

12. CENOZOIC OSTRACODES: THEIR IMPORTANCE FOR BATHYMETRY, HYDROLOGY, AND BIOGEOGRAPHY

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INTRODUCTION

Cenozoic ostracodes from Leg 48 of the IPOD program have been studied for the purpose of paleoecology. The aim is to define the environment as precisely and completely as possible and to arrive at an understanding of the evolution of the faunal associations throughout the course of time, in terms of nature and number, as reflected and explained by the hydrologic conditions: depth, T°C, dissolved O₂, nutritional supply, intensity of bottom circulation, etc.

Two areas were studied — the northern continental margin of the Bay of Biscay and the southwestern extremity of the Rockall Plateau.

About one hundred samples from six sites (400/400A, 402/402A, 403, 404, 405, 406) in the northeastern Atlantic were analyzed. They represent a period extending from the Paleocene to the Quaternary.

FAUNA FROM THE VARIOUS SITES

The ostracode microfauna is well preserved but generally poor and largely undiversified; it is characteristic of deep-water environments.

Northern Continental Margin of the Bay of Biscay

Hole 400A (Figure 1)

The fauna is poor with little variety. From the base of the Tertiary to the top of the lower Miocene, only juvenile forms of *Krithe* and *Agrenocythere*, an internal molds of *Buntonia* and a few unidentifiable fragments were recovered. The upper part of the sequence is marked by a development of *Henryhowella asperrima* (Reuss) (Pl. 3, Fig. 1), associated with less abundant *Krithe*, *Parakrithe*, and *Poseidonamicus* sp. 1 (Pl. 4, Fig. 1).

Site 401 (Figure 2)

Paleocene and Eocene faunas are better represented than in the previous hole (400A). There appear to be two successive faunal assemblages: the first, dating from the Paleocene and the early Eocene, contains *Bythocytheromorpha*, sp. 1, *Monoceratina tricuspidata* Jones and Hinde in Deltel, 1961, *Cytherella consueta* Deltel (Pl. 1, Fig. 1), *Bairdia cymbula* Deltel (Pl. 1, Figs. 8, 9), *Agrenocythere* sp. 1 (Pl. 2, Fig. 7); the second, dating from the middle and late Eocene and the early Oligocene, is richer and more diversified and contains *Cytherella transversa* Speyer (Pl. 1, Fig. 2), *Argilloecia angulata* (Deltel) (Pl. 5, Fig. 6), *Koilocythere* sp. 1 (Pl. 5, Fig. 4), *Cardobairdia* sp. 2 (Pl. 1, Fig. 7), *Trachyleberidea prestwichiana* (Jones and Sherborn) (Pl. 2, Fig. 8), and various species of *Krithe*, *Parakrithe*, *Cytherella*, and *Bair-*

Stratigraphy	Core	Section	Interval Sampled (cm) or Penetration (m)	Species													
				<i>Buntonia</i> sp. 3	<i>Agrenocythere</i> sp. 1	<i>Poseidonamicus</i> sp. 1	<i>Krithe</i> sp.	<i>Henryhowella asperrima</i> (Reuss)	<i>Bosquetina fenestratum</i> (Brady)	<i>Parakrithe</i> sp.	<i>Echinocythereis echinata</i> (Sars)	<i>Krithe</i> sp. D. 2. 2. e. n.	<i>Koilocythere</i> sp. 1	<i>Semicytherura</i> sp. 8	<i>Cytheropteron</i> sp. 8	<i>Krithe</i> (juvenile forms)	
Quaternary	1	1	68-70														
	2	2	114-116														
Late Pliocene	3	4	54-56														
	12	2	60-62														
Early Pliocene		5	60-62														
		4	64-66														
	13	CC															
	14	3	22-24														
		CC	207.5														
Late Miocene	16	1	143-145														
	17	CC															
		2	81-83														
		3	52-54														
	21	CC	275														
	24	6	67-68														
Middle Miocene	29	1	114-116														
		CC	351														
	32	CC	379.5														
	34	CC															
	35	3	103-105														
Early Miocene	37	1	44-46														
		4	72-74														
	39	1	117-118														
Middle Eocene	40	1	22-25														
	49	1	75-78														
Early Eocene	54	CC															
	55	CC															
	56	2	60-63														
Late Paleocene	57	2	4-7														
	58	CC															
Middle Paleocene	59	1	5-7														

Figure 1. Tertiary ostracode species at Hole 400A.

dia. We did not observe any change between the Eocene and Oligocene faunas. Many deep-water forms are comparable to those known from the Paleogene in the southern part of the Aquitaine Basin and in the Gulf of Gascony (Deltel, 1961; Ducasse, 1974, 1975, in press). In the Quaternary sediments only a few *Krithe* persist.

Holes 402/402A (Figure 3)

These two holes provided few samples and little fauna. We noted the presence of a deep-water Eocene form, *Bairdia* sp. 6 (Pl. 2, Figs. 1, 2), common to both Sites 401 and 402. The

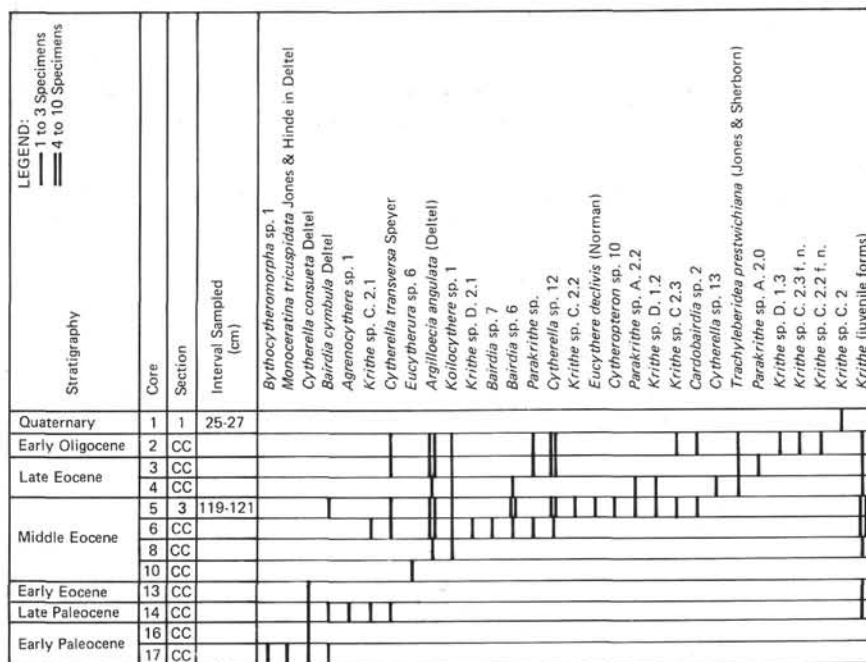


Figure 2. Tertiary ostracode species at Site 401.

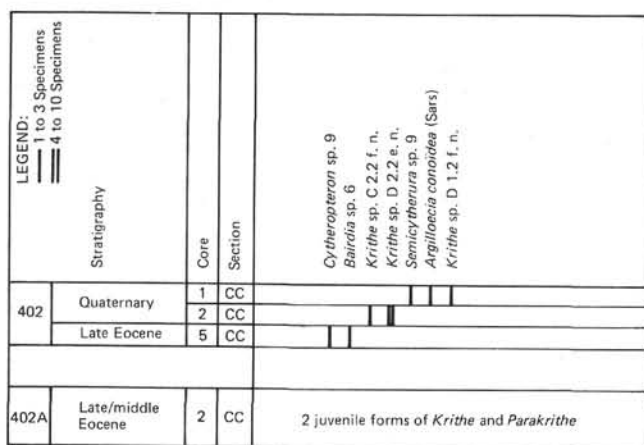


Figure 3. Tertiary ostracode species at Holes 402/402A.

same species is found on the southern margin of the Gulf of Gascony, on the continental plateau of northern Spain, east of the Santander Canyon. *Krithe* is predominant in the Quaternary sediments.

Southwestern Margin of the Rockall Plateau

Site 403 (Figure 4)

The Eocene fauna is poor and almost all of its constituents are represented on the northern margin of the Gulf of Gascony. From the upper Miocene a new fauna, relatively rich and diversified, is progressively established. It is essentially composed of *Henryhowella asperima* (Reuss), *Bradleya dictyon* (Brady) (Pl. 3, Fig. 9), *Poseidonamicus* sp. 1 and *Krithe*, with less frequently, *Agrenocythere* sp. 1, *Bairdia* sp. 1 Moyes (Pl. 1, Fig. 10), *Cytheropteron* sp. 26 (Pl. 5, Fig. 3), *Echinocythereis echinata* (Sars) (Pl. 2, Fig. 11), and *Thal-*

socythere acanthoderma (Brady) (Pl. 3, Fig. 4). During the upper Pliocene and the Quaternary, this fauna is considerably depleted.

Site 404 (Figure 5)

The fauna is poor. As at Site 403, a new fauna appears above the unconformity that separates the Eocene-Miocene; it declines during the Plio-Quaternary. The main forms encountered in the Eocene sediments are *Hermanites* (?) (Pl. 3, Figs. 7, 8), *Paracypris* (Pl. 5, Fig. 8), *Parakrithe*, and *Loxococoncha* (Pl. 4, Fig. 3). This is a different association from that encountered at Site 403. From the Miocene, *Henryhowella asperima* (Reuss), *Cytherella consueta* Deltel, *Krithe* and *Poseidonamicus* sp. 1 are characteristic. Almost all of these forms are found at Site 403. Plio-Quaternary sediments contain only *Poseidonamicus*.

Site 405 (Figure 6)

As at Sites 403 and 404, the fauna changes after the Eocene but remains richer into the Quaternary. The lower Eocene fauna is meager; consisting of *Cytherella consueta* Deltel and a small form of *Krithe* sp. E 1-2. The middle Eocene fauna is more varied, with the addition of *Hazelina* sp. 5 (Pl. 2, Fig. 9), *Trachyleberidea prestwichiana* (Jones and Sherborn), *Atlanticythere* (Pl. 3, Fig. 2), *Bythocypris* (Pl. 2, Fig. 4), and *Bairdia* (Pl. 2, Fig. 3) to the two already existing species. It differs from that of Sites 403 and 404. From the lower Pliocene the fauna is comparable to that found at Site 403. It is at Site 405 that the Quaternary fauna is most complete, comprising in particular *Poseidonamicus* sp. 1, *Henryhowella asperima* (Reuss), *Bradleya dictyon* (Brady), and *Thalassocythereis acanthoderma* (Brady), together with two new forms, *Oxycythereis dorsoserata* (Pl. 3, Fig. 3) and unidentified genus 3 (Pl. 5, Fig. 9).

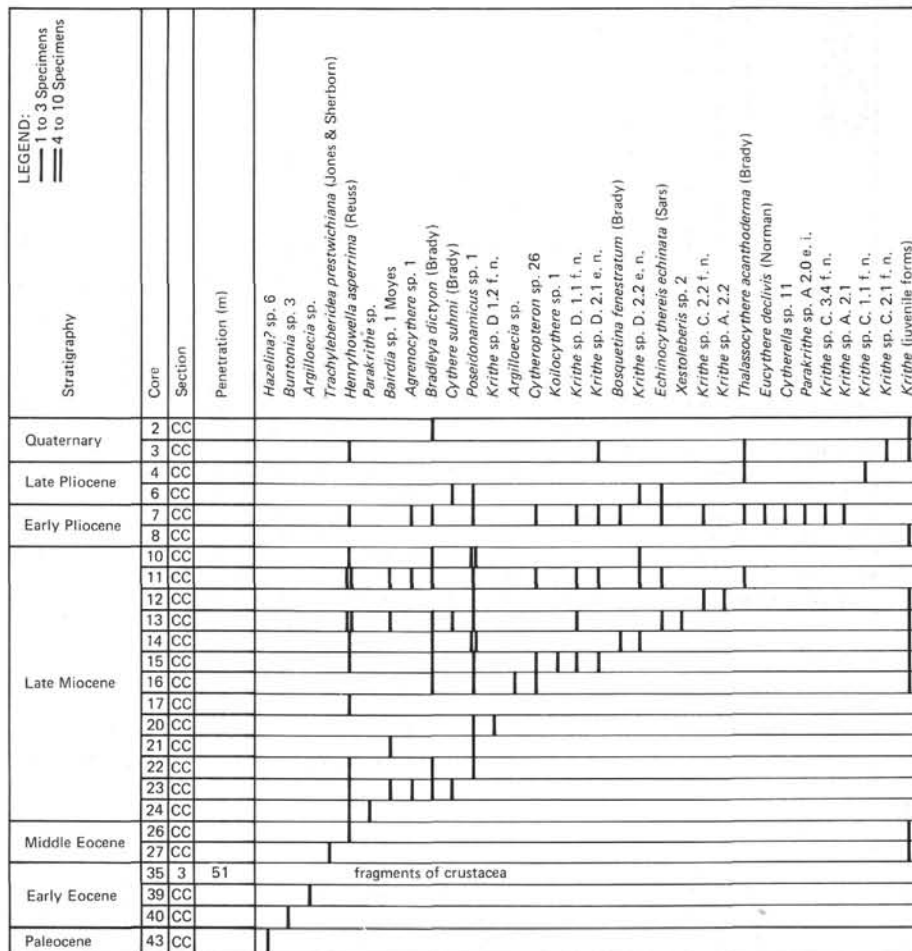


Figure 4. Tertiary ostracode species at Site 403.

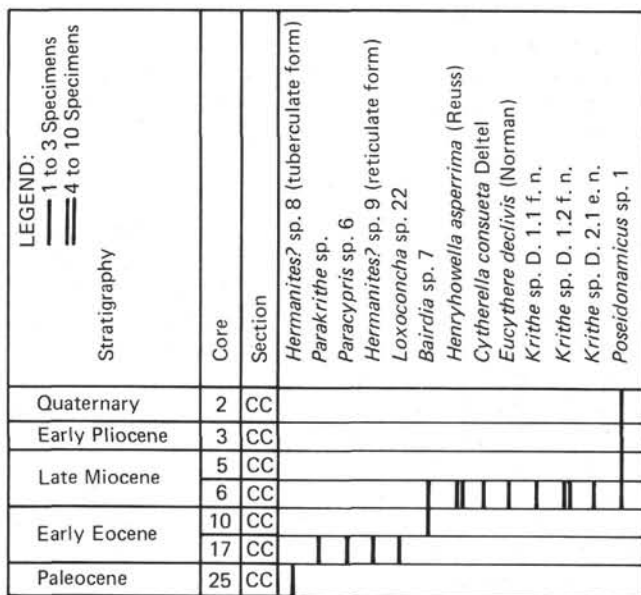


Figure 5. Tertiary ostracode species at Site 404.

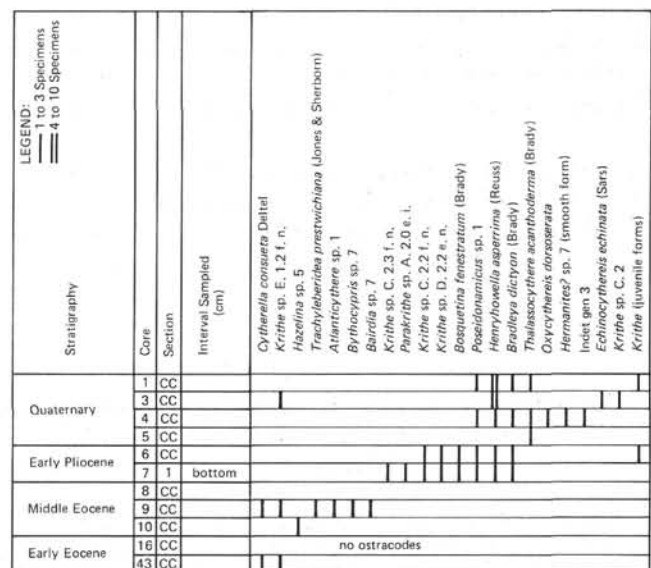


Figure 6. Tertiary ostracode species at Site 405.

Site 406 (Figure 7)

The most distinctive characteristics observed at this site are a greater homogeneity of the fauna down section and an earlier appearance of *Poseidonamicus* sp. 1 in the upper Eocene. During the Quaternary the unidentified genus 3 previously noted at Site 405 is again present.

DISCUSSION OF HYPOTHESES

Because each faunal assemblage reflects an ecological setting whose depth variable can be evaluated, analysis of their succession should demonstrate the evolution of the depth level at the site through time. Variations in the microfauna of deep environments in terms of its nature and density make it possible to follow not only the paleoecological evolution of the sites, but also circulation patterns in the bathyal and abyssal regions. Furthermore, the geographic distribution of forms leads to the definition of paleobiogeographic zones.

PALEOBATHYMETRY

Northern Continental Margin of the Bay of Biscay (Figure 8)

In Hole 400A, the ostracode microfauna shows the area to have been a deep region from as early as the Paleocene. The exclusive presence of juvenile forms of *Krithe* indicates an environment where conditions of life were difficult; the appearance of *Agrenocythere* suggests that the depth was over 2,000 meters, probably close to that of the site today. This interpretation appears to be corroborated by the nature of the faunal association which develops from the lower Miocene up to and including the Quaternary. The fauna is poor, of low diversity, and is dominated by the genera *Krithe* and *Henryhowella*. This type of fauna is encountered at the present time in the abyssal environments in the Gulf of Gascony at depths of between 3500 to 4500 meters.

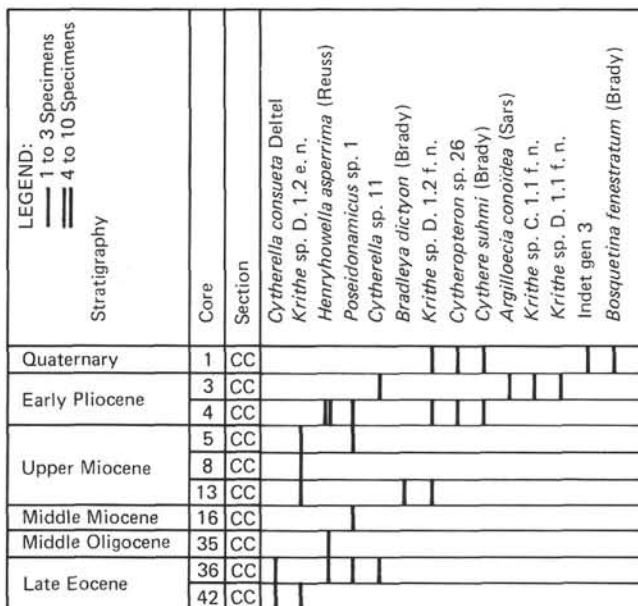


Figure 7. Tertiary ostracode species at Site 406.

Site 401 has been a deep area since the Paleocene. The fauna is richer and more diversified than at the previous site, implying less severe conditions in the environment. The simultaneous presence of *Bairdia cymbula* Deltel, *Monoceratina tricuspidata* Jones and Hinde, *Bythocytheromorpha*, *Agrenocythere*, and *Cytherella consueta* Deltel indicates a depth analogous to that of the present at about 2000 meters.

From the few samples from Holes 402 and 402A it is difficult to provide bathymetric details, but the fauna that has been recovered indicates a deep environment. The presence of *Parakrithe* sp. A in the upper Eocene, in a form identical to that found at the previous site, suggests that both sites were situated at the same level in depth.

In short, then, it appears that as early as the Paleocene the continental margin of North Gascony was among the deep zones and moreover, that Site 400 was already situated much lower than Sites 401 and 402.

Rockall Area (Figure 9)

At Site 403 the forms from upper Paleocene (Core 43) are typical of a continental platform area, but the lower Eocene ostracodes indicate that the depth increased very rapidly (Cores 40, 39, 35), probably to upper bathyal depths (500 m). In the middle Eocene the presence of *Trachyleberidea prestwichiana* (Jones and Sherborn) attests to an infra-bathyal environment (depth >1000 m). In the upper Miocene, the presence of *Agrenocythere*, *Bradleya*, *Poseidonamicus*, and *Echinocythereis*, associated with numerous *Krithe*, implies that the present-day depth of the site (2371 meters) had been reached.

At Site 404 during the Paleocene (Core 25), the presence of *Hermanites* (?) sp. 8, possessing a noticeable eye tubercule, suggests that the environment was that of a continental shelf (depth <150 m). However, the mixture of forms characteristic of the shelf (Cores 17 and 10) (*Hermanites* (?) and *Loxoconcha*) and species living in deeper zones (*Bairdia* and *Parakrithe*) encourages the belief that the setting was upper bathyal (about 200-500 m). *Loxoconcha* is an allochthonous form never found in the upper bathyal zone. The present-day depth of the site was reached in late Miocene time.

In short, the bathymetric evolution of Sites 403 and 404 was identical, from a continental shelf type at the end of the Paleocene to one of lower to middle bathyal depth in the middle Eocene.

At Site 405, in lower Eocene sediments, the ostracode fauna consists of *Krithe* sp. E-1-2 (a small form) and *Cytherella consueta* Deltel. It may represent a middle bathyal environment (500 to 1000 meters) deepened in the middle Eocene, as denoted by *Atlanticocythere*, *Trachyleberidea*, *Bythocypris*, and *Bairdia*, which are deep-water ostracode genera. During the Pliocene, the site reached its present depth, as confirmed by the presence of *Poseidonamicus* sp. 1, *Bradleya dictyon* (Brady) and *Bosquetina fenestratum* (Brady) in the fauna.

Site 406, the upper Eocene (Core 42) fauna consists of *Krithe* sp. D2-2 (a large form) and *Cytherella consueta* Deltel, indicating a middle to lower bathyal environment. From the end of late Eocene time, the presence of

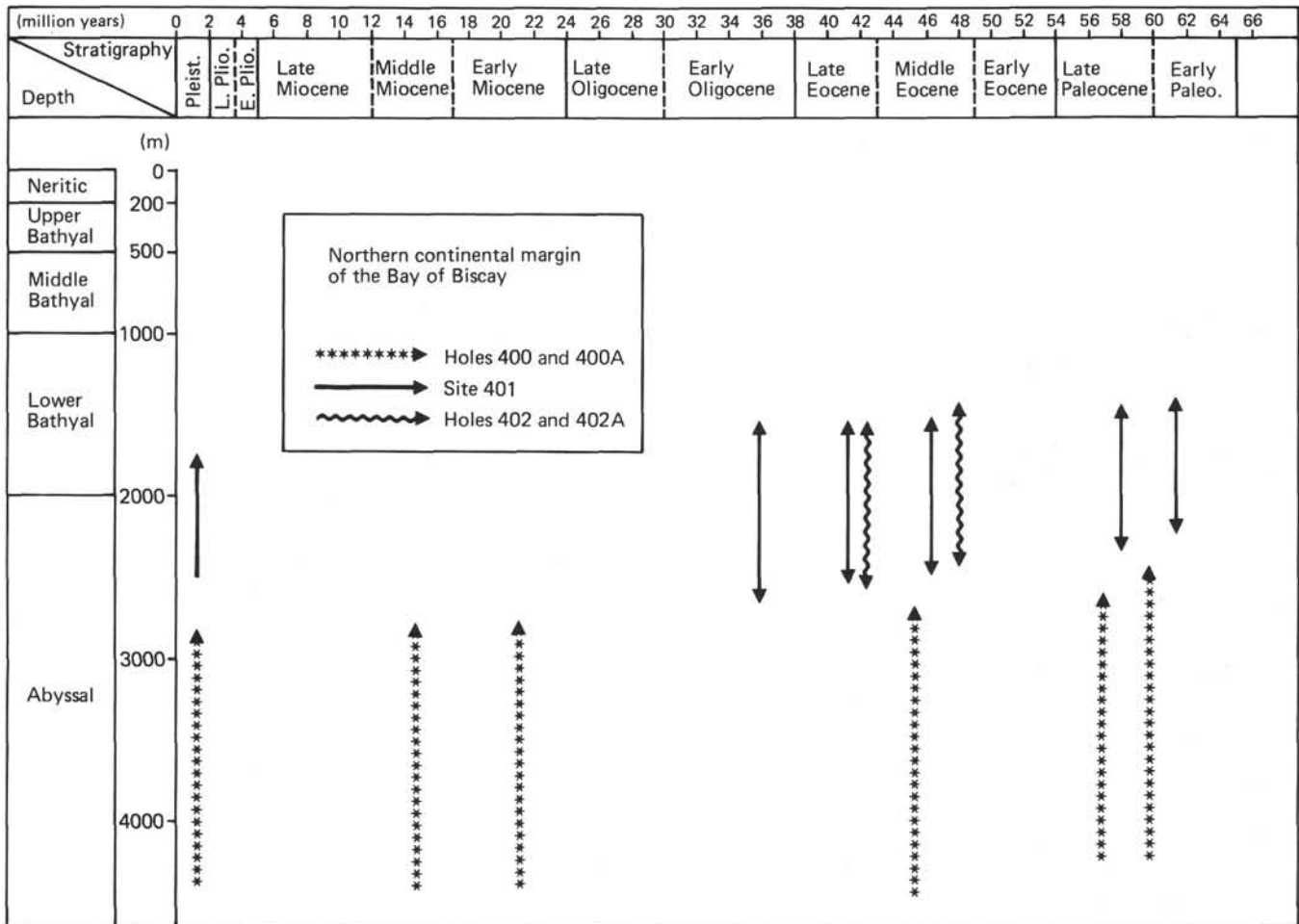


Figure 8. Estimated depth of sites: Northern continental margin of the Bay of Biscay.

Poseidonamicus and *Henryhowella* bear witness to a depth comparable to that of the present day.

As at the two previous sites (403 and 404), a pronounced subsidence occurred at the beginning of the Paleogene, in particular between the lower and upper Eocene. It seems, moreover, that Sites 405 and 406 were at a deeper level at this period than Sites 403 and 404.

Comparison of the depths estimated for the sites in the southwestern area of the Rockall Plateau and those of Sites 116 and 117 (Leg 12) of the Hatton-Rockall Basin (Benson, 1972; Laughton and Berggren, 1972) shows that the physiography of this region as we know it was roughly sketched out at the beginning of the Tertiary (Figure 10); it appears that, in Paleocene/early Eocene time, the Hatton-Rockall Basin had already formed (Sites 116/117 were characteristic of upper bathyal depths, 200-500 m). This internal depression had an outlet channel towards the south represented by Helm's Deep (Site 405) in which the depth was approximately 500 to 1000 meters. On the northwestern side of this trough a continental platform environment had grown up but it quickly became subsident.

It thus appears that the principal phase of deepening on the southern border of the Rockall Plateau area occurred during the Eocene. These conclusions are in accordance with those of Benson (1972) for Sites 116 and 117 in the area of the

Hatton-Rockall Basin, further to the north. In comparison with the more northerly part, the southwestern area seems, from the depth estimates, to have been tilted.

PALEOCIRCULATION AND WATER-MASS STRUCTURE

The Origin of Modern Deep Circulation

The composition of deep-water ostracode populations in the Rockall and the Bay of Biscay areas changes markedly at the end of the upper Eocene at Site 406 at Rockall and somewhat later in the Bay of Biscay.

During early Tertiary the deep-water ostracode fauna includes many genera such as *Cytherella*, *Bairdia*, *Monoceratina*, *Argilloecia*, *Cardobairdia*, *Atlanticythere*, and *Trachyleberidea* which become scarce or disappear during late Tertiary. Moreover, at the end of the Eocene and in the Oligocene, genera such as *Poseidonamicus*, *Bradleya*, *Agrenocythere*, and *Bosquetina*, representing the "modern" fauna of today, cosmopolitan in character, make their appearance. This fauna has been called "psychrospheric" by Benson and Sylvester-Bradley (1971) because it lives in "cold" deep-water zones ($T^{\circ} < 8^{\circ} - 10^{\circ}\text{C}$). Benson (1975) suggests that its appearance marks the beginning of a progressive

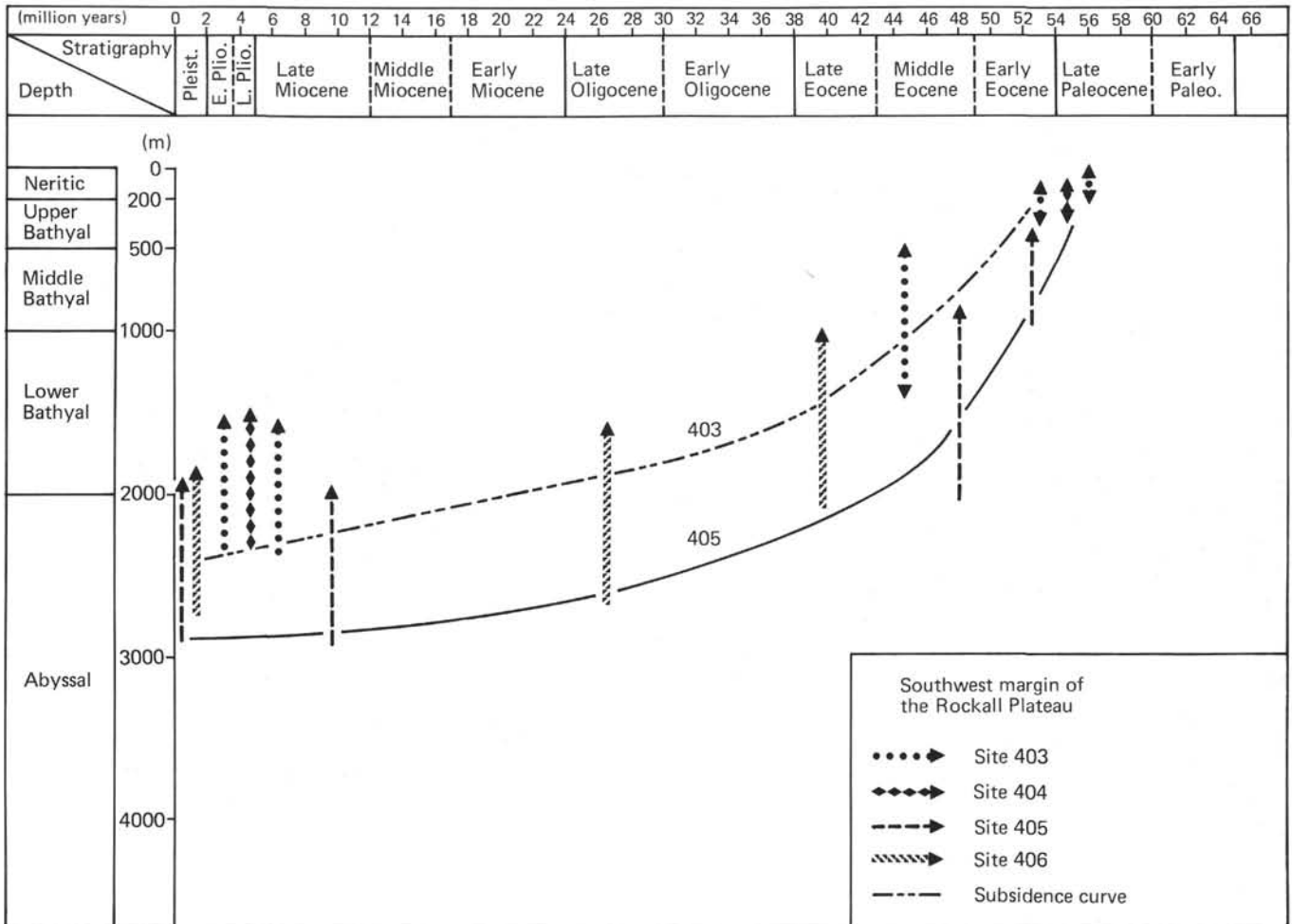


Figure 9. Estimated changes in depth of sites on the southwest margin of the Rockall Plateau.

transformation of the "thermospheric" ocean to a "psychrospheric" ocean and thus a significant cooling of the waters of the ocean bed. We would opt for the same interpretation for Site 406 at Rockall.

It is contended that, towards the end of late Eocene/early Oligocene time, an extensive glaciation developed in the Antarctic regions (Devereux, 1967; Kennett et al., 1975; Shackleton and Kennett, 1975). This cooling could have been responsible for the arrival of cold deep water from the Southern Hemisphere, according to the classic model for deep-sea circulations as defined by Stommel (1958), Stommel and Arons (1960a, b). However, we think that an equivalent flow of northern origin would provide a possible explanation for the cooling, for the Arctic Sea was opened at that time. The Norwegian Sea, formed by the separation of Greenland and Scandinavia at the beginning of the Eocene (Harland, 1969; Vine and Hess, 1971), was already in existence and the Faroe Iceland Ridge was submerged by middle Eocene (Doche, 1976). Because the subsidence at Rockall was already well advanced by late Eocene time (see Paleobathymetry, this paper) there was no longer anything to prevent the opening of cold, deep-water hydrologic relations between the northeast Atlantic and the Arctic/Norwegian Sea complex. Knowledge of the deep ostracode fauna of the Norwegian Sea in Tertiary time could prove or disprove the hypothesis of an Arctic influence at Rockall.

It should be noted that this psychrospheric environment is not to be found in the Bay of Biscay at the same period (Site 401). The deep-water fauna at this site at the end of the Eocene and the beginning of early Oligocene time is unquestionably of thermospheric type (Figure 11). This is not surprising because the area is further south and is out of the line of the "classic roads" of deep-ocean circulations from the north (Norwegian Sea) as shown in the circulation models defined by Worthington (1970) and Berggren and Hollister (1974).

These results obtained for the northeastern Atlantic may be compared to those of Benson (1975) who showed that in the South Atlantic (DSDP Leg 3) the psychrosphere was established at more or less the same time.

This is unquestionably a most important hydrological event in deep-sea circulation in the North Atlantic, and may be considered as the prime factor in the evolution and change of the benthic deep-sea ostracodes at the close of Eocene time because, in addition to the variation in temperature, which in itself is fundamental, there is no doubt that the bottom waters coming from the Norwegian Sea had different physico-chemical properties from those of the northwestern Atlantic and were capable of additionally influencing the morphological evolution of genera.

Without underestimating the role of tectonic activity, which may cause sedimentary hiatuses, it is also possible that

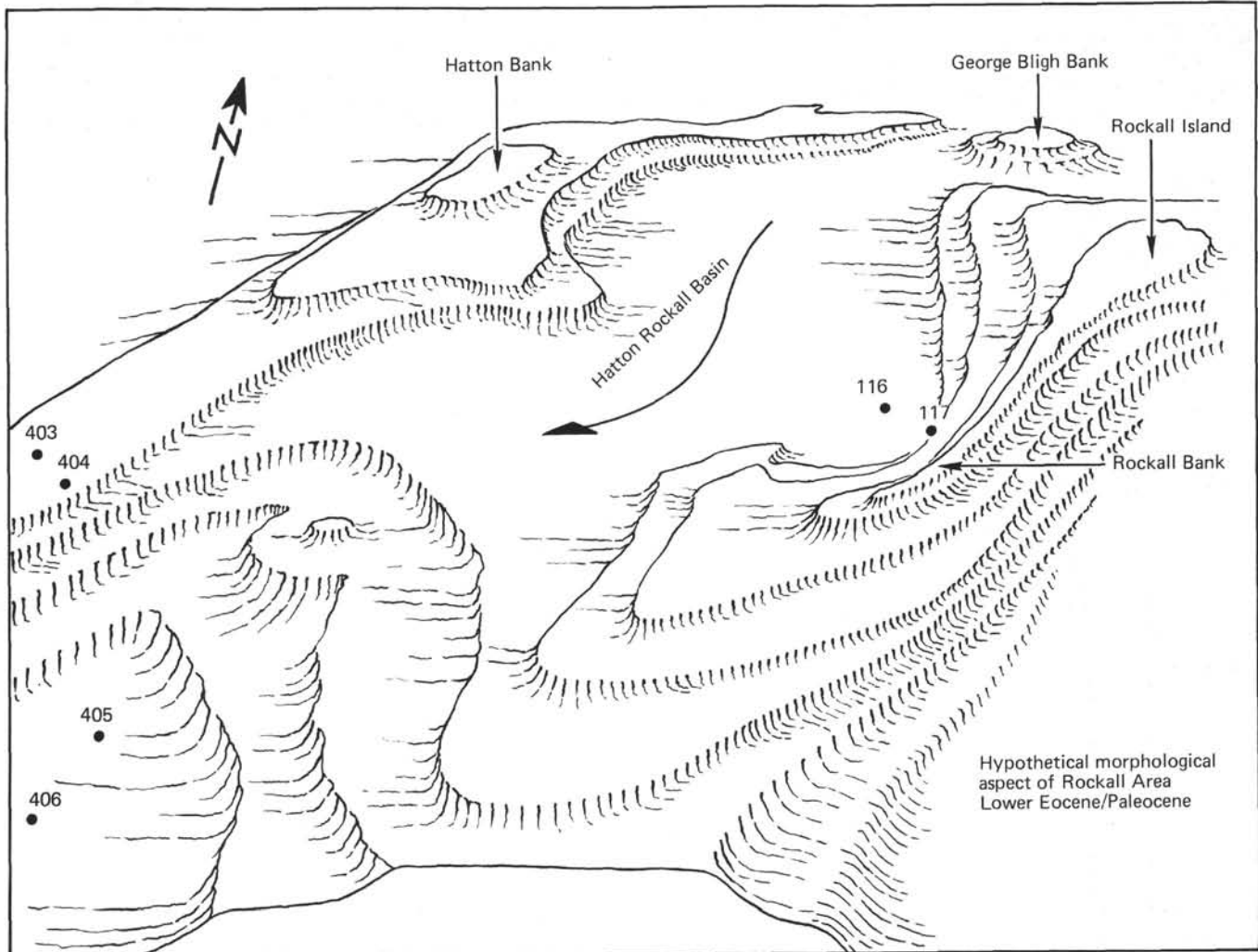


Figure 10. Hypothetical morphological aspect of Rockall area. Lower Eocene/Paleocene.

a strong deep-ocean circulation at this time may have been responsible for a number of breaks in sedimentation in the region, such as the absence of lower Oligocene strata at Sites 403, 404, 405, and 406, and the poor development of sedimentation in the Oligocene area.

Paleogene Changes in Water Circulation in Lower and Upper Levels

The establishment of the psychrosphere is certainly the major event in the deep-sea environment in the northeast Atlantic, but the analysis of the ostracode microfauna reveals other important hydrologic events. At Site 401, in the deep thermospheric environment, two quite distinct groups make up the Tertiary faunal association. At the base (Cores 17 to 10, lower Paleocene-lower mid-Eocene) the fauna is relatively poor and little varied whereas at the top (Cores 8 to 2, lower mid-Eocene to lower Oligocene) it becomes abundant and shows a great diversity of species.

In a deep-sea environment, specific diversity and the numerical significance of individuals in an ostracode assemblage are directly related to the availability of food, mainly provided by marine plankton which falls into the bottom (Peypouquet, doctoral thesis, in preparation). The presence

of *Parakrithe* sp. A above Core 8 implies a setting where P ions were relatively abundant, which calls for a large supply of organic material. The presence of *Krithe* sp. C 2-3 and *Parakrithe* sp. A 2-2 which are species having a wide vestibulum, suggests a slight lowering of the dissolved O_2 by the organisms living in the benthos. Lithological analysis demonstrates the presence of pyrite in the highly carbonated sediment, rich in nannoflora, and confirms the existence of a "reducing" environment and the ample supply of organic matter. Consequently, it appears that in the Bay of Biscay the circulatory processes on the ocean bottom, and probably on the surface, were modified between the lower and middle Eocene. Perhaps the orogenesis of the Pyrenees, which dates from the same period, may have been implicated in this hydrologic change. The gaps in sedimentation in Sites 118 and 119 (Laughton and Berggren, 1972) in the Bay of Biscay, contemporary with the above-mentioned events, give support to this hypothesis.

Neogene Stability

Other periods during the Tertiary are marked by an abundance and variety of deep-water ostracodes, for example, the late Miocene and early Pliocene. As on the North Gascony

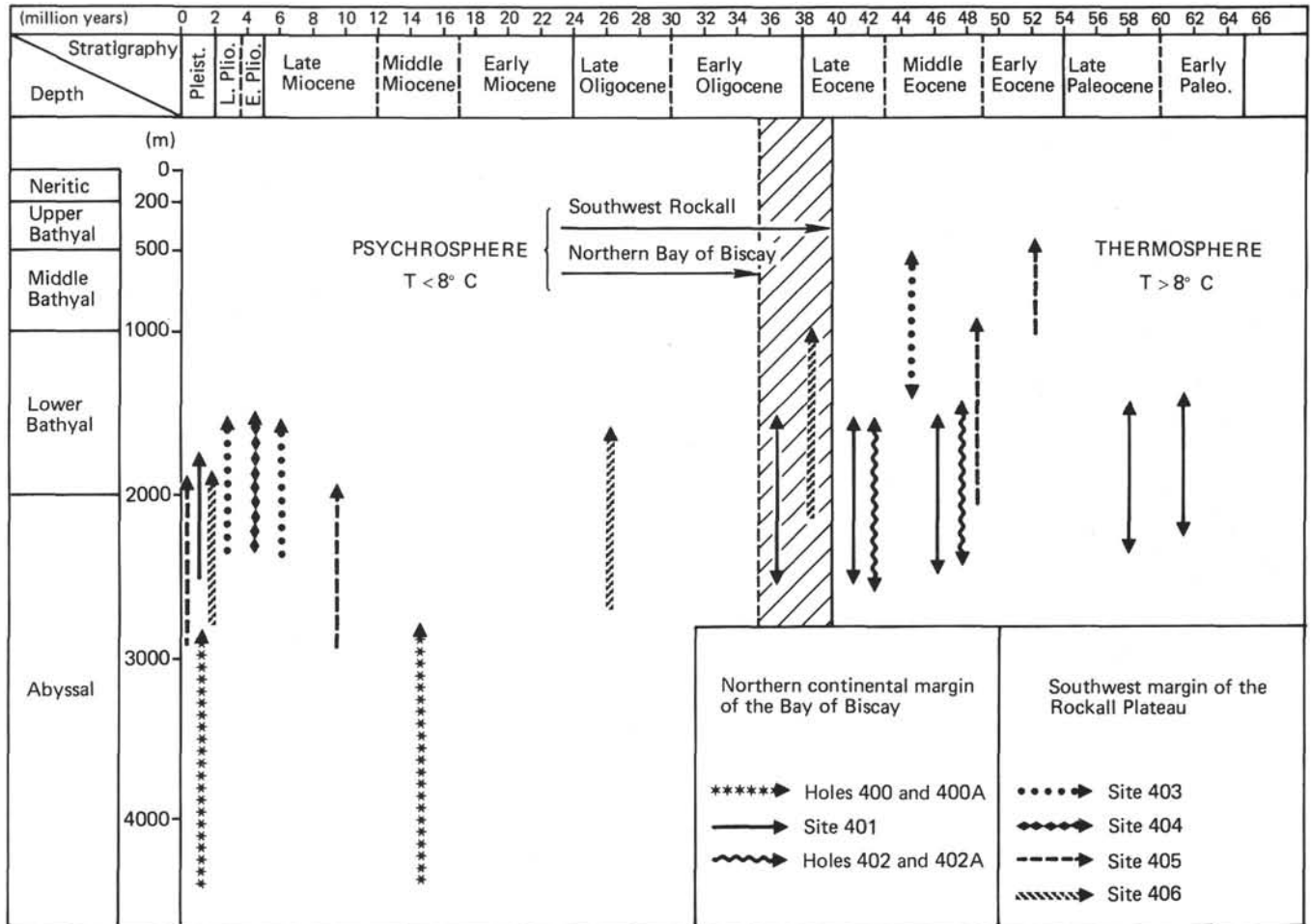


Figure 11. *The beginnings of the psychrosphere.*

margin, *Parakrithe* sp. A makes its appearance in late Eocene time, indicating an enrichment in P ions in the deep-ocean environment. These observations apply in particular at Sites 403 and 405 at Rockall. It is possible that during these episodes the bottom currents were of low intensity, and the supply of organic plankton enriched the level of nutrition in the surroundings and stimulated benthic activity. These episodes are marked by fairly extensive pelagic sedimentation.

The Glacial Interval

With the onset of glacial phenomena, at the transition from lower to upper Pliocene (Berggren, 1972), a re-intensified flow in the circulation in the deep ocean is attested, in some cases by a hiatus in the upper Pliocene section (Sites 401, 404, 405, and 406), in others by a marked impoverishment in the deep-water fauna of the upper Pliocene (Site 403). At the latter site the lower Pliocene fauna (Core 7) is extremely rich and varied (16 species) whereas the upper Pliocene (Cores 6 and 4) shows a sparse fauna (4 species). Deep-water mid-Tertiary forms (*Bradleya*, *Agrenocythere*, *Argilloecia*, *Parakrithe*, and *Poseidonamicus*) decline or disappear, and are replaced by other, better adapted genera (*Kriithe*, *Cytheropteron*, *Thalassocythere*, *Echinocythereis*, and *Bosquetina*). This phenomenon in the Rockall Basin has already been commented upon (Peypouquet, 1975b). The cause is

essentially hydrologic. The arrival of cold waters ($T^{\circ} < 3^{\circ}\text{C}$), very poor in nutrients, especially Si and P, is implicit in the theory that the Norwegian Sea operated as a Mediterranean Sea, as understood by Worthington (1970). This milieu is unfavorable to many species and caused a partial change in the fauna. The flow of Norwegian waters with their different physico-chemical characteristics encouraged evolution in the deep ostracode faunas.

BIOGEOGRAPHY

Comparative analysis of the ostracode fauna of the entire group of Leg 48 sites provides other insights. The deep-water forms of the Paleogene (*Bairdia cymbula* Deltel, *Argilloecia angulata* [Deltel], *Cytherella consueta* Deltel, *Cytherella transversa* Speyer, and *Trachyleberidea prestwichiana* [Jones and Sherborn]) on the northern continental margin of the Bay of Biscay are very similar to those of southern Aquitaine Basin (Deltel, 1961; Ducasse, 1974, 1975, in press). Some of these forms, in particular *Bairdia cymbula*, seem not to develop in the northeastern areas of Rockall. There, genera such as *Atlanticythere* and some species of *Hazelina* unknown in Aquitainia areas occur. The two areas, considered as deep-water biogeographical zones, have different ecological variables. This difference persisted into the Quaternary; *Poseidonamicus* and *Bradleya* are practically

non-existent in the Bay of Biscay at the present time, but are well represented in the North Atlantic.

The geographical setting of the two areas obviously plays some part in determining their peculiarities, but the deciding influence is most likely hydrology. Rockall is directly involved in the constant exchanges between the northeastern Atlantic and the Norwegian Sea, whereas the Bay of Biscay is slightly offset in relation to the ocean routes and less-directly influenced by northern elements. In the Tertiary, the Bay of Biscay and its northern margin were dependent on water which came from the Tethys or in the Quaternary, from the Mediterranean Sea (Peypouquet, 1973; Le Floch, 1968, 1969). As a result, the physico-chemical conditions of the deep-sea environment in these two areas, supplied as they are by two different sources, were dissimilar and gave rise to two distinct biogeographical provinces.

CONCLUSIONS

Analysis of the distribution in time and space of the deep-sea ostracodes in the northeastern Atlantic takes account of the major paleogeographical and paleohydrological events (Figure 12).

At the beginning of the Tertiary, the northern continental margin of the Bay of Biscay was already a deep zone; it had

undoubtedly reached its present depth. In the Paleocene, Site 400 had already reached a greater depth than Sites 401 and 402 and the conditions for benthic life were unfavorable.

In the Eocene, the southwestern margin of the Rockall Bank subsided markedly and the general physiography of the Rockall area was outlined. The establishment of the psychrospheric environment came into being by the end of late Eocene time at Rockall, and later, after the beginning of the Oligocene, in the Bay of Biscay. This phenomenon was the deciding factor in the renewal and expansion of the ostracode fauna. An increase in the intensity of bottom currents probably played a part in the sedimentary hiatus observed in the lower Oligocene at Rockall.

A major hydrologic transition occurred between the lower and middle Eocene in the Bay of Biscay, as evidenced by the increase in benthic productivity during middle Eocene up to lower Oligocene time. Decreases in the dissolved O_2 content on the bottom occurred during this period. Upper Miocene and lower Pliocene times appear as periods of distinct slackening in the deep-ocean circulation from the north. The principal influence of bottom currents came from the Norwegian Sea at the beginning of upper Pliocene time, contributing to the evolution of deep-water ostracode faunal assemblages and affecting sedimentation (hiatuses, condensed sequences).

	MAIN FAUNAL FEATURES		PALEOGEOGRAPHIC AND HYDROLOGICAL EVENTS	
	Southwest Rockall Plateau	North Bay of Biscay	Southwest Rockall Plateau	North Bay of Biscay
Pleistocene	2 nd renewal of microfauna		$T^{\circ} \approx 3^{\circ} C$	
Pliocene	Late	Scanty fauna	sedimentary gap	
	Early		influence of deep bottom Norwegian water T°	
Miocene	Late	Rich and diversified (Parakrithe) ostracode fauna		low velocity deep current of Norwegian origin
	Middle			
	Early			
Oligocene	Late			beginning of the psychrosphere $T^{\circ} < 8-10^{\circ} C$
	Early	1 st renewal of microfauna	numerous sedimentary gaps	
Eocene	Late	<i>Poseidonamicus</i> appears (Site 406)		beginning of psychrosphere $T^{\circ} < 8-10^{\circ} C$
	Middle	lower bathyal fauna		
	Early	mid. bathyal fauna	rich and diversified fauna (Parakrithe)	
Paleocene	Late	upper bathyal fauna	qualitative change of ostracode assemblages	hydrological change in the north part of bay of Biscay
	Early	typical fauna of continental shelf (Sites 403-404)	deep thermospheric fauna	

Subsidence and tilting

Poor abyssal fauna (Site 400)

Juvenile forms of *Krithe* (Site 400)

Figure 12. Main faunal features and paleogeographic and circulation events in the northern continental margin of the Bay of Biscay and southwest margin of the Rockall Plateau.

Finally, it appears that the northern continental margin of the Bay of Biscay and the Rockall area were, from the beginning of the Tertiary to the present time, two distinct ocean zones, each undergoing the influence of masses of deep water of separate origin, and are therefore two individual biogeographical areas.

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PLATE 1

- Figure 1 *Cytherella consueta* Deltel.
Left valve; Site 401, Sample 16, CC, early Paleocene.
- Figure 2 *Cytherella transversa* Speyer.
Left valve; Site 401, Sample 14, CC, late Paleocene,
×60.
- Figures 3, 4 *Cytherella* sp. 11.
3. Right valve; Site 403, Sample 7, CC, early
Pliocene, ×50.
4. Left valve; dorsal view, Site 403, Sample 7, CC,
early Pliocene ×50.
- Figure 5 *Cytherella* sp. 12.
Right valve; Site 401, Sample 2, CC, early Oligocene,
×110.
- Figure 6 *Cytherella* sp. 13.
Left valve; Site 401, Sample 4, CC, late Eocene,
×110.
- Figure 7 *Cardobairdia* sp. 2.
Carapace, right valve; Site 401, Sample 5-3, 119-121
cm, middle Eocene, ×200.
- Figures 8, 9 *Bairdia cymbula* Deltel.
8. Right valve; Site 401, Sample 17, CC, early
Paleocene, ×50.
9. Left valve; Site 401, Sample 5, sect. 3, 119-121
cm, middle Eocene, ×50.
- Figure 10 *Bairdia* sp. 1 Moyes.
Left valve; Site 403, Sample 21, CC, late Miocene,
×50.

PLATE 1

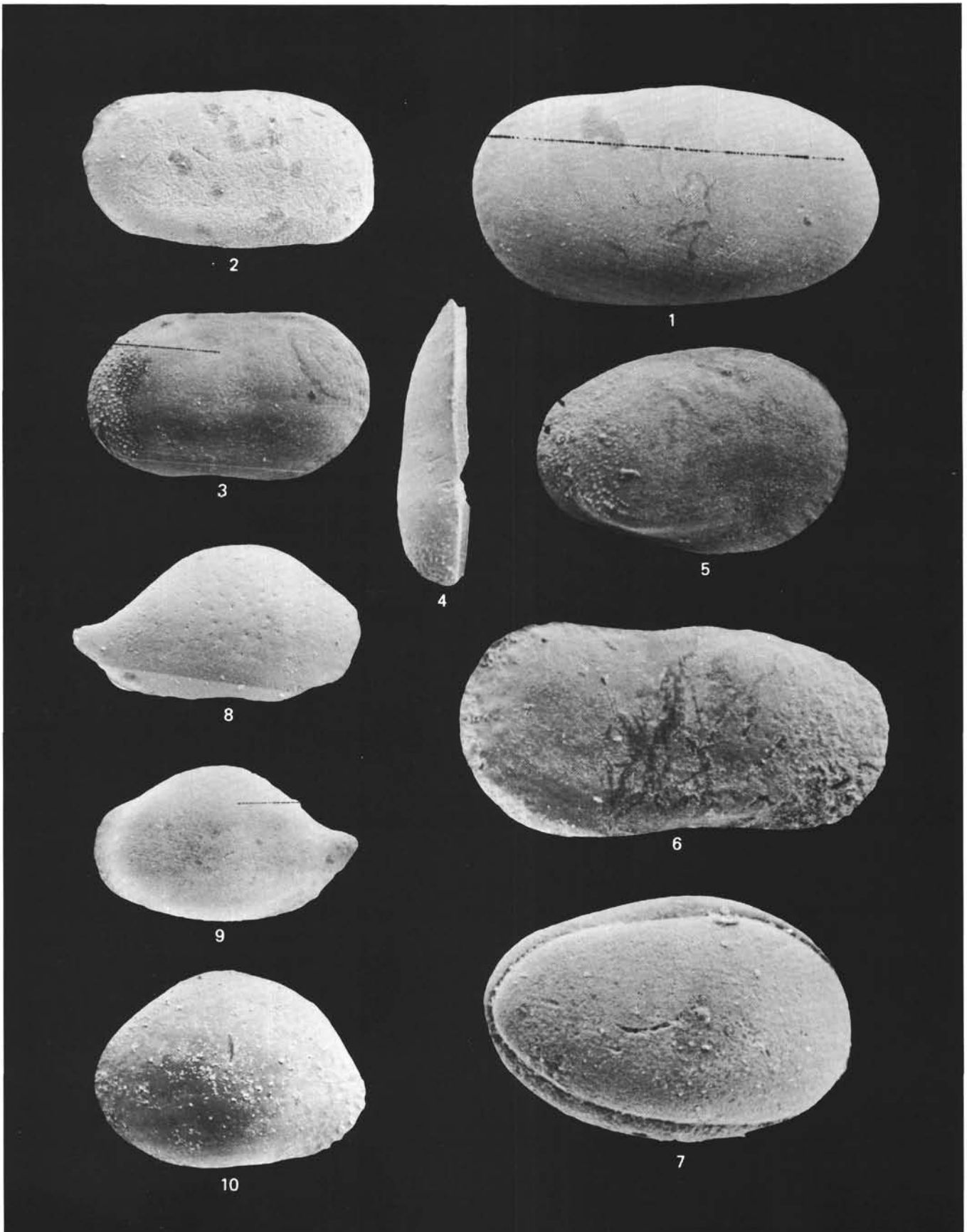


PLATE 2

- Figures 1, 2 *Bairdia* sp. 6.
1. Left valve; Site 401, Sample 503,
119-121 cm, middle Eocene, $\times 110$.
2. Carapace, dorsal view, Site 401,
Sample 5-3, 119-121 cm, middle
Eocene, $\times 110$.
- Figure 3 *Bairdia* sp. 7.
Right valve; Site 404, Sample 6,CC, late
Miocene, $\times 40$.
- Figure 4 *Bythocypris*.
Right valve; Site 405, Sample 9,CC,
middle eocene, $\times 50$.
- Figure 5, 6 *Cythere suhmi* (Brady).
5. Left valve; Site 403, Sample 6,CC, late
Pliocene, $\times 50$.
6. Right valve; Site 403, Sample 6,CC,
late Pliocene, $\times 40$.
- Figure 7 *Agrenocythere* sp. 1.
Left valve; Hole 400A, Sample 37-1, 44-46
cm, early Miocene, $\times 40$.
- Figure 8 *Trachyleberidea prestwichiana* (Jones and
Sherborn).
Left valve; Site 405, Sample 9,CC, middle
Eocene, $\times 60$.
- Figure 9 *Hazelina* sp. 2.
Right valve; Site 405, Sample 10,CC,
middle Eocene, $\times 110$.
- Figure 10 *Hazelina*?
Right valve; Site 403, Sample 43,CC,
Paleocene, $\times 110$.
- Figure 11 *Echinocythereis echinata* (Sars).
Right valve; Site 405, Sample 3,CC,
Quaternary, $\times 40$.

PLATE 2

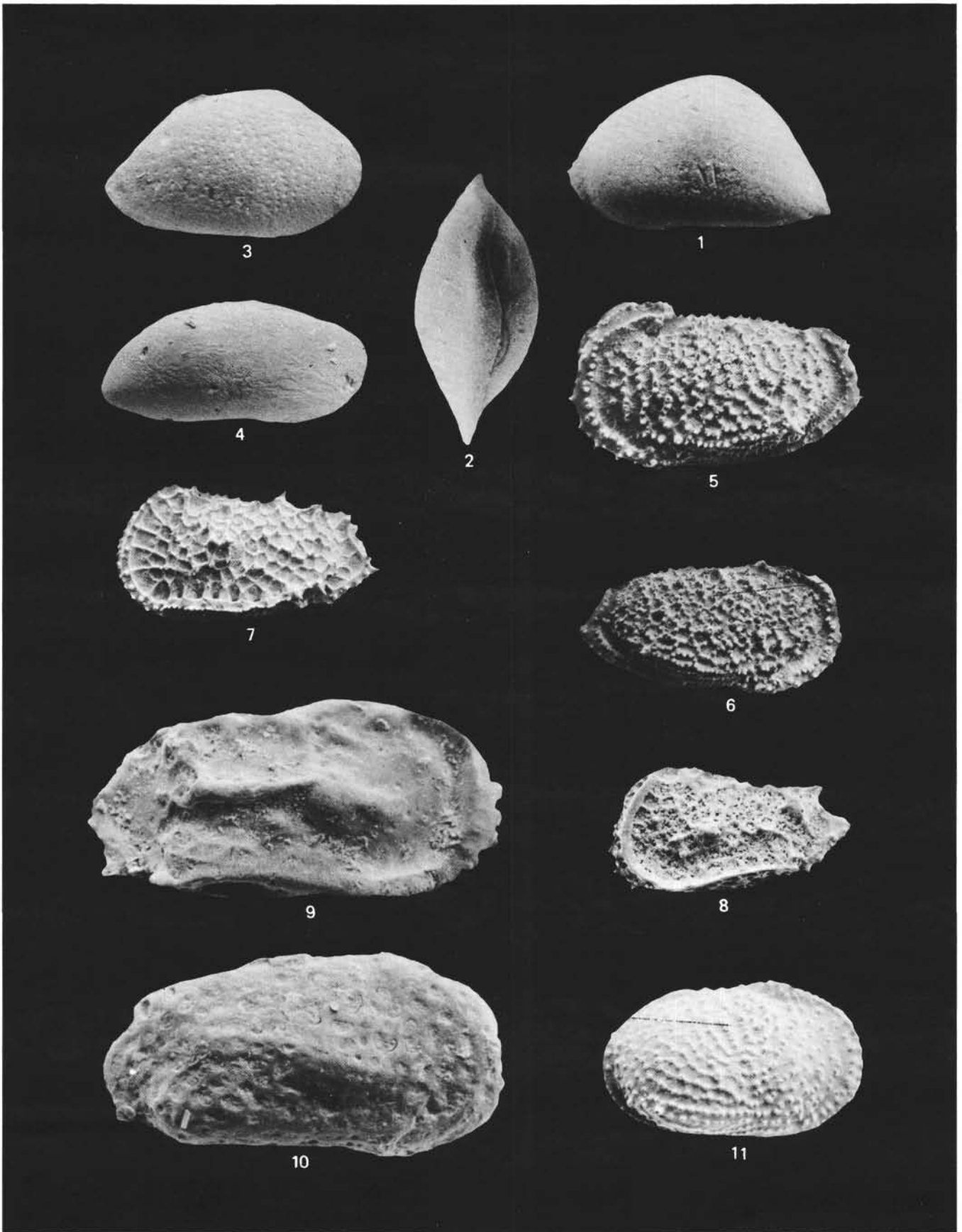


PLATE 3

- Figure 1 *Henryhowella asperrima* (Reuss).
Left valve; Site 403, Sample 7, CC, early Pliocene,
×60.
- Figure 2 *Atlanticythere* sp. 1.
Left valve; Site 405, Sample 9, CC, middle
Eocene, ×50.
- Figure 3 *Oxycythereis dorsoserata*.
Right valve; Site 405, Sample 4, CC, Quaternary,
×50.
- Figure 4 *Thalassocythere acanthoderma* (Brady).
Right valve; Site 405, Sample 4, CC, Quaternary,
×40.
- Figure 5 *Buntonia* sp. 3.
Left valve; Hole 400A, Sample 56-2, 60-63 cm,
early Eocene, ×110.
- Figure 6 *Hermanites* ? sp. 7 (smooth form).
Left valve; Site 405, Sample 4, CC, Quaternary,
×50.
- Figure 7 *Hermanites* ? sp. 8 (tuberculate form).
Carapace, right valve; Site 404, Sample 25, CC,
Paleocene, ×50.
- Figure 8 *Hermanites* ? sp. 9 (reticulate form).
Right valve, Site 404, Sample 17, CC, early
Eocene, ×110.
- Figure 9 *Bradleya dictyon* (Brady).
Left valve; Site 405, Sample 4, CC, Quaternary,
×50.

PLATE 3

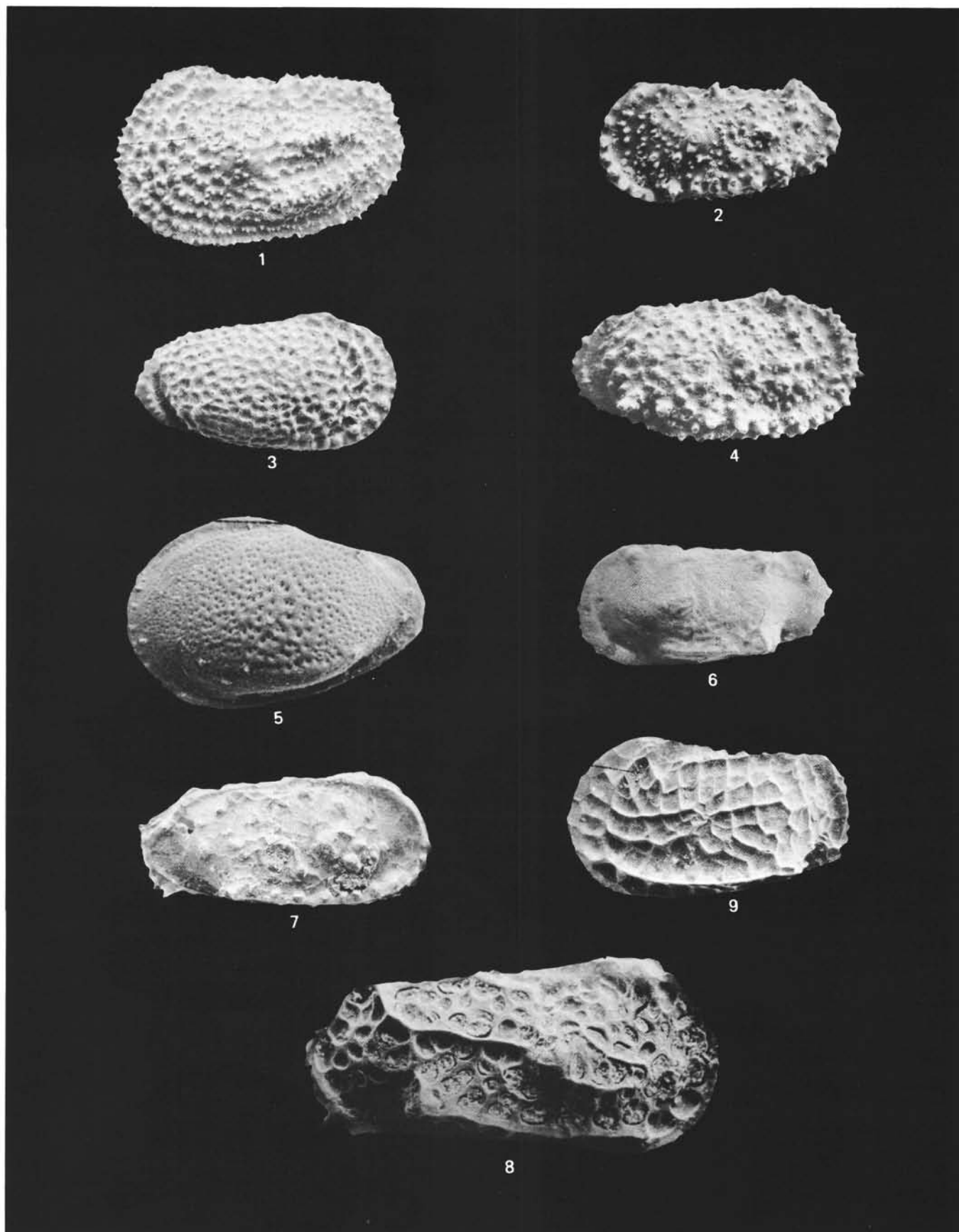


PLATE 4

- Figure 1 *Poseidonamicus* sp. 1.
Right valve; Site 404, Sample 5, CC, late Miocene,
×50.
- Figure 2 *Bosquetina fenestratum* (Brady).
Right valve; Site 405, Sample 7-1, Bottom, early
Pliocene, ×110.
- Figure 3 *Loxoconcha* sp. 22.
Left valve; Site 404, Sample 17, CC, early Eocene,
×110.
- Figure 4 *Eucytherura* sp. 6.
Left valve; Site 401, Sample 10, CC, middle Eocene,
×280.
- Figure 5 *Semicytherura* sp. 8.
Right valve; Hole 400A, Sample 2-2, 114-116 cm,
Quaternary, ×150.
- Figure 6 Juvenile form of *Semicytherura* sp. 9.
Right valve; Site 402, Sample 1, CC, Quaternary,
×110.
- Figure 7 *Cytheropteron* sp. 8.
Right valve, Hole 400A, Sample 1-1, 68-70 cm,
Quaternary, ×150.
- Figure 8 *Cytheropteron* sp. 9.
Right valve; Site 402, Sample 5, CC, late Eocene,
×220.

PLATE 4

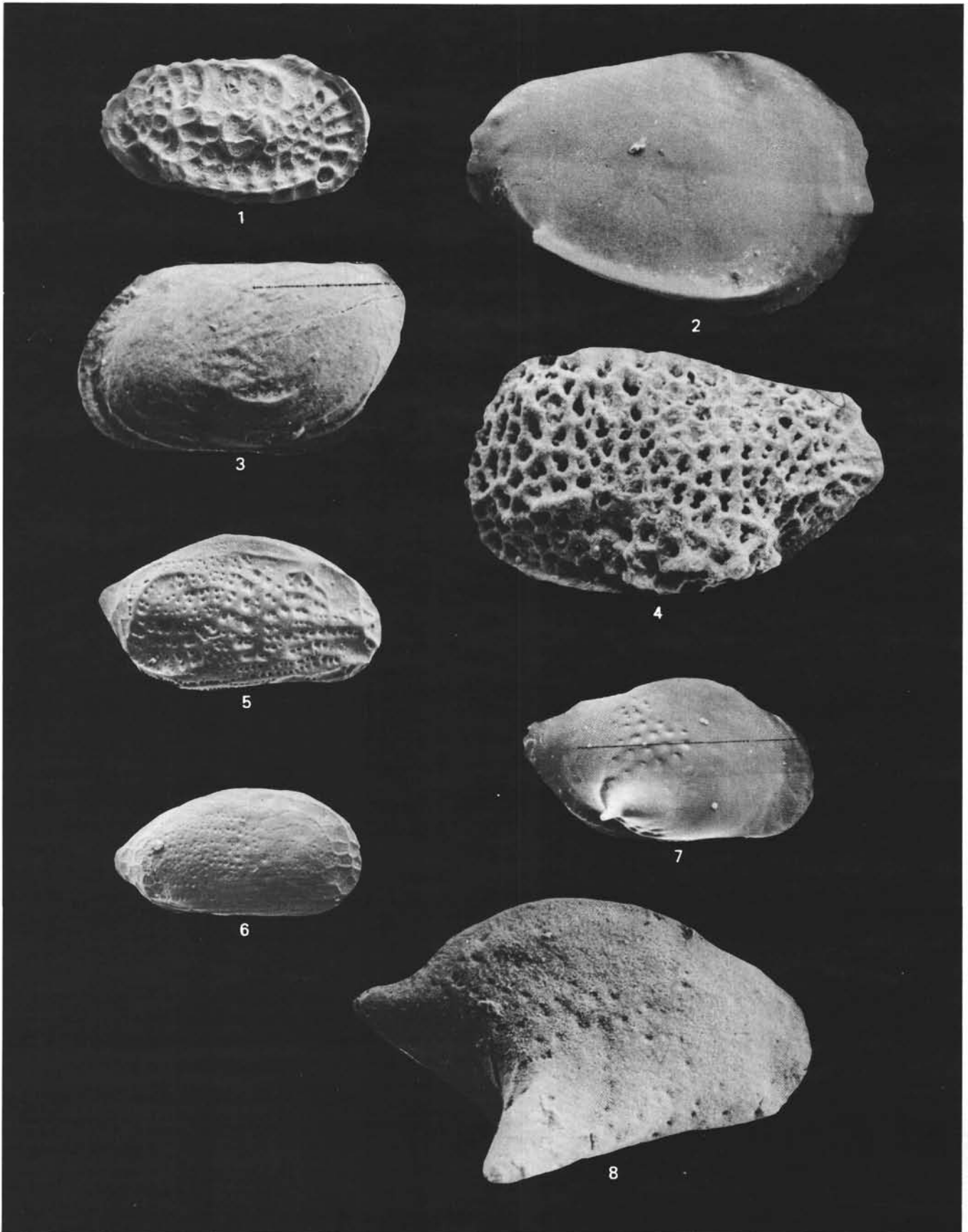


PLATE 5

- Figures 1, 2 *Cytheropteron* sp. 10.
1. Right valve; Site 401, Sample 5-3, 119-121 cm, middle Eocene ×220.
2. Left valve, dorsal view; Site 401, Sample 5-3, 119-121 cm, middle Eocene, ×220.
- Figure 3 *Cytheropteron* sp. 26.
Right valve; Site 403, Sample 15, CC, late Miocene, ×110.
- Figure 4 *Koilocythere* sp. 1.
Left valve; Site 403, Sample 15, CC, late Miocene, ×110.
- Figure 5 *Xestoleberis* sp. 2.
Right valve; Site 403, Sample 13, CC, late Miocene, ×110.
- Figure 6 *Argilloecia angulata* (Deltel).
Carapace, left valve; Site 401, Sample 3, CC, late Eocene, ×110.
- Figure 7 *Argilloecia conoidea* (Sars).
Left valve; Site 402, Sample 1, CC, Quaternary, ×150.
- Figure 8 *Paracypris* sp. 6.
Right valve; Site 404, Sample 17, CC, early Eocene, ×50.
- Figure 9 *Indet. gen. 3.*
Left valve; Site 406, Sample 1, CC, Quaternary, ×110.

PLATE 5

