentified	1
	11	<i>Bairdia</i> sp.	5
Sample 5-3, 33-35 cm; mid Miocene, N14-15:		<i>Bradleya</i> sp.	1
<i>Bradleya dictyon</i>	5	<i>Cytherella</i>	2
<i>Poseidonamicus pintoi</i>	19	" <i>Oxycythereis?</i> "	1
<i>Krithe</i> sp.	4		<hr/>
<i>Henryhowella asperrima</i>	1		30
" <i>Suhmicythere</i> " sp.	1	Sample 17-3, 33-35 cm; late Oligocene, P22:	
	<hr/>	<i>Agrenocythere hazelae</i>	2
	30	<i>Poseidonamicus</i>	2
Sample 6-3, 33-35 cm; early Miocene, N6-7:		<i>Bairdia</i> sp.	2
" <i>Thalassocythere</i> " <i>acanthoderma?</i> (Brady)	4	<i>Bradleya dictyon?</i>	1
<i>Poseidonamicus</i> instars	8	<i>Krithe</i> sp.	2
<i>Krithe</i> sp. 2	7		<hr/>
<i>Henryhowella asperrima?</i>	2		9
	<hr/>	Sample 18-3, 31-33 cm; Oligocene:	
	21	<i>Agrenocythere hazelae</i>	1
Sample 7-3, 33-35 cm; early Miocene, N6-7:		<i>Krithe</i> sp.	15
<i>Poseidonamicus pintoi?</i>	14	<i>Bairdia</i>	4
" <i>Thalassocythere</i> " <i>acanthoderma?</i>	3	<i>Poseidonamicus</i> sp.	3
<i>Krithe</i> sp. 2	9	unidentified	2
	<hr/>		<hr/>
	26		25
Sample 8-3, 33-35 cm; early Miocene, N5-6:		Sample 19-2, 50-52 cm; early Oligocene, P18-19:	
<i>Poseidonamicus</i> sp.	10	<i>Bradleya</i>	1
<i>Agrenocythere hazelae</i>	2	<i>Krithe</i> sp.	2
<i>Bradleya dictyon?</i>	1	<i>Rocaleberis nascens?</i> Bertels	2
" <i>Thalassocythere</i> " sp.?	3		<hr/>
<i>Krithe</i> sp.	7		5
	<hr/>		
	23		

Sample 20-2, 145-147 cm; late Eocene, P16-17:	
<i>Krithe</i> sp.	13
<i>Atlanticythere murareticulata</i> n. sp.	2
<i>Rocaleberis nascens?</i> Bertels	4
<i>Brachyocythere</i> instar	1
<i>Cytheropteron</i> sp.	2
" <i>Thalassocythere</i> "	3
unidentified sp.	4
<i>Eocytheropteron</i> sp.	2
<i>Bythocythere</i> sp.	2
<i>Bairdia</i> sp.	7
	<hr/>
	40
Sample 21-2, 74-76 cm; middle/lower Eocene, P14-15:	
<i>Atlanticythere?</i> sp. (badly preserved)	10
<i>Paleoabyssocythere</i> (grossly reticulate)	1
<i>Eocytheropteron</i> (large)	2
<i>Cytherella ovata</i>	1
<i>Cytherelloidea</i> sp.	1
<i>Bythocythere</i> sp.	2
	<hr/>
	17
Sample 22-3, 81-83 cm; middle Eocene, P11-14:	
<i>Atlanticythere?</i> <i>eocenica</i> Benson, n. sp.	15
<i>Trachyleberis?</i>	1
<i>Cytherella</i> sp.	1
<i>Cytherelloidea</i> sp.	1
<i>Krithe</i> sp.	7
	<hr/>
	25
Sample 23-3, 45-57 cm; middle Eocene, P11-14:	
<i>Krithe</i> sp.	7
<i>Cytherella</i> sp.	1
<i>Bairdia</i> sp.	1
<i>Bradleya</i>	1
<i>Agrenocythere hazelae</i>	1
	<hr/>
	11
Sample 25, CC; middle Eocene, P11-12:	
<i>Krithe</i> sp.	6
<i>Bairdia</i> sp.	1
	<hr/>
	7
Sample 26-3, 49-51 cm; middle Eocene, P11-12:	
<i>Atlanticythere eocenica</i>	1
<i>Krithe</i> sp.	2
bythocyprid	1
	<hr/>
	4
Sample 27-3, 79-91 cm; early Eocene, P8:	
<i>Atlanticythere eocenica?</i>	1
bythocyprid	1
<i>Krithe</i> sp.	2
	<hr/>
	4
Sample 28-3, 62-64 cm; early Eocene, P8:	
<i>Krithe</i> sp.	1
	<hr/>
	1
Sample 30-3, 47-49 cm; Danian:	
<i>Atlanticythere maestrichtia</i> Benson, n. sp.	5
<i>Bairdia</i> sp.	5
<i>Krithe</i> sp.	2
	<hr/>
	12
Total	485

COMPARISON OF TAXA AND FAUNAL ASSEMBLAGES

Of the 23 ostracode genera that have been found in the samples of Sites 356 and 357, all but 5 have been previously described. Two new genera, *Atlanticythere* and *Paleoabyssocythere*, will be described in a section to follow. The three remaining genera are represented by imperfectly known modern species (that is, the lectotypes have not yet been selected; *vide* H. S. Puri, who is in the process with the British Museum in these

designations). These species originally described by Brady (1880) should serve as the type-species of the new genera, for which an informal usage of the new generic names (in quotes) is given here.

The ostracode faunas of Sites 21, 21A, 22, 356, and 357 are similar at a given stratigraphic horizon for that portion of the section where there are samples in common. The greatest change with time takes place in late Eocene or early Oligocene. Ornate ostracodes such as *Atlanticythere* and *Paleoabyssocythere* end or evolve rapidly into new forms at this time. They have remained morphologically stable since the Campanian, except for an increased degree of secondary reticulation. *Phacorhabdotus*, *Eocytheropteron*, and the presence of *Cytherelloidea* also terminate. After this time, the modern deep-sea ostracode fauna begins with the general cooling of the World Ocean and the formation of the psychrosphere (Benson, 1975a; Shackleton and Kennett, 1975). Among the ornate genera, *Poseidonamicus*, *Bradleya* (whose earliest record is in the middle Eocene of Site 357), "*Suhmiocythere*" (based on *Cythere suhmi* Brady, 1880), "*Thalassocythere*" (based on *Cythere acanthoderma* Brady), and *Henryhowella* tend to dominate the new psychrospheric faunas.

Several smooth ostracodes, such as *Bairdia*, *Cytherella*, *Krithe*, and *Bythocypris*, continue on through the change. These genera are typical of deep water, but also have a broader depth range than many of the ornate genera. Their continuance indicates less reaction of these forms to new environments. These smooth ostracodes continually pose a problem of species identification for the paleontologist, yet their value as ecologic indicators is great.

The number of species present in samples from the cores from the Rio Grande Rise, or the ocean floor in general, does not increase or decrease significantly from the Cretaceous to the present, but the diversity does fluctuate identifiably near the Eocene-Oligocene boundary (Figure 1). A late Eocene sample (2-2, 145-147 cm) of Site 357 contained 10 species with only 40 specimens present. In the lower Oligocene of the same site (18-3, 31-33 cm), there were only five species with 25 specimens present. A similar decrease in number of individuals and species was indicated in cores of Sites 19 and 20 of Leg 3. Comparisons with other samples, such as one from the late Miocene of Site 357 (3-3, 33-35 cm) having only five species with 46 specimens found, may indicate other periods of a possible local decline in faunal diversity. There were low diversities in the N15-16 zones of Sites 15 and 16. However, no change in faunal composition is indicated during the Neogene.

Comparison of the ostracode faunas of Sites 356 and 357 shows that of Site 356 to be very poor. Of course, much of the upper Tertiary is missing at Site 356. The late Miocene and Plio-Pleistocene samples of this site, as do those of Site 357, contain typical psychrospheric genera. The few forms that are represented in the lowermost Tertiary of Site 356 are comparable to those of the same age of Sites 21A and 357.

All of these census records tend to reinforce each other. Although admittedly the amount of material from Site 356, and to a lesser degree from Site 357, was

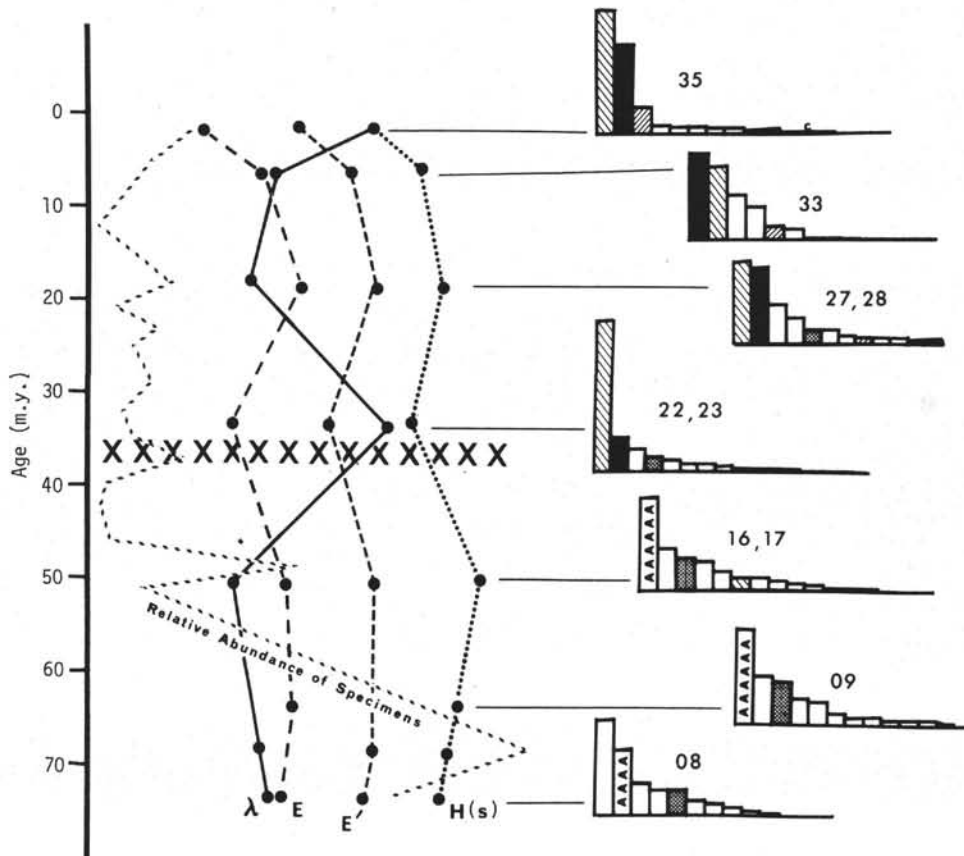


Figure 1. General changes in ostracode assemblage structure and assemblage abundance through 75 m. y. in the South Atlantic (after Benson, 1975 a, b). Note (1) the striking decrease in the relative number of individuals from the early Paleogene onward, (2) the central fluctuation in the four statements of diversity at about 38 m.y.B.P. and (3) the continuity of assemblage structure as shown in the histograms from the Cretaceous through the Eocene, a great change in the Oligocene, and a stabilization in the Neogene. (The histogram identification numbers = the composite foraminiferal zones as shown in Table 1.)

not as abundant as should be present for this kind of analysis, the variability of faunal composition was minimal. The overall trends of the ostracode faunal structure indicate an abrupt change from an ancestral restricted fauna to a descendant deep-sea fauna. There are only two faunas known from the overall fossil succession of the floor of the South Atlantic, and only one general fauna known from post-Eocene times from the ocean (Benson, 1975a). The taxonomic adjustments between these two faunas are reflected at Sites 356 and 357 to complement Sites 21, 21A, and 22. These in total give a relatively complete record of the transition from a deep-water (presumably stressed) thermospheric fauna to a deep-water psychrospheric fauna (Tables 1 and 2). The nature of the stressed or restricted fauna is better understood as other factors besides diversity are considered.

The Maestrichtian and Paleogene ostracode faunas of Argentina have been well described by Bertels (1973, 1974, 1975), especially from the Colorado Basin. This basin, which lies in central Argentina and was contiguous with the Atlantic, contains moderately deep water thermospheric ostracodes (as much as 500 m).

During the Danian, indications of cooling are evident in changes in the fauna of the Rocanian Stage (Bertels, 1975). Some elements of this fauna may be seen in the cores of Sites 356 and 21 (a hiatus is present in Site 357). However, the ostracode faunas of the São Paulo Plateau and the Rio Grande Rise were still deeper than those of the Colorado Basin. There are few species in common (maybe *Rocaleberis nascens* Bertels), although several genera are the same (*Krithe*, *Cytherella*, *Bythocythere*, *Phacorhabdotus*, *Bythocypris*?). Among the ornate species, those of the Colorado Basin are notably more massive in architecture and their ancestry can be traced (except perhaps for the species of *Rocaleberis* and *Wichmannella*) into known shelf depth species (of the genus "*Costa*," *Actinocythereis*, *Munseyella*, and *Buntonia*).

This Argentine fauna is interesting for its differences with the deeper fauna, and these differences should not go unnoticed. First, this shallower fauna is probably the one that would be present if the Rio Grande Rise had been shallow during the late Cretaceous and early Paleogene; and secondly, a lowering of temperatures is noticed even in shelf areas during the Danian. This

TABLE 1
Composite Foraminiferal Zones

Youngest Age (m.y.B.P.)	New Zone Number Used Herein	Planktonic Foraminiferal Zones, etc.
0	35	N21-23
3	34	N19-20
5	33	N17-18
7	32	N16
10	31	N15
12	30	N14
14	29	N9-13
16	28	N6-8
19	27	N5
21	26	N4
22.5	25	N3, P22
26	24	N2, P21
30	23	N1, P20
32	22	P19
35	21	P18
37.5	20	P16,17
41	19	P14, 15
44	18	P12, 13
47	17	P10, 11
49	16	P7-9
52	15	P6
54	14	P5
56	13	P4
58	12	P3
60	11	P2
62	10	P1
65	9	Maestrichtian
70	8	Campanian
76	7	Santonian
81	6	Coniacian
86	5	Turonian
92	4	Cenomanian
100	3	Albian
106	2	Aptian
112	1	Barremian

latter change may portend the conditions that lead to the formation of the psychrosphere. This seems a strong extrapolation. But the ostracodes of this cooling are those that later become important ostracode genera in the psychrosphere of the southern Ocean region, and they remain without great morphologic change since the Paleogene. The lack of the presence of the uppermost slope or shelf ostracode fauna seems to refute the notion that the Rio Grande Rise was much shallower during the latest Cretaceous or Paleogene than it was subsequently.

CHANGES IN OSTRACODE MORPHOLOGY

The notation of a succession of taxa assumes considerably more importance as their evolution is shown to be tied to adaptive responses. Ostracodes live within a thermal-metabolic budget that controls the amount of calcite available for the multiple secretion (molting, ecdysis) of their exoskeleton. Among modern species, those that live in deep cold water are frequently larger in size and almost always have thinner or more delicate carapaces than their more massive warm and usually shallow-water counterparts. To compensate for both of these relative decreases in shell material, the structures that provide strength to the carapace become

better organized and usually more conspicuous. These structures are often deterministic in that they totally react as a static frame. This readjustment of morphological features to fit new conditions can often be seen as increased ornamentation, even if not always understood as members of a structural system (Benson, 1975a).

The morphologic adjustments in structure between antecedent and descendant species of the pre-Oligocene fauna and the post-Eocene fauna are quite noticeable (i.e., *Atlanticythere*). In several cases, this difference is of generic importance (i.e., *Paleoabyssocythere-Abyssocythere*). In view of this structural compensation, it can be stated that there is a definite trend from usage of massive amounts of material as strength to usage of "ornament" or recognizable structure for strength. This is especially notable in the increase and then dominance of reticulation and appearance of secondary reticulation. In the older fauna reticulation is subdued or absent. The shells have a massive appearance. In the younger fauna the ornate shells are reticulate, or spinose, and eventually much larger in size (Figure 2).

DEPTH OF WATER

To consider any hypothesis or argument of subsidence of the South Atlantic basins as seen through paleontological evidence, it is necessary to state a few limitations and strengths of the benthonic indicators as shown by the ostracodes.

First, the ostracodes that occur in the marine fossil record are restricted to the sea or ocean floor. They have no known pelagic larval stages. They are adapted to the conditions of the bottom; that is, to the conditions of mechanical, thermal, and biological stress. They must adapt to larger changes after the fact. The evolution occurs most quickly in the carapace design. If we could understand the statics of shell structure, which is not wholly possible yet, they should indicate in a relatively precise manner, the change in bottom water depth.

Secondly, depth from a paleontological view is seldom a direct function of changes in temperature, decreasing light, movement of water, etc. However, depth does affect ostracodes in proportion to its increase, usually in an exponential manner. Thus, in response to depth, diversity of species decreases, architecture becomes more sophisticated, shell walls thin, size increases, blindness becomes universal, many taxa change as members of assemblages, etc. Some of these changes, such as blindness and decrease in skeletal material, are direct functions of decrease in light or the lowering of temperature. The change in diversity, or presence of certain taxa may be more the result of barriers to immigration and more complex historical limitations that can be easily interpreted in the first examination of a fauna.

To conclude, from the examination of the ostracodes of Site 357 and comparison of these with the faunas of Sites 21A and 22, the depths seem deeper than 1000 meters from the Danian to the present time. The faunas are totally blind (indicating probable depths greater than 800 m) with generally large specimens. The low

TABLE 2
Species - Zone Matrix: South Atlantic

Taxa	Cretaceous		Paleo- cene		Eocene				Oligocene						Miocene			Plio- Pleistocene			Total Specimens	No. of Samples		
	08	09	11	15	16	17	18	19	20	21	22	23	24	25	26	27	28	31	33	34			35	
<i>Cytherelloidea</i>	132	37				1		1															169	8
<i>Glossicythere</i>	6	73																					79	3
<i>Atlanticythere</i> #1	91	151																					242	7
<i>Cythereis</i>	2	8		2																			12	5
<i>Paleoabyssocythere</i>	19	13			1			1															34	7
<i>Atlanticythere</i> #2	34	34			17	67																	152	8
<i>Phacorhabdotus</i>	15			4																			19	3
<i>Atlanticythere</i> #3		9		43	13	16		10	2														93	10
<i>Rocaleberis</i>		11							4	2				2	2								21	6
<i>Australoecia</i>			1		1	1																	3	3
<i>Bairdia</i>	10	27		12	23	8	1	1	8	4	1	4	1	10	8				3		4	125	41	
<i>Argilloecia</i>	2	1																					3	3
<i>Bythocypris</i>	41	11		3	2	1						1											59	10
<i>Cytherella</i>	33	64	1	4	14	20			1	10	4	2	3	2	6		5		1		2	172	37	
<i>Trachyleberidea</i>	3				3	14																	20	5
<i>Cytheropteron</i>		1			4	33			2	1				1				1				5	48	11
<i>Macrocypris</i>	1										2	3											6	3
<i>Kriithe</i>		10	4	2	87	30		1	14	50	42	26	14	32	76	14	36	5	63	28	153	618	100	
<i>Eucythere</i>																		1	2		1		4	4
<i>Eocytheropteron</i>				1		8													1		1		11	4
<i>Mesocythereis</i>				5	1	1								1		1	1						10	6
<i>Oxycythereis</i>					2			1		2		1		4	2		8				1		21	13
<i>Abyssocythere</i>					1	1			1	3	8	2	5	2		4	9		24				60	22
<i>Acanthocythereis</i>						6	1				1				9								17	4
<i>Reticuloechinocythereis</i>							2		2		2	2	2	2			5		17				34	12
<i>Rectangulocythereis</i>							2																2	1
<i>Ambocythere</i>						1									1		1						3	1
<i>Agrenocythere</i>							1			1	3	1		2		3	2				1		14	11
<i>Brachyocythere</i>			1						1		1	1		1	1		1		2		8		17	13
<i>Henryhowella</i>					1					4	2		5	6	19		4		8	10	29		88	28
<i>Poseidonamicus</i>										7	11	4	3	9	46	12	46	3	60	41	111		353	51
<i>Thalassocythere</i>									3	2				7	4	7		6	1	9			39	18
<i>Bradleya</i>							1			1				2	6	1		3	4	2	9		29	16
<i>Pelecocythere</i>											2		1		2				1	1	3		10	8
<i>Echinocythereis</i>																					5		5	4
<i>Suhmicythere</i>													1	1					2		2		6	6
<i>Pseudocythere</i>													1	1					2		2		2	1

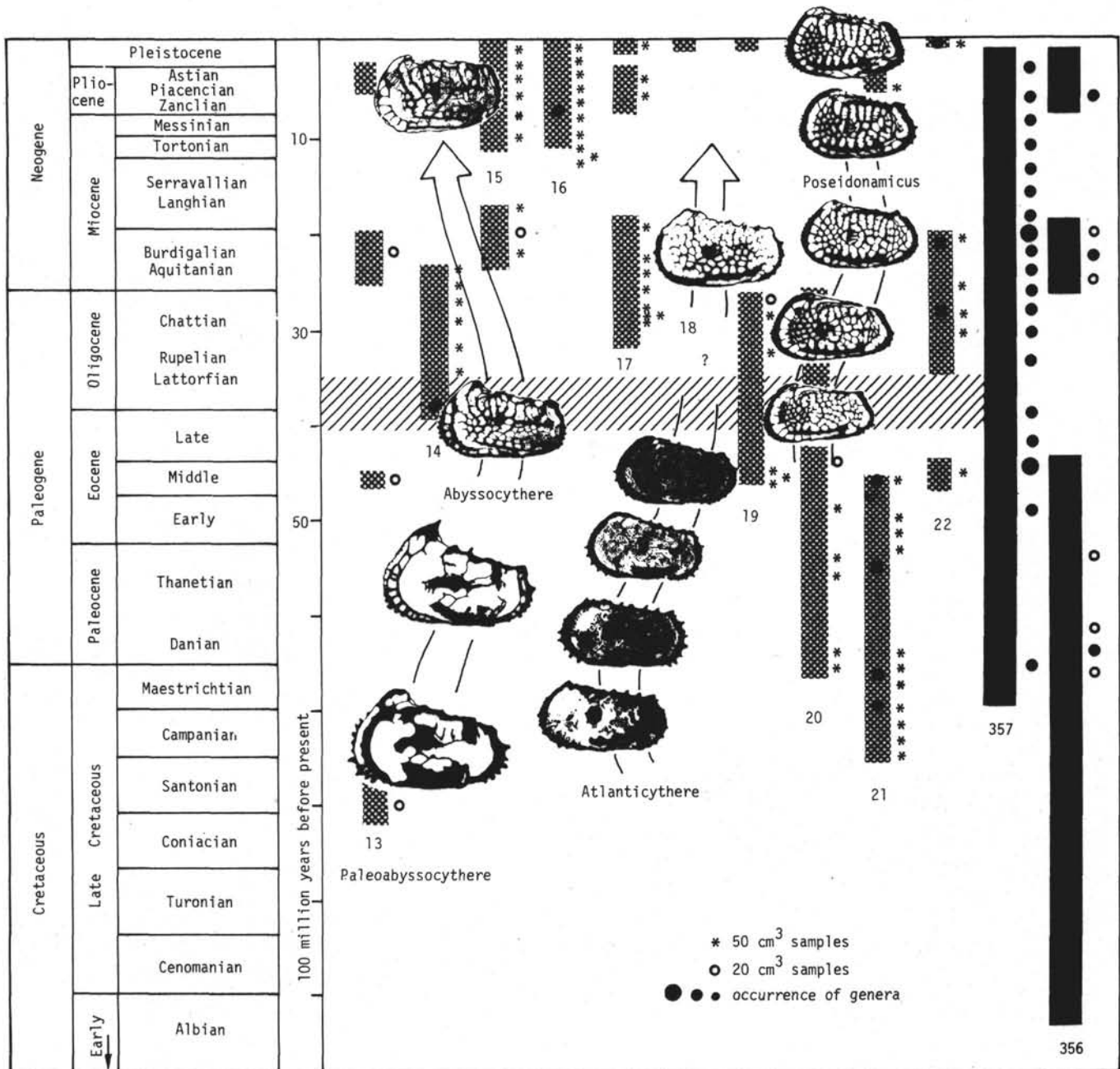


Figure 2. Phyletic lineages of the deep-sea ostracode genera *Abyssocythere*, *Paleoabyssocythere*, *Atlanticythere*, and *Poseidonamicus* as found in the cores of DSDP Sites 13-22 (half-tone) of Leg 3, and Sites 356 and 357 of Leg 39 of the South Atlantic (modified after Benson, 1975 a, b). Note the increase in reticulation with the formation of the psychrosphere 38-40 m. y. B.P. Also note the common occurrence of these important deep-sea ostracodes at Site 357 from Cretaceous onward.

diversity indicates depths greater than 500 meters (Benson, 1975a). Even where as many as 300 specimens were found (often in samples of Sites 21A and 22), there were less than 12 species. Shallow faunas, unless they are in restricted marginal conditions, usually have two to three times as many species. The older ostracode taxa are easily traceable into the modern psychrospheric genera. This is very significant as most of these taxa are not known from shallow-water records. The psychrospheric faunas of the late Paleogene contain

genera now typical of lowermost bathyal and abyssal depths. *Cytherella*, *Bairdia*, *Krithe*, and the "bythocyprids," although not identifiable as species in these cores, continue from the Campanian to the Recent. In no way could these ostracode faunas be considered typical of shallow seas.

TESTING ENVIRONMENTAL HYPOTHESES

This report has remained general. It is intended as a preliminary study of Sites 356 and 357. Yet changes in

the ostracodes clearly support certain hypotheses about the origins of the Rio Grande Rise and São Paulo Plateau while contesting others. The conclusions are as follows:

1) Cold deep-water faunas begin in the Oligocene. The ostracodes clearly show the origin of a new and colder ocean system (the psychrosphere) after about 38-40 m.y. B.P. This trend is worldwide (Benson, 1975b). There are no indications of the invasion of northern faunas; much of the fauna began in situ and some came from species descending down the Argentine slope.

2) Subsidence in the Cretaceous. The ostracodes are deep (800 to 1000 m minimum) in the Danian of Site 357 (different faunas of 500 m or less are known from Argentina) and have been deep without noticeable change since the Campanian as shown in Site 22. The waters of the restricted and formative South Atlantic of the later Cretaceous and early Paleogene may have been warm throughout their depth (temperatures higher than 10°C), but were no shallower than 800 meters and probably deeper.

3) Subsidence in comparison with the Sclater et al. curve. It has been suggested, from the Summary and Conclusions of the shipboard report, that if the Sclater curve were used for comparison, one could retrodict a rising sea floor into the past to the point where the Rio Grande Rise would have been a subaerial plateau 2100 meters above sea level. The ostracodes of Sites 21A, 356, and 357 do not show any time, dating back to about 75 m.y. B.P., wherein shallow faunas were present. It might be argued that the surface topography of such a Rio Grande Archipelago may have also included deep-water troughs. If so, the sites were in these troughs. The ostracodes could only be used as evidence of such troughs, if they had freely circulating bottom waters, but not of shallowing. In the case of Rockall Bank (Benson, 1970), such a history was indeed evident, but not here.

I have not examined the Santonian-Coniacian ostracodes of Leg 39, but I have studied those of Leg 3 extensively. They are deep water. Their co-occurrence with *Inoceramus* causes no conflicts in interpretation. *Inoceramus* is also "deep-sea" as described by Kauffman (1976) from Site 317A of the central Pacific (Manihiki Plateau). In Site 357 *Inoceramus* most likely represents an in situ occurrence of a normal bathyal fauna, without the need for planktonic or allochthonous origins (Kauffman, personal communication). Therefore, the long-term depth interpretations suggested by the microfaunas (benthonic foraminifera and ostracodes) is not refuted by the presence of the macrofossil assemblage.

SYSTEMATIC PALEONTOLOGY

The following abbreviated descriptions are of new taxa represented in Sites 21A, 22, 356, and 357. The specimens illustrated on Plates 1 and 2 are from Sites 21, 21A, and 22 where larger populations were found and preservation was better. These descriptions (see Sylvester-Bradley and Benson, 1971, for terminology) are intended to validate the names and give information for preliminary identifications.

Subclass OSTRACODE Latrielle, 1806

Order PODOCOPIDA Pokorný, 1953

Superfamily CYTHERACEA Baird, 1850

Family TRACHYLEBERIDIDAE Sylvester-Bradley, 1948

PALEOABYSSOCYHERE, new genus

Type-species: *Paleoabyssocythere cenozoica* Benson, new species.

Diagnosis: Distinguished from *Abyssocythere* by the absence of a levatum in the anteromedian region of the reticulum, the presence of an extremely "eared" anterodorsal margin. The general suppression or lack of primary reticulation and the nodose development of the ventrolateral "ridge" complex. The hinge tends to be lobodont with a strongly lobed anterior booth on the right valve.

Remarks: This genus contains a series of species beginning in the Cretaceous with a massive, nodose, poorly defined foveolate carapace surface, an angulate dorsal ridge, and a massive anteromarginal rim. It becomes more reticulate in the Paleogene with more strongly differentiated regions including the dorsal bullar series, a higher muscle-scar node, an attenuated ocular ridge but not a levatum. There are many definable stages of the organization from a finely pitted surface, into secondary reticulation, then rising into a primary reticulum. Reference to the original descriptions of *Abyssocythere* Benson, 1971, will provide additional comparisons.

Age and distribution: Found worldwide in sediments of late Cretaceous and Paleogene age, but known best from the South Atlantic.

Paleoabyssocythere cenozoica Benson, new species

(Plate 2, Figure 7)

Holotype: USNM 190285; Plate 2, Figure 7. Designated type-species.

Description: Ocular ridge sharply attenuated, anteromarginal rim subreticulate, reticulum generally undifferentiated but beginning to form from secondary reticulation some elements of the dorsal bullar series peaked, the gamos ridge evident; no reticulation in the ventromarginal ridge area.

Remarks: Differs from *P. cretacea* Benson by the elevation of the gamos ridge, increased reticulation, and alate ocular ridge.

Type-locality: Sample 21A-3-4, 50-56 cm. Thanetian (upper Paleocene).

Distribution: Found in upper Paleocene of Sites 21 and 21A; Samples 21-2-4, 50-56 cm and 21A-3-4, 50-56 cm.

Paleoabyssocythere cretacea Benson, new species

(Plate 2, Figure 8)

Holotype: USNM 190168; Plate 2, Figure 8.

Diagnosis: Ocular ridge subdued although known also to be spinose within a single population, surface lumpy with fine and closely spaced foveolae except on the large bullae or the marginal rims, no gamos ridge.

Remarks: This species is the massively structured predecessor of *P. cenozoica*. Its features are much more crudely defined, although some suggestion of reticular ridge formation is evident.

Type-locality: Sample 21-6-4, 53-59 cm. Campanian.

Distribution: Found at the type-locality throughout Cores 5 to 8 but especially in Core 6.

ATLANTICYTHERE, new genus

Type-species: *Atlanticythere maestrichtia* Benson, new species.

Diagnosis: Distinguished from other nonreticulate trachyleberids by well-defined, almost equally rounded anterior and posterior marginal rims, an open foveolate to secondarily reticulate surface with small but prominent pore-conuli. Hinge holamphidont; interior trachyleberid.

Remarks: The lateral outline, especially the posterior, is somewhat bradleyid as opposed to being drawn out. It bears some resemblance to Cretaceous species of *Oertliella* (Pokorný, 1963), although not reticulate. The pore-conuli of the posteromedian region join to form a short median ridge in younger forms. This with the addition of reticulation seems to be one traceable line of phyletic development (see Plate 1, Figures 7 and 8) into the Paleogene and Neogene. Another line is traceable into a dominantly spinose group.

Distribution: Known primarily from the Cretaceous and Paleogene of the South Atlantic.

Atlanticythere maestrictia Benson, new species
(Plate 2, Figure 3)

Holotype: USNM 190166; Plate 2, Figure 4. Designated type-species.

Diagnosis: Distinguished from other species of the genus by the open foveolate surface and distinct, restricted pore-conuli. No posteromedian ridge is present. Without secondary spines.

Remarks: Variation within the species seems to be limited to the degree of roughness of the general surface and the development of marginal rise. Some populations seem dominantly smooth, but upon cleaning show an increase in foveolation. Also the muscle-scar node may become multibullate or remain relatively simple. The positions of the pore-conuli are constant, though they may increase in prominence, especially in the anterior. Campanian predecessors have no marginal rims.

Type-locality: Sample 21-4-4, 60-66 cm. Maestrichtian.

Distribution: Upper Cretaceous of the South Atlantic.

Atlanticythere murareticulata Benson, new species
(Plate 2, Figure 3)

Holotype: USNM 190306; Plate 2, Figure 3.

Diagnosis: Distinguished from other species of the genus by the organization of foveolate into secondary reticulation with some primary reticulation and conjunctive spines and the joining of the posteromedian pore-conuli into a short ridge.

Remarks: Variations of the initial reticular development characterize this species during the Paleogene ranging from strongly foveolate in Thanetian forms to subreticulate lower Eocene forms. These precede *A. eocenica* Benson, n. sp. which has only primary reticulation.

Type-locality: Sample 21A-1-4, 50-56 cm. Lutetian.

Distribution: Lower Paleogene of the South Atlantic.

Atlanticythere? eocenica Benson, new species
(Plate 1, Figure 7)

Holotype: USNM 190307; Plate 1, Figure 7.

Diagnosis: Distinguished from other species of the genus by a more rugose appearance and primary reticulation without either secondary reticulation or foveolation.

Remarks: Changes in outline or shape and an increased grossness in ornamentation suggest enough difference to question the generic assignment. This species and *A. ? neogenica* Benson, n. sp. may be considered later as generically distinct.

Type-locality: Sample 22-5-2, 50-56 cm. Lutetian.

Distribution: Paleogene of the South Atlantic.

Atlanticythere? neogenica Benson, new species
(Plate 1, Figure 8)

Holotype: USNM 190300; Plate 1, Figure 8.

Diagnosis: Distinguished from other species of the genus by a well defined primary reticulation spread over all of the surface; without nodes or bullae.

Remarks: Possibly the penultimate development of the *Atlanticythere* lineage, assuming that yet undiscovered gross reticulate stages follow. The posteromedian ridge is noticeable, but tends to be absorbed by the reticulation.

Type-locality: Sample 22-2-4, 50-56 cm. Aquitanian.

Distribution: Thus far known only from the lower Miocene of the South Atlantic.

Atlanticythere? prethalassia Benson, new species
(Plate 2, Figure 1)

Holotype: USNM 190297; Plate 2, Figure 1.

Diagnosis: Distinguished by its secondary spinosity, among the primary pore-conuli, and secondary reticulation.

Remarks: It is not certain whether this is a morphotype or a developing species. It is associated in the same assemblage as *A. maestrictia*, without apparent morphologic transition. Although it is common, it is named here with some doubt about its relationship to the development of the reticulate species.

Type-locality: Sample 21-5-3, 50-56 cm. Maestrichtian.

Distribution: Upper Cretaceous of the South Atlantic.

Genus ACANTHOCYTHEREIS Howe, 1963

Acanthocythereis? presequenta Benson, new species
(Plate 2, Figure 5)

Holotype: USNM 190283; Plate 2, Figure 5.

Diagnosis: Distinguished by its very subdued to missing primary reticulation and clavellate or club-like pore-conuli.

Remarks: Only a few of the principal pore-conuli are present as compared with *A. ? subsequenta*, which has a complete set. The generic assignment is quite problematical.

Type-locality: Sample 21-2-4, 44-50 cm. Thanetian.

Distribution: Known only from the Paleocene of the South Atlantic.

Acanthocythereis? subsequenta Benson, new species
(Plate 2, Figure 6)

Holotype: USNM 190290; Plate 2, Figure 6.

Diagnosis: Distinguished by its delicate primary reticulation, sharp cardinal angles, clavate and castellate pore conuli, and accessory conjunctive spines.

Remarks: This species seems to be a more spinose developmental stage of *A. ? presequenta*. The generic assignment is problematical.

Type-locality: Sample 21A-1-4, 50-56 cm. Lutetian.

Distribution: Known only from the Paleocene of the South Atlantic.

Genus PHACORHABDOTUS Howe and Laurocich, 1958

Phacorhabdotus subtridentus Benson, new species
(Plate 1, Figure 2)

Holotype: USNM 190315; Plate 1, Figure 2.

Diagnosis: Distinguished by absence of an anterior and posterior marginal ridge and subdued posterior longitudinal ridges. Pore-conuli are absent, although the pores are evident.

Remarks: This species is about the same in carapace size as the type species *P. texanus* from the Pecan Gap Chalk (Campanian?), but without the well-defined ornament of the margin and ridges. It is also much more subdued in appearance than *P. simplicatus* (Reuss) of Coniacian age as shown by Pokorný, 1963. Campanian variants in South Atlantic have even less well developed ridges.

Type-locality: Sample 21A-3-4, 50-60 cm. Thanetian.

Distribution: From the late Cretaceous and Paleogene of the South Atlantic.

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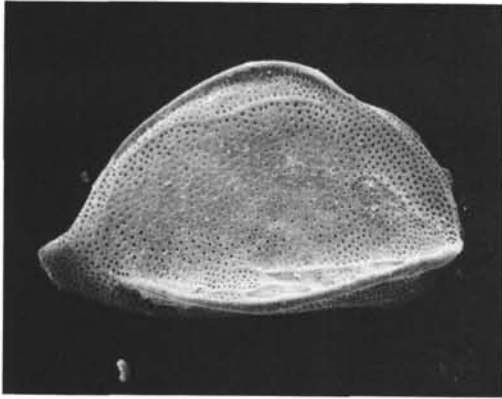
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PLATE 1

Ostracode species from Sites 22, 356, and 357

- Figure 1 *Cytheropteron testudo* Sars, right valve, adult; SEM $\times 160$, length 0.58 mm; USNM 190758; Sample 22-1-3, 50-56 cm, Pleistocene.
- Figure 2 *Phacorhabdotus subtridentus* Benson, n. sp., holotype, left valve, adult female?; SEM $\times 115$, length 0.80 mm; USNM 190315; Sample 21A-3-4, 50-56 cm, Thanetian (*Globorotalia velascoensis* Zone).
- Figure 3 *Bradleya dictyon* (Brady), left valve, adult female; SEM $\times 90$, length 1.03 mm; USNM 190299; Sample 22-2-4, 50-56 cm, Aquitanian (*Globigerinita dissimilis* Zone).
- Figure 4 *Bradleya* aff. *B. dictyon* Brady, left valve, adult; SEM $\times 100$, length 0.92 mm; USNM 190302; Sample 22-4-4, 53-59 cm, Chattian (*Globigerina ampliapertura* Zone).
- Figure 5 *Poseidonamicus* sp., left valve, adult male?; SEM $\times 120$, length 0.77 mm; USNM 190303; Sample 22-4-2, 77-79 cm, Chattian (*Globigerina ampliapertura* Zone).
- Figure 6 *Agrenocythere hazelae* (Bold), left valve, adult male?; SEM $\times 80$, length 1.09 mm; USNM 190301; Sample 22-4-4, 53-59 cm, Chattian (*Globigerina ampliapertura* Zone).
- Figure 7 *Atlanticythere? eocenica* Benson, n. sp., left valve, adult female; SEM $\times 115$, length 0.79 mm; USNM 190307; Sample 22-5-2, 50-56 cm, Lutetian (*Globorotalia lehneri* Zone).
- Figure 8 *Atlanticythere? neogenica* Benson, n. sp., holotype, left valve, adult female; SEM $\times 110$, length 0.85 mm; USNM 190300; Sample 22-2-4, 50-56 cm, Aquitanian (*Globigerinita dissimilis* Zone).

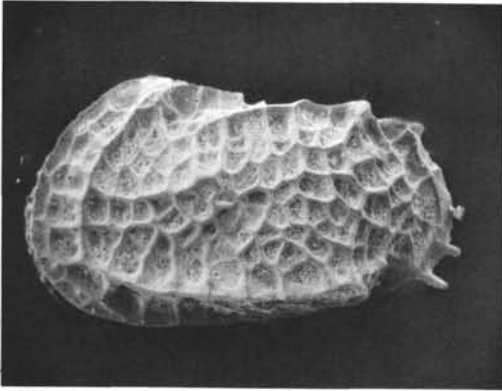
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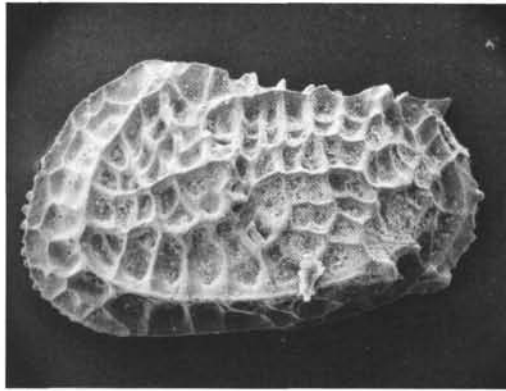
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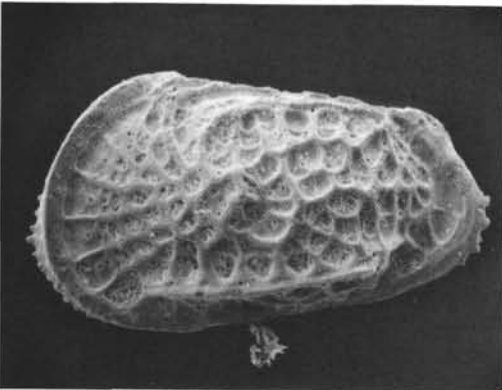
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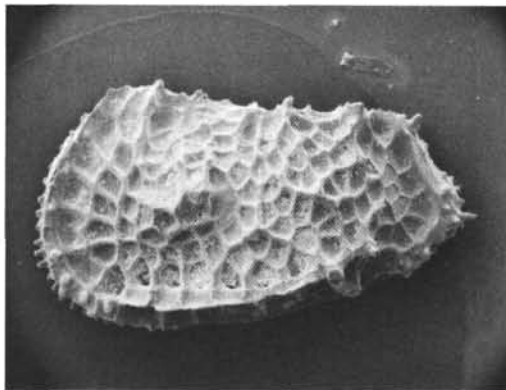
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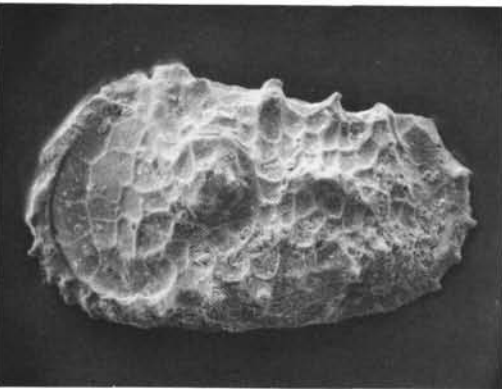
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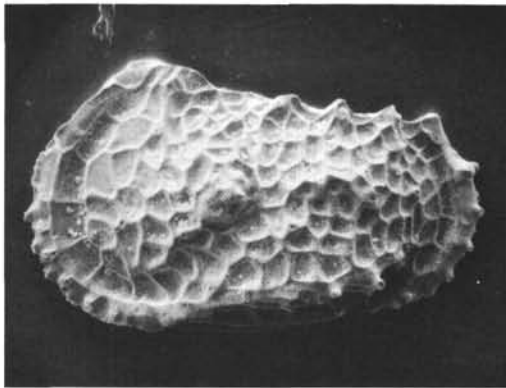
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PLATE 2

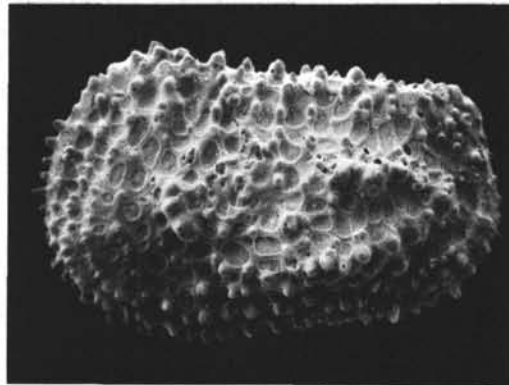
Ostracode species from Sites 21, 21A, 356, and 357

- Figure 1 *Atlanticythere? prethalassia*, Benson, n. sp., n. gen., holotype; left valve, adult; SEM $\times 90$, length 0.87 mm; USNM 190297; Sample 21-5-3, 50-56 cm, Maestrichtian (*Rugotruncana subcircumnoidifera* Zone).
- Figure 2 *Henryhowella asperrima?* Reuss, left valve, adult female; SEM $\times 110$, length 0.90 mm; USNM 190757; Sample 21-1-1, 50-56 cm, upper Pliocene.
- Figure 3 *Atlanticythere murareticulata* Benson, n. sp., n. gen., holotype; left valve, adult male; SEM $\times 110$, length 0.87 mm; USNM 190306; Sample 21A-104, 50-56 cm, Lutetian.
- Figure 4 *Atlanticythere maestrichtia* Benson, n. sp., n. gen., holotype and type-species; left valve, adult male; SEM $\times 90$, length 1.03 mm; USNM 190166; Sample 21-4-4, 60-66 cm, Maestrichtian (top of *Rugotruncana subcircumnoidifera* Zone).
- Figure 5 *Acanthocythereis? presequenta* Benson, n. sp., holotype; left valve, adult; SEM $\times 110$, length 0.84 mm; USNM 190283; Sample 21-2-4, 44-50 cm, Thanetian (*Globorotalia velascoensis* Zone).
- Figure 6 *Acanthocythereis? subsequenta* Benson, n. sp., holotype; left valve, adult; SEM $\times 140$, length 0.66 mm; USNM 190290; Sample 21A-1-4, 50-56 cm, Lutetian (*Globigeraspis kugleri* Zone).
- Figure 7 *Paleoabyssocythere cenozoica* Benson, n. sp., n. gen., holotype and type-species; left valve, adult male?; SEM $\times 110$, length 0.80 mm; USNM 190285; Sample 21A-3-4, 50-56 cm, Thanetian (*Globorotalia velascoensis* Zone).
- Figure 8 *Paleoabyssocythere cretacea* Benson, n. sp., n. gen., holotype; left valve, adult female; SEM $\times 125$, length 0.80 mm; USNM 190168; Sample 21-6-4, 53-59 cm, Campanian (*Pseudotextularia elegans* Zone).

PLATE 2



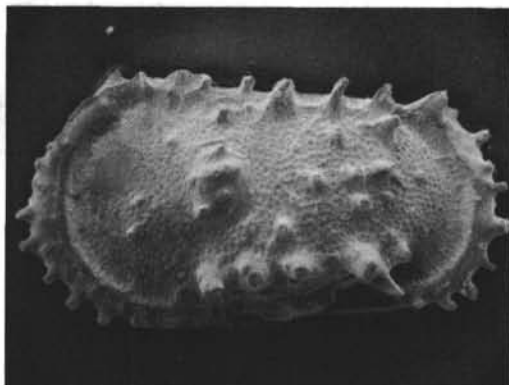
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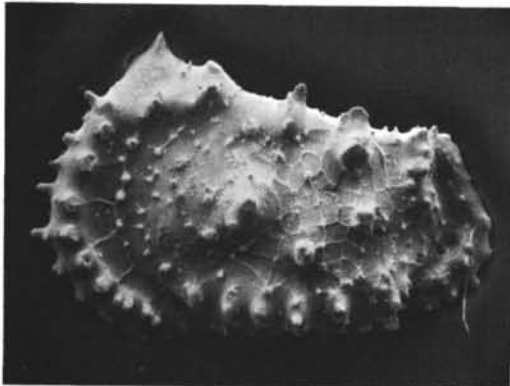
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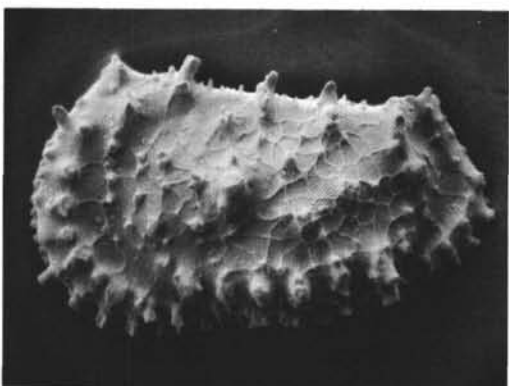
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