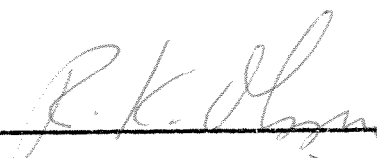

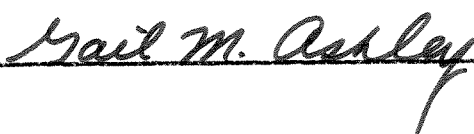


UPPER JURASSIC-LOWER CRETACEOUS  
FORAMINIFERAL BIOSTRATIGRAPHY, PALEOECOLOGY,  
AND PALEOBIOGEOGRAPHY OF THE COST B-2 WELL

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## ABSTRACT

The C.O.S.T. B-2 well, which was the first well drilled in the New Jersey Outer Continental Shelf, contains two marine intervals of Late Jurassic-Early Cretaceous age between 11,510-13,100 feet. A biostratigraphic, paleoecologic, and biogeographic analysis of these intervals revealed the following results from the B-2 well. Foraminiferal assemblages characteristic of Barremian (*G. barremiana*-*L. sigali* zone), Upper Valanginian-Lower Hauterivian, and Kimmeridgian-Tithonian ages are recognized in the Upper Jurassic-Lower Cretaceous interval of the B-2 well. The placement of the boundary between the Upper Jurassic-Lower Cretaceous occurs at 13,000 feet and agrees with Swain's (1978) conclusion. Evidence indicates that the environment of deposition during Upper Jurassic-Lower Cretaceous was marginal marine with intervals of nonmarine deposition. The global sea level curve of Vail et al. (1977) compares favorably to the marine and nonmarine cycles recognized in the B-2 well. All faunal assemblages exhibit worldwide biogeographic extent. The occurrence of *Lenticulina nodosa nodosa* in the Barremian assemblage indicates that the area of the B-2 well lay within the tethyan realm during Early Cretaceous time.

### ACKNOWLEDGEMENTS

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## INTRODUCTION

The Lower Cretaceous System of the Atlantic Coastal Plain is known from both surface exposures and wells. These sediments which are of nonmarine origin are called the Potomac Group. The Potomac Group which ranges in age from Neocomian-Albian (Brenner, 1963; Doyle and Hickey, 1972) is extensively developed in the coastal plain subsurface where it projects beneath the Atlantic shelf (Fig.1). Upper Jurassic marine sediments have been identified in some wells drilled in coastal areas (Swain and Brown, 1972; Bate, 1977) where they intercalate with nonmarine strata. Most of the Jurassic interval in coastal plain wells is nonmarine however. These nonmarine sediments are known to extend beneath a large part of the Atlantic shelf because they were encountered in the first well, the C.O.S.T. B-2 well, drilled in the Baltimore Canyon Basin of the U.S. Atlantic offshore (Smith et al., 1976). Although Smith et al. did not identify Jurassic age sediments in the B-2 well, subsequent studies have delineated a Jurassic section (Jansa et al., 1978; Swain, 1978). In this well the nonmarine intervals are interlayered with marine intervals, thus giving evidence of several cycles of transgression and regression.

Micropaleontologic studies on the marine intervals have been cursory and intended only for stratigraphic purposes (Jansa et al., 1978; Smith et al., 1976; Swain, 1978). Numerous studies on Lower Cretaceous and Upper Jurassic foraminifera have been conducted in the European sector of

STAGE	L.I.	NJ SURFACE	S. JERSEY HIGH SUBSURF.	SALIS. EMBAY. A-D #1	DEL.-MD.	ALBE. EMBAY. HAT. LT. #1	COST B-2
ALBIAIAN		POTOMAC	POTOMAC GR.	POTOMAC GR.	POTOMAC GR.	SS. LS.	SS. SH. CONGL. COAL
APTIAN							
BARREMIAN						SS. LS. DOLO.	
NEOCOMBIAN							
JURASSIC						CONGL.	

Figure 1. Comparison of stratigraphic columns in the coastal plain to the COST B-2 well (after Olsson, 1978).

the Atlantic Basin. The few analyses that have been completed in the Western Atlantic include Bartenstein et al. (1957) in Trinidad, Gradstein (1978) on the Blake Nose-Blake Plateau, Luterbacher (1972) from DSDP Leg 11, and Williams et al. (1974) and Gradstein et al. (1975) on the Scotian Shelf. Thus the B-2 well provides an important link in understanding the distribution of foraminifera between the northern and southern parts of the Western Atlantic Basin.

In this study the foraminifera are selected for biostratigraphic, paleoecologic, and biogeographic analysis. Data on the Lower Cretaceous and Upper Jurassic foraminifera in the B-2 well will provide important information on understanding the stratigraphic setting of the Atlantic Basin during this interval of geologic time.

Samples used in this study are rotary well cuttings. The marine intervals of the Upper Jurassic-Lower Cretaceous occur between 11,510-13,100 feet (Fig.2). Below 13,100 feet to the total depth of the well (16,042 feet) the section is non-marine. From 11,510-13,100 feet, the majority of the samples were taken at 30 foot intervals, but some were taken at 10 foot intervals to as thick as 80 feet. Samples were routinely processed for foraminiferal content and picked. Identifications and interpretations followed this step.



Sample Interval (feet)	Haplophragmoides concavus	H. cushmani	Ammobaculites torosus	Ammo. sp. A	Ammo. sp. B	Haplophragmium aequale	Trochammina globigeriniformis	Quinqueloculina sp. A	Lenticulina acuta	L. muensteri	L. nodosa gibber	L. nodosa nodosa	L. praegaultina	L. roemerii	L. subalata	Lent. sp. A	Gavelinella barremiana	G. cf. Intermedia	Epistomina caracolla caracolla	E. chapmani	E. cf. hechti	E. ornata	E. parastelligera	E. cf. spinulifera	E. uhligi
11,510-48	0																								
11,560-90																				0					
11,590-620	0						1												0						
11,620-50																									
11,650-80							0			1															
11,680-710	0						0			1				0											
11,710-40																									
11,740-70	4						1	0				2				0	0			1					
11,770-800	1																			0					
11,800-30							0					0													
11,850-60	0																								
11,860-90							1			0			0				2							0	
11,890-920	0									0							0		2	2		1		0	
11,920-50						1						1					0		3	2		1			
11,950-80															1						1				
11,980-															0						0				
12,000															0										
12,020-40																			0						
12,070-100																			1	1					
12,100-30	0								0			0			1					0					
12,130-60		1				0									0				1						
12,160-90	0																								
12,220-50	1								0										1	1					
12,250-80	5	1	0			2									1										
12,280-310	2																		1						
12,310-40	0																		4	2					
12,340-70	1																		2	0					
12,370-400												0							1						
12,400-30	0											0							1						
12,430-60	0																		1						
12,460-90	1																								
12,490-520	1																		0						
12,520-50																			1						
12,550-80	1								1	0					1				0						
12,630-40															1										
12,660-70	1																								
12,680-90	1								0																
12,700-10	1																								
12,730-40	1	0										0							0						
12,760-70	0																								
12,800-10	2																		0		1				
12,820-30	1					0																			
12,860-70	1																								
12,890-900	2		1												0										
12,920-30	2		0																						
12,950-60	2																								
12,980-90	0		0																						
13,000-10	0			0																				0	
13,010-20																									
13,020-30			0																						
13,030-40																									
13,040-50	1																					0			
13,050-60																									
13,060-70																									
13,070-80	2								0													1			
13,080-90	2														0							0			
13,090-100	1																								
13,100-10																								1	

# of specimens	Key	Rank #
0-1	Rare	0
1-5	Few	1
5-15	Present	2
15-25	Common	3
25-40	Abundant	4
>40	Very Abundant	5

Figure 2. Distribution of foraminifera.

### STRATIGRAPHY

The lithology of the Upper Jurassic-Lower Cretaceous sediments of the B-2 well consists of interbedded sandstones, shales, limestones, and coal beds (Rhodehamel, 1977). Many of the sandstones and shales are calcareous. These sediments are equivalent in part to strata identified throughout the Atlantic Coastal Plain as the Potomac Group (Fig.1). Figure 3 shows that the C.O.S.T. B-2 well was drilled near the axis of the Baltimore Canyon Trough, an elongate, northeast trending structural depression in continental basement rock filled with more than 40,000 feet of sediments. The trough which extends from Long Island, N.Y. to Cape Hatteras, N.C. is explained by Mattick (1977) as a possible extension of the Salisbury Embayment. In profile (Fig.4), the sediments thicken seaward and for the most part are gently dipping.

Because sediments of Jurassic age exist in the B-2 well, there is still the question on where to place the location of the boundary between the Upper Jurassic-Lower Cretaceous. Swain (1978) places the boundary at 13,000 feet based on ostracod evidence and Jansa et al. (1978) using dinoflagellate biostratigraphy and lithostratigraphy, place it at 13,400 feet.



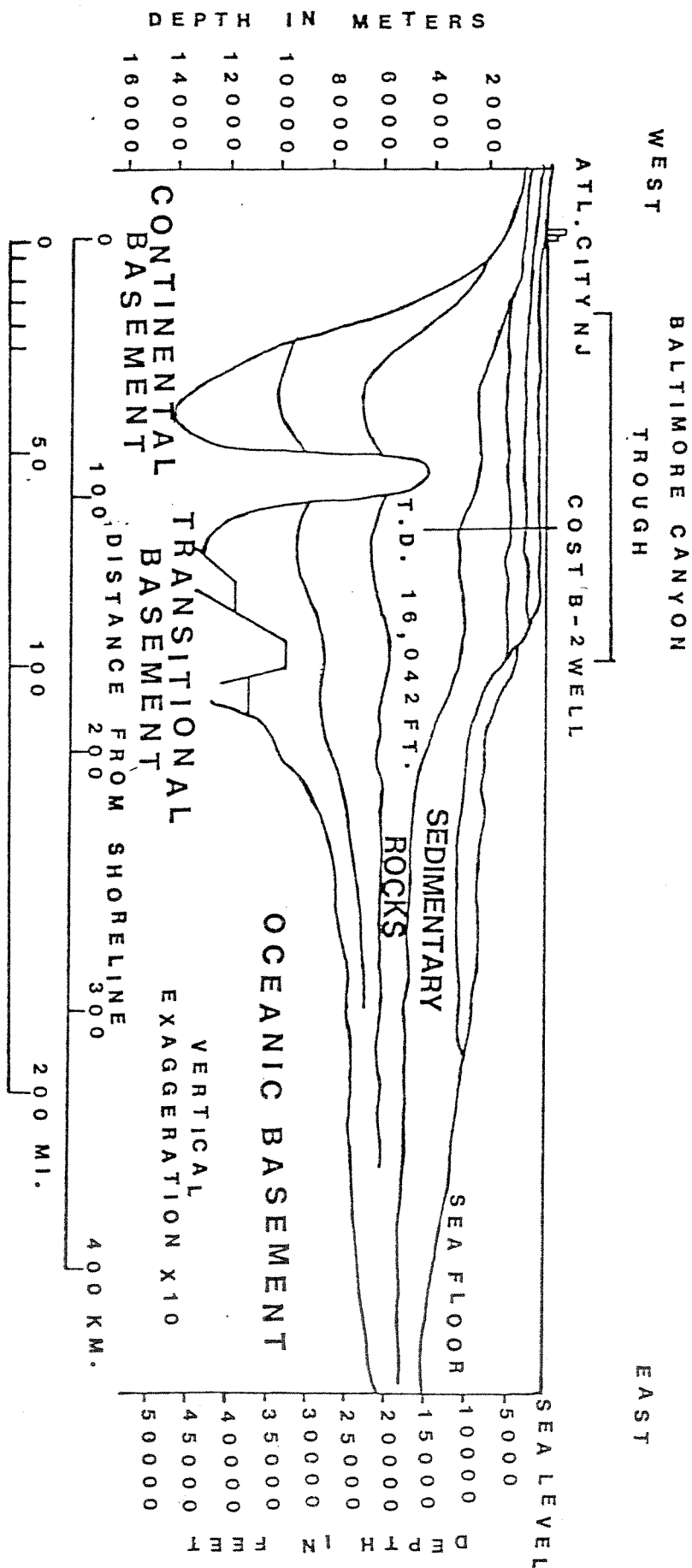


Figure 4. Cross-section of New Jersey continental margin (after Mattick, 1977).

### BIOSTRATIGRAPHY

Benthonic foraminifera are present but sparse throughout the marine intervals (Fig. 2). The low number of foraminifera are probably due to a combination of the shallow water environment in which they lived and to the effects of post-depositional dissolution. The foraminiferal assemblages consist almost entirely of rotaliids and textulariids. No planktonic foraminifera were observed. Three distinct foraminiferal assemblages are recognized. They are 1) Barremian 2) Upper Valanginian-Lower Hauterivian and 3) Kimmeridgian-Tithonian in age (Fig. 5). The above findings are significant because

- a) Lower Cretaceous foraminifera have been identified for the first time on the New Jersey Continental Shelf and
- b) Upper Jurassic foraminifera have been recognized supporting the conclusions of Swain (1978) and Jansa et al. (1978).

Barremian: Foraminifera from the Barremian Stage of Europe are well known from the studies of Bartenstein (1952), Bartenstein et al. (1971), Micheal (1967), Simon and Bartenstein (1962), and Ten Dam (1948). Species which characterize an assemblage of Barremian age include Gavelinella barremiana, Epistomina caracolla caracolla, E. ornata, E. spinulifera, Lenticulina nodosa, L. praegaultina, and Haplophragmium aequale. The presence of this assemblage in the B-2 well places the Barremian in the interval from 11,740-11,950 feet (Fig. 5). Ranges for some of the diagnostic species (Gradstein, 1978b) are:

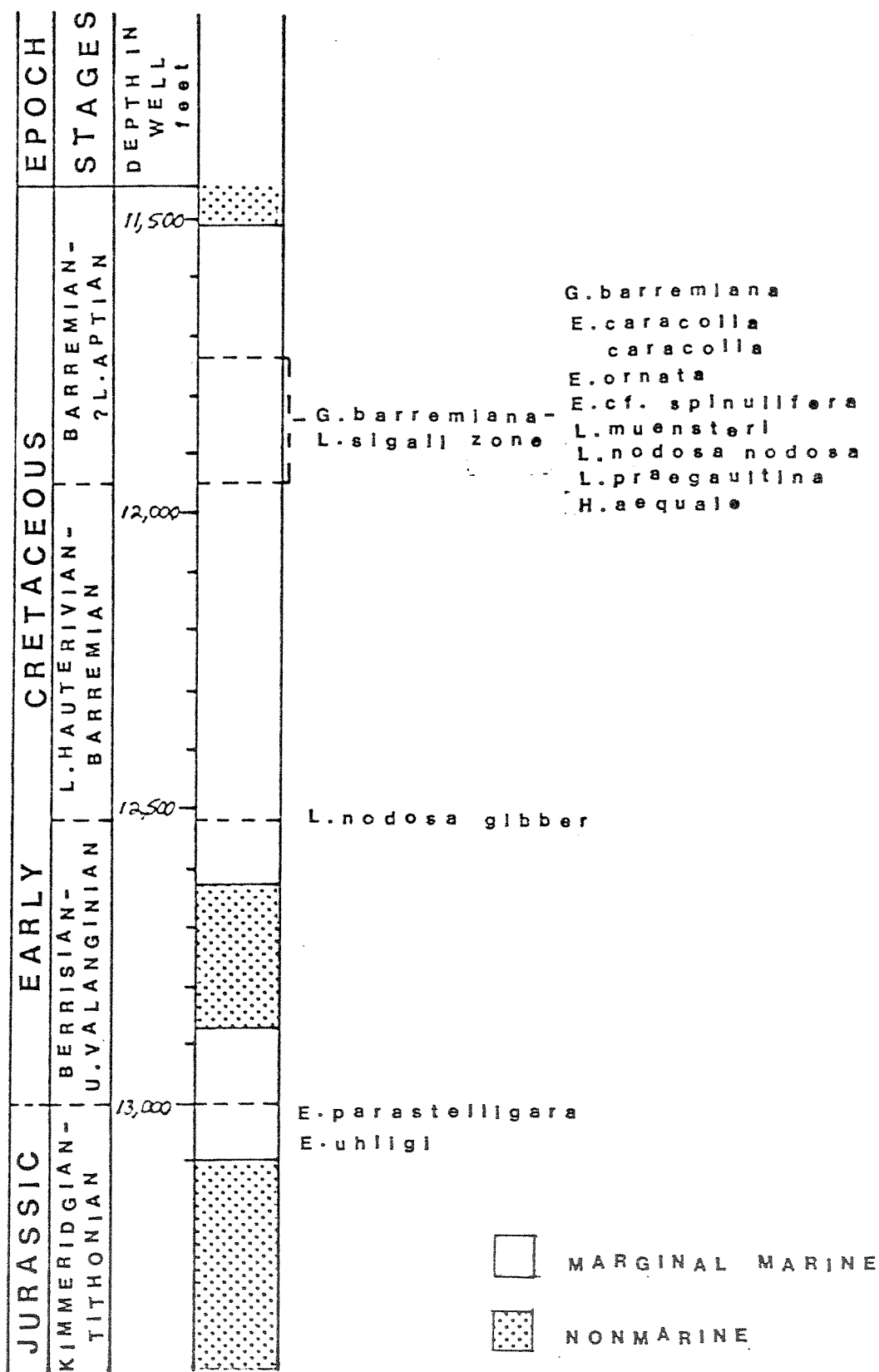


Figure 5. Jurassic-Lower Cretaceous marine intervals of COST B-2 well showing important foraminiferal species.

G. barremiana: middle-upper Barremian, ?lower Aptian;  
E. caracolla caracolla and E. ornata: Valanginian-middle  
 Barremian; and E. spinulifera: middle Barremian-Albian.

Gradstein (1978b) in his study of the Barremian of the Blake Nose-Blake Plateau, established an informal zone which he named the Gavelinella barremiana-Lenticulina (M.) sigali zone. This zone is based on the occurrence of the above species in association with G. barremiana, E. caracolla caracolla, E. ornata, E. spinulifera, L. muensteri, and L. nodosa. The zone is recognized at DSDP sites 392A, 390, and 391C (Fig. 6). The similar faunal characteristics between the Blake Nose-Blake Plateau and the B-2 well make it possible to extend this informal zone to the New Jersey Continental Shelf (Fig. 5). The above species are not found in the Lower Cretaceous in DSDP sites in the area, such as 99A, 100, 101A, and 105 (Fig. 6). Gradstein (1978b) suggests that Lower Cretaceous deposition in the area took place below the carbonate compensation depth so that the environment was not suitable for these species.

The G. barremiana-L. sigali zone can also be extended to Trinidad where characteristic Barremian assemblages are described by Bartenstein et al. (1957). Species identified by them which characterize this zone include G. barremiana, E. caracolla caracolla, E. ornata, L. muensteri, and L. nodosa. Included as part of this assemblage are L. praegaultina, L. roemerii, and H. cf. aequale.

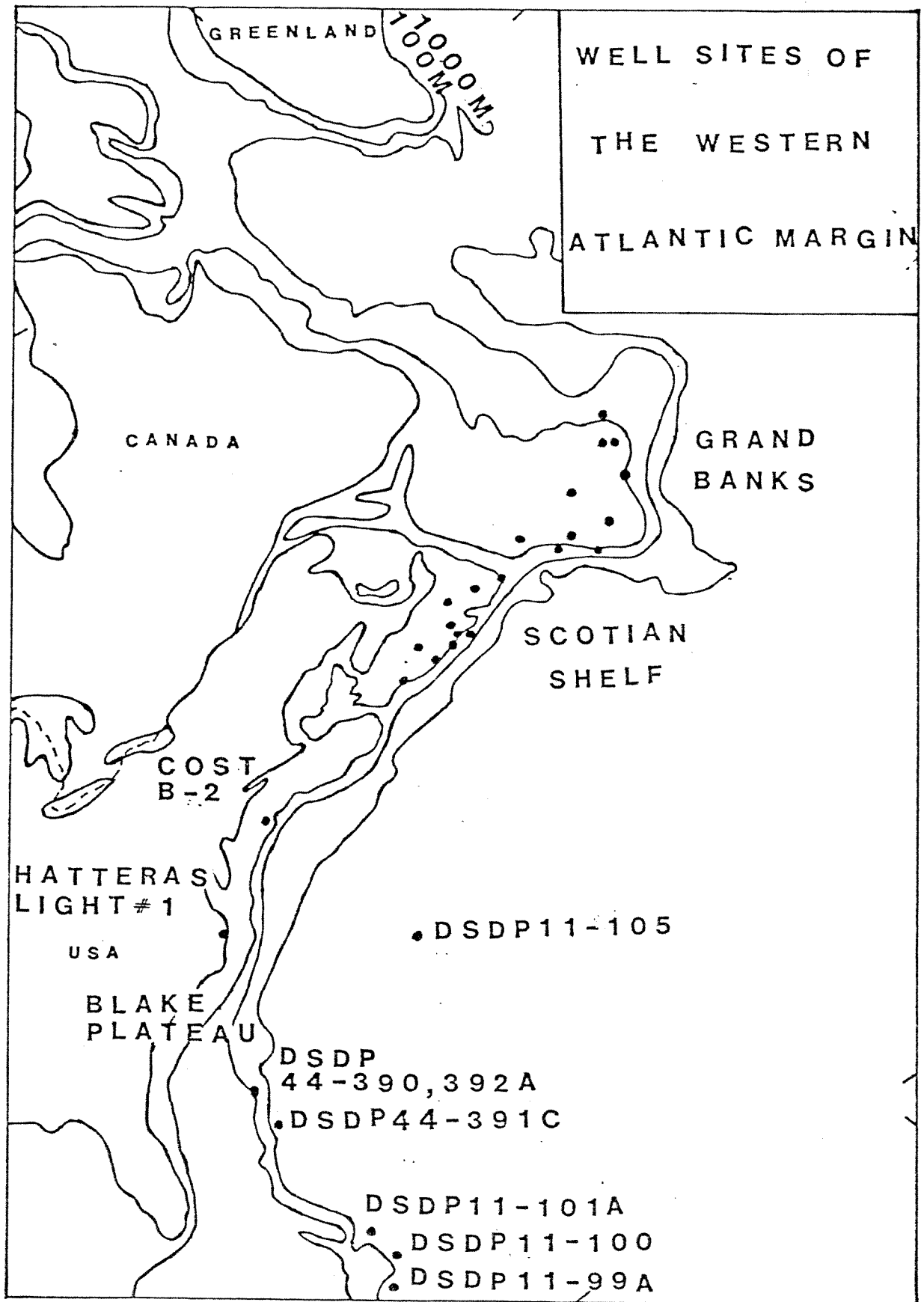


Figure 6. Well locations (after Gradstein, 1977a).



Information from wells drilled on the Scotian Shelf (Fig. 6) shows that a Barremian fauna has been observed there too (Gradstein et al., 1975; Williams et al., 1974). The species identified include G. barremiana, E. caracolla caracolla, E. ornata, and L. nodosa. Based on these observations, it seems reasonable that an extension of the G. barremiana-L. sigali zone to the Scotian Shelf is also possible.

A comparison of the B-2 to the Gulf Coast shows that the sediments of the Comanche Series (Fig. 7) are stratigraphically younger than the B-2 sediments. Below the Comanche Series lie the sediments of the Coahuila Series (Fig. 7). These may be of equivalent age but have not yet been differentiated. Some of the long ranging species, such as L. muensteri, L. subalata, and Haplophragmoides concavus have been identified in both localities, but they are not stratigraphically useful.

Upper Valanginian-Lower Hauterivian: At 12,520 feet (Fig. 5), a single specimen of the species Lenticulina nodosa gibber was recovered. According to Aubert and Bartenstein (1976), the range of this species is Upper Valanginian-Lower Hauterivian. At first the interval from 12,000-16,042 feet was regarded as Berrisian in age (Smith et al., 1976), but with the identification of this species, it is possible to delineate an Upper Valanginian-Lower Hauterivian age (Fig. 5). Also found with L. nodosa gibber are L. muensteri and L. subalata.

SERIES	STAGES		TEXAS	
LOWER CRETACEOUS	ALBIAN		COMANCHE SERIES	WASHITA GR.
				FREDERICKSBURG GR.
				TRINITY GR.
	APTIAN		COAHUILA SERIES	
				?
	NEOCOMIAN	BARREMIAN		
		HAUTERIVIAN		
		VALANGINIAN		
		BERRISIAN		

Figure 7. Comparison of Gulf Coast to European stages (after Kummel, 1970).

Aubert and Bartenstein (1976) report L. nodosa gibber as only occurring in Tierro del Fuego, South Africa, and Madagascar. The presence of this subspecies in the C.O.S.T. B-2 well greatly extends its biogeography and also increases its utility as a biostratigraphic marker. The rare occurrence here may indicate why it has not been observed at other localities in the northern Atlantic region.

Kimmeridgian-Tithonian: Between 13,000-13,100 feet in the B-2 well, Upper Jurassic Epistominellids occur in marine sands (Fig. 5). The species are Epistomina parastelligara and E. uhligi. This is the first time that species of Upper Jurassic foraminifera have been identified from the New Jersey continental margin. Luterbacher (1972) observed these species at DSDP site 105 (Fig. 6). In the Grand Banks and Scotian Shelf (Fig. 6), E. uhligi occurs frequently (Gradstein, 1978a; Williams et al., 1974). E. parastelligara has not been observed in the Canadian Shelf, which may indicate that this species has a northern biogeographic boundry. The B-2 assemblage lacks such diagnostic species as E. mosquensis and Pseudocyclamina jaccardi, which are used to recognize the Upper Jurassic benthonic foraminiferal zones described by Gradstein (1977b; 1978a), so it is not possible to make any regional correlation. The age assigned to the B-2 assemblage is based on the Kimmeridgian-Tithonian range of these species (Luterbacher, 1972).

The Upper Jurassic-Lower Cretaceous boundry in the B-2 well as previously mentioned is placed by Swain (1978) at

13,000 feet and by Jansa et al. (1978) at 13,400 feet. At 13,000 feet, E. uhligi first occurs and at subsequent intervals down to 13,100 feet numerous specimens of E. parastelligara and E. uhligi are present. The foraminiferal data in this study supports the work of Swain (1978) in placing the boundry at 13,000 feet (Fig. 5). This conclusion contradicts Smith et al. (1976) that the last 8,000 feet of sediment in the C.O.S.T. B-2 well is Lower Cretaceous in age, when in fact much of it (13,000-16,042 feet) is actually Jurassic in age.

## PALEOECOLOGY

### Environment of Deposition

Before the C.O.S.T. B-2 well was drilled, Minard et al. (1974) concluded that the Lower Cretaceous sediments of the Atlantic Coastal Plain were deposited as part of a major deltaic sequence. The Lower Cretaceous sediments in the B-2 well contain a high percentage of massive sandstones, which indicates that deltaic sediments extended seaward over much of the shelf (Mattick, 1977). Sheridan et al. (1978) describe the environment of the B-2 well during Tithonian-Barremian time as marginal marine to nonmarine and being associated with delta-like extensions. Sediment was supplied to the area from erosion of the Appalachians and rapidly accumulated to form thick variegated sandstones, shales, and coal beds.

The results of this study concur with the assumptions made above. Foraminiferal evidence indicates that deposition of sediments occurred in a marginal to nonmarine environment. The term marginal marine includes environments such as estuary, lagoon, bay, areas just off the beach (to a depth of several meters), and areas immediately above the shoreline. The type of foraminiferal assemblage that occurs in the Upper Jurassic-Lower Cretaceous of the B-2 well is one of low diversity-high dominance. This non-specific character is a good indicator of shallow water conditions, as opposed to a high diversity-low dominance assemblage, which indicates deeper water conditions. Although it has to be assumed that a certain degree of dissolution has occurred, as evidenced

by the generally poorly preserved assemblages, the main body or core of the assemblage can still be recognized. It is composed of three main groups 1) simple arenaceous foraminifera 2) lagenids and 3) epistominellids. Throughout the entire section, all or part of the above groups comprise the faunal assemblages. This type of assemblage is very similar to ones which inhabit marginal marine environments today. For instance, simple arenaceous foraminifera like Haplophragmoides and Ammobaculites dominate modern marginal marine habitats. Also found in shallow water environments are Lenticulina and Epistomina. Species of these particular genera can be found in environments other than marginal marine, but the above association indicates a shallow water environment. Other evidence of marginal marine conditions is derived from the fact that coal is interbedded throughout the sequence (Rhodehamel, 1977). This association almost always indicates marginal marine conditions. The lack of planktonic foraminifera is another indication of shallow water conditions. (One specimen of what may be a species of Hedbergella was found in the entire section.)

Gordon (1970) reviewed the biogeographic distribution of Jurassic foraminifera and distinguished five broad types of assemblages:

- A) Shelf Assemblages
  - 1) Nodosariid and Nodosariid mixed assemblages.
  - 2) Dominantly simple arenaceous assemblages.
  - 3) Calcareous benthonic foraminifera other than Nodosariids conspicuous.

- B) Tethyan Assemblages
  - 1) Complex arenaceous species dominant.
  - 2) Planktonic assemblages.

The Upper Jurassic assemblage in the B-2 well (Fig. 2) is characterized by all the aspects of the shelf assemblages (in particular A2 and A3). No Tethyan assemblage is evident. If this same concept is applied to the Lower Cretaceous faunas a similar conclusion is reached: shelf assemblage. Although this is a broad classification, it is added evidence for a shallow water environment.

Gordon (1970) suggests that the presence of Epistomina may indicate deep water shelf conditions. In the Barremian section (Figs. 2,4) Epistomina dominates in several intervals and is associated with Gavelinella. These intervals lack arenaceous foraminifera and the only specimen of a possible planktonic foraminifera also occurs here. Although most of the Upper Jurassic-Lower Cretaceous section is interpreted as marginal marine in origin, perhaps somewhat more offshore conditions were present during deposition of the intervals that contain Epistomina and Gavelinella.

#### Regional Comparison

A regional overview of the Western Atlantic region shows that some areas had an environment of deposition similar to the B-2 well during Early Cretaceous time, while others were different. For instance, Jansa et al. (1978) show that on the Scotian Shelf there are marked similarities in both areas in the thick Lower Cretaceous clastic sequences. This may indicate that both areas have undergone a similar

geologic history during the Early Cretaceous. In the Blake Plateau, Lower Cretaceous clastic sediments are insignificant. Carbonate sequences comprise the section (Sheridan et al., 1978). Sheridan et al. (1978) propose that a carbonate reef bank, of a probable Jurassic-? Early Cretaceous age, acted as a barrier to deposition of clastic sediments on the continental shelf in the Atlantic region. At some point in time enough clastics were supplied to the Baltimore Canyon and Scotian Shelf, so that the barrier was overwhelmed and buried beneath the shelf. On the Blake Plateau, perhaps insufficient clastics were being shed from the continent to bury the reef bank so that only carbonate was deposited. Seismic evidence appears to show the existence of a carbonate reef in the Baltimore Canyon (Sheridan et al., 1978).

#### Neocomian Stagnation

Another hypothesis which can be viewed in a regional sense is the suggestion that periods of ocean-wide stagnation occurred during the Cretaceous (Ryan and Cita, 1977). In the Neocomian a period of stagnation apparently occurred in the North Atlantic. It is suggested from the presence of organic rich shales in DSDP sites 101 and 105 (in Ryan and Cita, 1977; fig. 1). Stagnation is thought to have resulted from deposition of sedimentary layers rich in organic content (saposels), mainly in the deep ocean basins, but there is speculation that the oxygen minimum zone extended onto the shelf. An oxygen minimum situation could be created by



restricting abyssal circulation within the narrow seaway of the North Atlantic during Early Cretaceous time. This would result in the depletion of oxygen from the bottom water and an increase in carbon (Ryan and Cita, 1977).

An extensive cycle of stagnation apparently occurred in the latest Barremian (in Ryan and Cita, 1977; fig. 1). In the Barremian fauna of the B-2 well, many of the specimens of Gavelinella and Epistomina are pyritized; and indication of reducing conditions. It was pointed previously that more open marine conditions may have existed in this interval. But the fact that foraminifera were living in this environment is an indication that the oxygen minimum zone did not extend over the shelf. The pyritization is probably the result of post-depositional diagenesis.

#### Comparison to the Vail Curve

In the Upper Jurassic Lower Cretaceous section of the B-2 well, two marine and three nonmarine intervals are present (Fig. 8a). A correlation with the curve of Vail et al. (1977) which shows global cycles of sea level fluctuations is possible (Fig. 8b). The nonmarine interval below the Jurassic marine interval in the Upper Jurassic correlates to the regressive trend shown on the curve (Fig. 8). The following marine interval compares well with the curve where a general rising of sea level is shown in Tithonian-Berrisian time (Fig. 8). A regression occurs in the curve of Vail et al. at the base of the Valanginian. This event corresponds to the second nonmarine interval in the basal part of

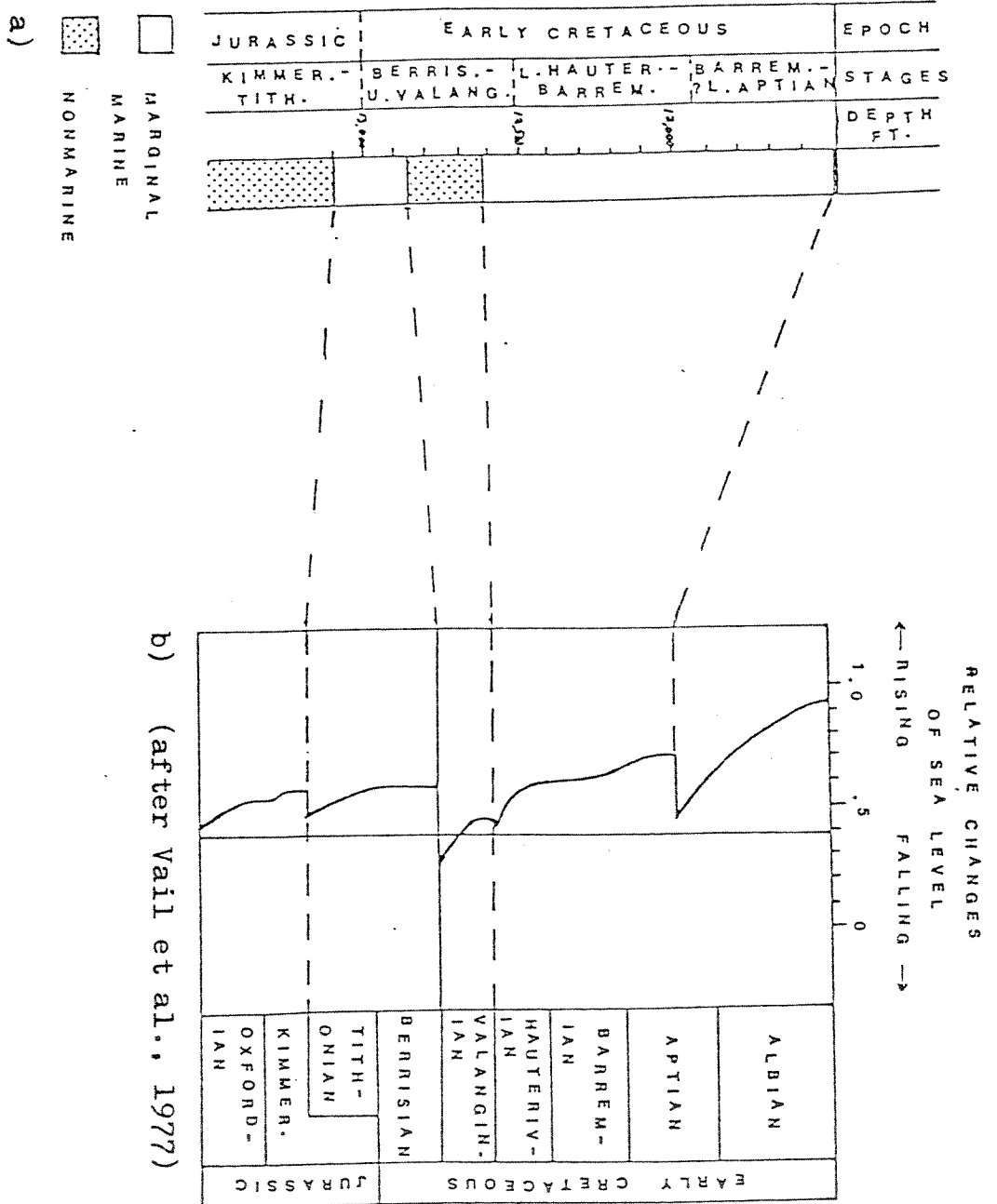


Figure 8. Correlation of marine cycles of COST B-2 well to the Vail et al. (1977) curve showing global cycles of sea level fluctuation.

the Lower Cretaceous section in the B-2 well. The general rising of sea level in the Neocomian on the curve correlates well with the upper marine interval in the B-2 well. The nonmarine interval in the B-2 well above 11,510 feet may be indicative of the Aptian regressive cycle of the curve of Vail et al., but more precise paleontological age dating of this interval is not yet available.

### BIOGEOGRAPHY

The continents during the Upper Jurassic and Lower Cretaceous were much closer together, so it can be assumed that continental shelves were more continuous and widespread (Fig. 9a). This may have made it possible for various species of benthonic foraminifera to attain a cosmopolitan distribution and would help explain the occurrence of the same species of foraminifera in the New Jersey Continental Shelf, in Europe, Eastern Canada, Trinidad, and other areas of the world.

Gordon (1970) and Aubert and Bartenstein (1976) show the existence of various realms in the oceans of the world during Late Jurassic-Early Cretaceous time (Fig. 9a). The realms are classified as 1) temperate or boreal and 2) tethyan. The temperate realm is divided into a northern realm and a southern realm. A species can be found throughout the various realms, but its stratigraphic range within each realm may be different. A case in point is Lenticulina nodosa nodosa. In the northern temperate realm it ranges from Upper Berrisian-Lower Hauterivian. In the tethyan realm it has a longer stratigraphic range; Upper Berrisian-Upper Aptian (Aubert and Bartenstein, 1976). In the B-2 well, L. nodosa nodosa occurs in the Barremian assemblage (see biostratigraphy). Aubert and Bartenstein (1976) show the area where the B-2 well was drilled as part of the northern temperate realm. The presence of L. nodosa nodosa in the B-2 well indicates that the boundary between the

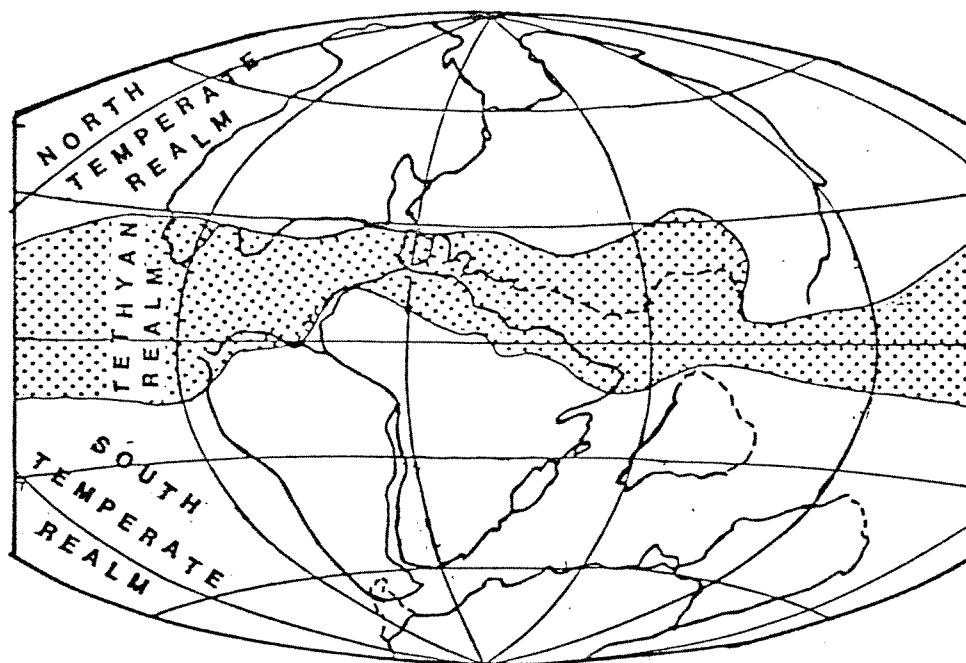


Figure 9a. Position of continents and oceanic realms during Upper Jurassic-Lower Cretaceous time (after Aubert and Bartenstein, 1976).

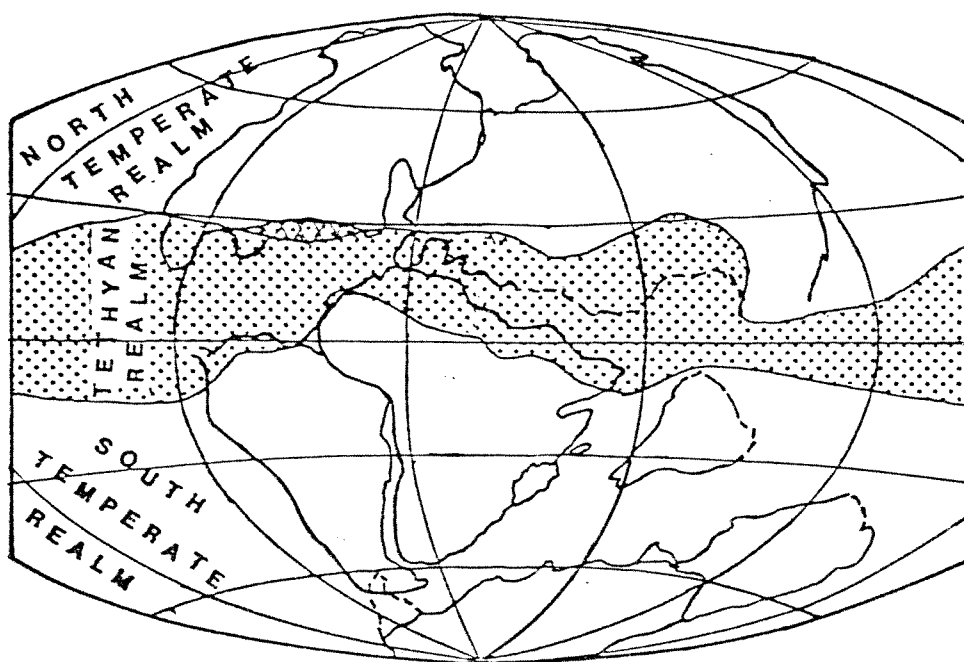


Figure 9b. Revision of paleogeographic map showing the extension of the Tethyan realm to include the COST B-2 well site (after Aubert and Bartenstein, 1976).

northern temperate realm lay further north of the position shown in the above authors paleogeographic map (Fig. 9b). The fact that Neocomian foraminifera have not been recognized in this area before, may account for this discrepancy. Eastern Canada at first was included as part of the northern temperate realm (Bartenstein, 1974), but with the subsequent discovery of species characteristic of the tethyan realm, it has since been placed as part of the tethyan realm as is shown in Bartenstein (1976c) and Aubert and Bartenstein (1976).

Other species of Barremian foraminifera, as previously mentioned, also have a widespread distribution. They include G. barremiana, E. caracolla caracolla, and E. ornata. These species are significant, because in a series of papers by Bartenstein (1976a,b,c) he establishes their utility in zonation schemes for correlation of the Lower Cretaceous on a worldwide basis (in particular, the Barremian sections). A widespread distribution is one of the criteria that is used in establishing index foraminifera and these particular examples fit the description fairly well. As more information is compiled on diagnostic benthonic foraminifera worldwide, they will become increasingly important in terms of zonation of the Lower Cretaceous.

The importance in the discovery of Lenticulina nodosa gibber has been emphasized previously. This Upper Valanginian-Lower Hauterivian species has only been identified to date in Tierra del Fuego, South Africa, and Madagascar; all

which are located in the southern temperate realm. With the discovery of this species in the B-2 well its paleogeographic range has been greatly expanded to include the tethyan realm. This short ranging species may well become an index for the Upper Valanginian-Lower Hauterivian as more information from other localities becomes available.

The two Upper Jurassic species identified in the B-2 well, E. parastelligara and E. uhligi, also seem to have a fairly wide distribution. They have been reported throughout Europe and along the Atlantic margin (Luterbacher, 1972). Epistomina uhligi has also been reported on the Canadian Shelf, but E. parastelligara has not. This suggests that the biogeographic limits of E. parastelligara did not extend into the Canadian Shelf area. A possible reason for this may be an environmental factor, such as depth or salinity.

Table 1 summarizes the distribution of the various assemblages at different localities worldwide. The fact that many have a cosmopolitan distribution increases their value as index species. In particular, note the distribution of L. nodosa gibber and its absence in the other areas of the world.

TABLE 1

Biogeographic distribution of faunal assemblages

	<u>New Jersey</u>	<u>Blake Nose- Blake Plateau</u>	<u>Trinidad</u>	<u>Scotian Shelf</u>	<u>N.W. Europe</u>
<u>G. barremiana</u>	X	X	X	X	X
<u>E. caracolla</u> <u>caracolla</u>	X	X	X	X	X
<u>E. ornata</u>	X	X	X	X	X
<u>E. spinulifera</u>	X	X		X	X
<u>L. muensteri</u>	X	X	X		X
<u>L. nodosa nodosa</u>	X	X	X	X	X
<u>L. praegaultina</u>	X		X		X
<u>H. aequale</u>	X		X		X

	<u>New Jersey</u>	<u>Scotian Shelf</u>	<u>DSDP 105</u>	<u>N.W. Europe</u>	<u>Gorringer Bank</u>
<u>L. muensteri</u>	X	?	X	X	X
<u>L. nodosa gibber</u>	X				
<u>L. subalata</u>	X	?	X	X	X

	<u>New Jersey</u>	<u>Scotian Shelf</u>	<u>DSDP 105</u>	<u>N.W. Europe</u>	<u>Grand Banks</u>
<u>E. parastelligara</u>	X		X	X	
<u>E. uhligi</u>	X	X	X	X	X



### SUMMARY

In conclusion, the following statements can be made concerning this study:

1) Foraminiferal faunal assemblages characteristic of Barremian (G.barremiana-L.sigali zone), Upper Valanginian-Lower Hauterivian, and Kimmeridgian-Tithonian ages are recognized in the Upper Jurassic-Lower Cretaceous interval of the B-2 well.

2) The boundry between the Upper Jurassic-Lower Cretaceous is placed at 13,000 feet and is in agreement with the conclusion of Swain (1978).

3) The Upper Jurassic-Lower Cretaceous sediments from 11,510-13,100 feet were deposited in a marginal marine setting which included intervals of nonmarine deposition. There is good agreement with the global sea level curve of Vail et al. to explain this. For example, the regression at the base of the Valanginian can be correlated to the second nonmarine interval.

4) All the faunal assemblages show biogeographic extent worldwide, which makes them useful for biostratigraphy. The most significant find is the discovery of Lenticulina nodosa gibber, a species which was previously reported only from the southern temperate realm. The occurrence of Lenticulina nodosa nodosa shows that the area of the B-2 well lay within the boundries of the tethyan realm during Early Cretaceous time.

Finally, it must be pointed out that this region is now undergoing extensive exploration and as more research is accomplished, a better understanding of the Late Jurassic-Early Cretaceous events will be realized.

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## SYSTEMATIC PALEONTOLOGY

Order FORAMINIFERIDA Eichwald, 1830

Family LITUOLIDAE de Blainville, 1825

Genus HAPLOPHRAGMOIDES Cushman, 1910

Haplophragmoides concavus (Chapman)

pl. 1, fig. 1

Trochammina concava n. sp. Chapman, 1892, J. Roy. Microscop. Soc. London, Ser.C, vol. 12, p. 327, pl. 6, fig. 4.  
Haplophragmoides concavus Bartenstein and Bolli, 1973, Eclog. Geol. Helv., vol. 66, no. 2, p. 393, pl. 3, fig. 2-26.

Remarks: Haplophragmoides concavus is a long ranging species and is the most abundant species observed in the Upper Jurassic-Lower Cretaceous interval of the B-2 well.

Haplophragmoides cushmani Loeblich and Tappan

pl. 1, fig. 4

Haplophragmoides D-5 (pars) Hecht, 1938, Senckenbg. Natf. Ges., Abh. 443, pl. 10a (II, pars); pl. 10b, fig. 63; pl. 11a (III, pars); pl. 12b, fig. 61-68.  
Haplophragmoides cushmani Loeblich and Tappan, 1946, J. Paleo., vol. 20, no. 3, p. 244, pl. 35, fig. 4.

Remarks: The only occurrence of H. cushmani is at sample interval 12,250-80 feet. It occurs in association with Haplophragmoides concavus, Ammobaculites torosus, and Haplophragmium aequale.

Genus AMMOBACULITES Cushman, 1910

Ammobaculites torosus Loeblich and Tappan

pl. 1, fig. 5

Ammobaculites torosus n. sp. Loeblich and Tappan, 1949, J. Paleo., vol. 23, no. 3, p. 251, pl. 46, fig. 6-7.  
 Bartenstein and Bolli, 1973, Eclog. Geol. Helv., vol. 66, no. 2, p. 394, pl. 1, fig. 42-56.

Remarks: The early portion of the test is close coiled and involute, usually four chambers, with the later portion becoming uniserial. The occurrence of A. torosus is rare.

Ammobaculites sp. A

pl. 1, fig. 6

Remarks: Early portion of the test is close coiled and involute. Later portion becomes uniserial. Specimens are similar to the species Ammobaculites goodlandensis, but do not have as many chambers in the last whorl. Poor preservation makes identification difficult too. Species occurrence is rare; found between 12,890-13,020 feet.

Ammobaculites sp. B

Remarks: Test small, early portion close coiled, later portion uniserial. Occurrence is very rare; only observed at sample interval 13,000-10 feet.

Genus HAPLOPHRAGMIUM Reuss, 1860

Haplophragmium aequale (Roemer)

pl. 1, fig. 2

Spirolina aequalis n. sp. Roemer, 1841, Verst. Norddeutsh Kreidegeb., Hannover, p. 98, pl. 15, fig. 3.

Haplophragmium aequale Bartenstein, 1952, Senckenbg., vol. 33, no. 4/6, p. 325, pl. 1, fig. 1,; pl. 2, fig. 17-26; pl. 3, fig. 1-6,; Maync, 1973, Initial Reports of DSDP, vol. 13, Washington (U.S. Gov't Printing Office), p. 1083, pl. 1, fig. 20-21.

Remarks: Maync (1973) states that H. aequale is an index form of the Hauterivian-Barremian. In the B-2 well, H. aequale is present in the Barremian assemblage.

Family TROCHAMMINIDAE Schwager, 1877

Genus TROCHAMMINA Parker and Jones, 1859

Trochammina globigeriniformis (Parker and Jones)

pl. 1, fig. 3

Lituola nautiloidea var. globigeriniformis n. var.

Parker and Jones, 1865, Phil. Trans. Roy. Soc. of London, vol. 155, p. 407, pl. 15, fig. 46-47.

Trochammina globigeriniformis Cushman, 1946, U.S.G.S. Prof. Paper 206, p. 51, pl. 15, fig. 8,10,11; Maync, 1973, Initial Reports of DSDP, vol. 13, Washington (U.S. Gov't Printing Office), p. 1084, pl. 1, fig. 27-28.

Remarks: The stratigraphic range of T. globigeriniformis is long; Liassic-Recent. In the B-2 well, this species occurs in the upper part of the Barremian interval, between 11,590-11,860 feet.

Family MILIOLIDAE Ehrenberg, 1839

Genus QUINQUELOCULINA d'Orbigny, 1826

Quinqueloculina sp. A

Remarks: A single, recrystallized specimen at sample interval 11,510-48 feet occurs in the Lower Cretaceous interval of the B-2 well. It may be significant because Miliolids generally indicate shallow water conditions.

Family NODOSARIIDAE Ehrenberg, 1838

Genus LENTICULINA Lamarck, 1804

Lenticulina acuta (Reuss)

Cristellaria acuta Reuss, 1860, Westph. Kreide, p. 213, pl. 10, fig. 3.

Lenticulina acuta Bartenstein and Bolli, 1973, Eclog. Geol. Helv., vol. 66, no. 2, p. 400, pl. 4, fig. 13-22.

Remarks: One specimen of L. acuta occurs at sample interval 11,740-70 feet. The specimen compares favorably to those figured in Bartenstein and Bolli (1973).

Lenticulina muensteri (Roemer)

pl. 2, fig. 8

Robulina muensteri Roemer, 1841, Verst. Nordd. Kreidegeb., p. 98, pl. 15, fig. 30.

Robulus muensteri Cushman, 1946, U.S.G.S. Prof. Paper 206, p. 53, pl. 17, fig. 3-9.

Lenticulina muensteri Bartenstein, Bettenstaedt, and Bolli, 1957, Eclog. Geol. Helv., vol. 50, pt. 1, pl. 2, fig. 54; pl. 3, fig. 80-81.

Remarks: Lenticulina muensteri is a long ranging species and one which shows a lot of intraspecific variation. It occurs throughout the Upper Jurassic-Lower Cretaceous interval of the B-2 well.



Lenticulina nodosa gibber (Espitalie and Sigal)

pl. 3, fig. 9

Astacolus gibber n. sp. Espitalie and Sigal, 1963, Majunga: 36, pl. 13, fig. 8-11.

Lenticulina nodosa gibber Bartenstein, 1974, Eclog. Geol. Helv., vol. 67, no. 3, p. 550, pl. 2, fig. 7-8, 13-15; text fig. 1,3,6; Aubert and Bartenstein, 1976, Bull. Centre Rech. Pau-SNPA, vol. 10, no. 1, pl. 2, fig. 1-3.

Remarks: Early portion of test planispiral with later portion in a uniserial stage. There are nine chambers in the last whorl, sutures are raised, and the periphery is marked by sharp nodes; from which the name is derived.

Lenticulina nodosa nodosa (Reuss)

pl. 3, fig. 10

Robulus nodosa Reuss, 1863, Hils. u. Gault: 78, pl. 9, fig. 6.

Lenticulina nodosa nodosa Bartenstein, 1974, Eclog. Geol. Helv., vol. 67, no. 3, p. 572, pl. 1, fig. 3-17; pl. 2, fig. 5-6, 9-12, 16-17; text fig. 1-7; Aubert and Bartenstein, 1976, Bull. Centre Rech. Pau-SNPA, vol. 10, no. 1, pl. 1, fig. 1-2, 4-13, 17-21; pl. 2, fig. 13-15, 20-24; pl. 3, fig. 6-8; pl. 4, fig. 1, 4-8.

Remarks: Test is planispiral, ten chambers in the last whorl, sutures raised, and periphery is marked by prominent nodes. The main occurrence of L. nodosa nodosa is in sample interval 11, 740-70 feet.

Lenticulina praegaultina Bartenstein, Bettenstaedt, and Bolli

pl. 3, fig. 7-8

Lenticulina praegaultina Bartenstein, Bettenstaedt, and Bolli, 1957, Eclog. Geol. Helv., vol. 50, pt. 1, p. 24, pl. 3, fig. 48; pl. 4, fig. 63-65; Maync, 1973, Initial Reports of DSDP, vol. 13, Washington (U.S. Gov't Printing Office), p. 1087, pl. 2, fig. 4.

Remarks: Lenticulina praegaultina is characterized by a broad peripheral keel, about ten chambers in the last whorl which are separated by translucent sutures, and the umbilicus which is largely filled with calcite. The species has a Hauterivian-Barremian range.

Lenticulina roemeri (Reuss)

Cristellaria roemeri Reuss, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, p. 75, pl. 8, fig. 9.  
Lenticulina roemeri Bartenstein, Bettenstaedt, and Bolli 1957, Eclog. Geol. Helv., vol. 50, pt. 1, pl. 4, fig. 93.

Remarks: Lenticulina roemeri is characterized by many chambers, up to 13, and a smooth wall. This species only occurs in sample interval 11,680-710 feet.

Lenticulina subalata (Reuss)

pl. 2, fig. 7

Cristellaria subalata Reuss, 1854, Ostalpen, p. 68, pl. 25, fig. 13.  
Lenticulina subalata Bartenstein, Bettenstaedt, and Bolli, 1957, Eclog. Geol. Helv., vol. 50, pt. 1, pl. 4, fig. 92; Luterbacher, 1972, Initial Reports of DSDP, vol. 11, Washington (U.S. Gov't Printing Office), p. 582, pl. 3, fig. 9-10.

Remarks: Like L. muensteri, L. subalata is a long ranging species and exhibits much intraspecific variation. It occurs throughout the Upper Jurassic-Lower Cretaceous interval of the B-2 well.

Lenticulina sp. A

Remarks: This specimen is characterized in having an elongate, biconvex test, large central boss, and 9 chambers in the last whorl. This species is similar to Lenticulina sp. 1 figured in Bartenstein et al. (1957). The only occurrence of this species is at sample interval 11,740-70 feet.

Family ANOMALINIDAE Cushman, 1927

Genus GAVELINELLA Brotzen, 1942

Gavelinella barremiana Bettenstaedt

pl. 1, fig. 7-9

Gavelinella barremiana Bettenstaedt, 1952, Senckenbg., vol. 33, no. 4/6, p. 275, pl. 2, fig. 26-29; Bartenstein, Bettenstaedt, and Bolli, 1957, Eclog. Geol. Helv., vol. 50, pt. 1, pl. 6, fig. 168-169; Gradstein, 1978, Initial Reports of DSDP, vol. 44, Washington (U.S. Gov't Printing Office), p. 674, pl. 1, fig. 10; pl. 6, fig. 14-17.

Remarks: Gavelinella barremiana occurs between sample intervals 11,860-11,920 feet in the B-2 well. The species has a cosmopolitan distribution, which makes it valuable for biostratigraphy. On the Scotian Shelf and Grand Banks it is used as a Barremian-Lower Aptian marker (Gradstein, 1978).

Gavelinella cf. intermedia (Berthelin)

Remarks: A specimen similar to G. intermedia is present in sample interval 11,740-70 feet. The specimen is badly preserved but is similar to the one shown in Gradstein, 1978 (pl. 1, fig. 9). G. intermedia is found in the Blake Plateau in Hole 391C in the G. barremiana-L. sigali zone.

Family CERATOBULIMINIDAE Cushman, 1927

Genus EPISTOMINA Terquem, 1883

Epistomina caracolla caracolla (Roemer)

pl. 2, fig. 1-3

Gyroidina caracolla Roemer, 1841, Verst. Nordd. Kreidegeb., p. 97, pl. 15, fig. 22.

Epistomina caracolla Ten Dam, 1948, J. Paleo., vol. 22, no. 2, p. 187, pl. 32, fig. 17, 20-21.

Epistomina (Hoglundina) caracolla caracolla Bartenstein, Bettenstaedt, and Bolli, 1957, Eclog. Geol. Helv., vol. 50, pt. 1, pl. 4, fig. 113-114; pl. 5, fig. 142.

Remarks: The species is characterized by a biconvex test, 9-10 chambers in the last formed whorl, and a prominent umbo on the umbilical side. Epistomina caracolla caracolla is the most abundant epistominellid in the Upper Jurassic-Lower Cretaceous interval of the B-2 well.

Epistomina chapmani (Parker and Jones)

pl. 2, fig. 6,9

Rotalia elegans Parker and Jones, 1860, Qly. J. Geol. Soc., vol. 16, pl. 20, fig. 46.

Epistomina chapmani Ten Dam, 1948, Rev. de Instit. Franc. Petro. Annal. des Combust. liquides, vol. 3, no. 6, p. 166, pl. 1, fig. 5; Gradstein, 1978, Initial Reports of DSDP, vol. 44, Washington (U.S. Gov't Printing Office), p. 673, pl. 8, fig. 5.

Remarks: Epistomina chapmani is similar to E. caracolla caracolla except it has a fewer number of chambers and lacks an umbo. The occurrence of E. chapmani in the B-2 well is in the upper part of the Lower Cretaceous interval.

Epistomina cf. hechti

Remarks: Both specimens occur at sample interval 12,760-70 feet. They appear similar to Epistomina hechti but are too poorly preserved and broken up to be compared to this species.

Epistomina ornata (Roemer)

pl. 2, fig. 4-5

Truncatulina ornata Roemer, 1841, Verst. Nordd. Kreidegeb., p. 98, pl. 15, fig. 25.

Epistomina ornata Ten Dam, 1948, J. Paleo., vol. 22, no. 2, p. 188, pl. 32, fig. 16, 18-19; Bartenstein, Bettenstaedt, and Bolli, 1957, Eclog. Geol. Helv., vol. 50, pt. 1, pl. 4, fig. 115; pl. 5, fig. 143; Gradstein, 1978, Initial Reports of DSDP, vol. 44, Washington (U.S. Gov't Printing Office), p. 673, pl. 4, fig. 11.

Remarks: Epistomina ornata occurs in sample interval 11,890-11,950 feet in the B-2 well. The species is characterized by strongly raised sutures and 9-10 chambers in the last formed whorl. Epistomina ornata is a diagnostic species for the Barremian.

Epistomina parastelligara (Hofker)

pl. 3, fig. 1-3

Brotzenia parastelligara Hofker, 1954, Palaeontographica, vol. 105, pt. A, p. 180, text fig. 4-6.

Epistomina parastelligara Said and Baraket, 1958, Micropaleo., vol. 4, no. 3, p. 267, pl. 3, fig. 43; pl. 5, fig. 35.

Epistomina sp. ex. gr. (Brotzenia) parastelligara Luterbacher, 1972, Initial Reports of DSDP, vol. 11, Washington (U.S. Gov't Printing Office), p. 584, pl. 4, fig. 17-19.

Remarks: Epistomina parastelligara occurs between the interval 13,040-13,080 feet of the B-2 well. The test of the species are biconvex; the spiral side being more convex than the umbilical side; and there are 7-8 chambers in the last formed whorl. The test has a star-like appearance, hence the species name.

Epistomina cf. spinulifera

Remarks: Both specimens are broken and poorly preserved but retain enough morphology to resemble E. spinulifera. The most characteristic features are the strongly raised sutures and rounded periphery. The occurrence of the specimens are at 11,860-11,890 feet.

Epistomina uhligi (Uhlig)

pl. 3, fig. 4-6

Epistomina stelligara Uhlig, 1883, Jb. K. K. Geol. Reichsanst., vol. 33, p. 770, pl. 7, fig. 10; pl. 8, fig. 1-3.

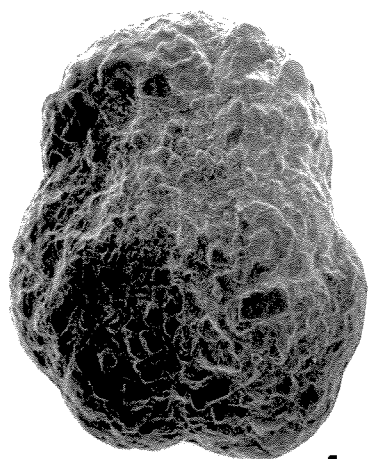
Epistomina uhligi Gradstein, 1978, J. Foram. Res., vol. 8, no. 2, pl. 1, fig. 2.

Remarks: The first appearance of E. uhligi is at 13,000 feet, hence the placement of the Upper Jurassic-Lower Cretaceous boundary at this interval. The species is characterized by a strongly biconvex test, particularly the umbilical side, and 9-10 chambers in the last formed whorl.

Epistomina uhligi occurs in the Upper Jurassic of the Scotian Shelf and the Grand Banks (Gradstein, 1977, 1978).

## Explanation to Plate 1

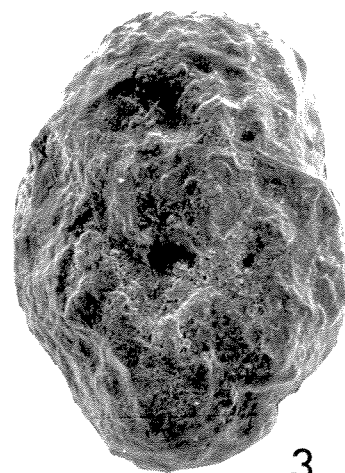
- Figure 1. - Haplophragmoides concavus (Chapman). From COST B-2: 11,740-70 feet, side view, 40X.
2. - Haplophragmium aequale (Roemer). From COST B-2: 11,920-50 feet, side view, 40X.
3. - Trochammina globigeriniformis (Parker and Jones). From COST B-2: 11,650-80 feet, umbilical view, 108X.
4. - Haplophragmoides cushmani Loeblich and Tappan. From COST B-2: 12,250-80 feet, side view, 72X.
- 5.- Ammobaculites torosus Loeblich and Tappan. From COST B-2: 12,250-80 feet, side view, 40X.
- 6.- Ammobaculites sp. A. From COST B-2: 13,020-30 feet, side view, 40X.
- 7-9.- Gavelinella barremiana Bettenstaedt.  
 7, from COST B-2: 11,860-90 feet, umbilical view, 128X; 8, from COST B-2: 11,860-90 feet, edge view, 120X; 9, from COST B-2: 11,860-90 feet, spiral view, 120X.



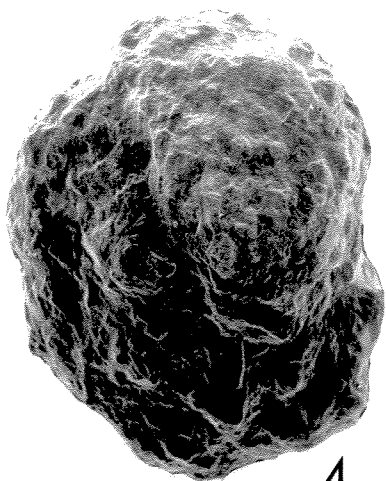
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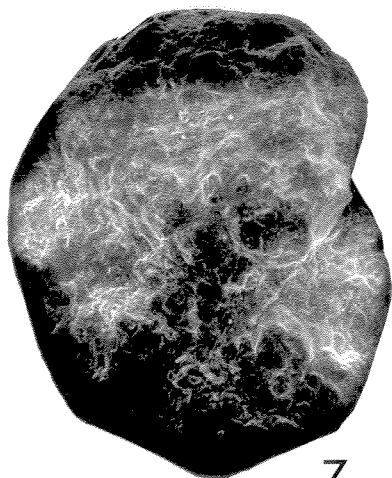
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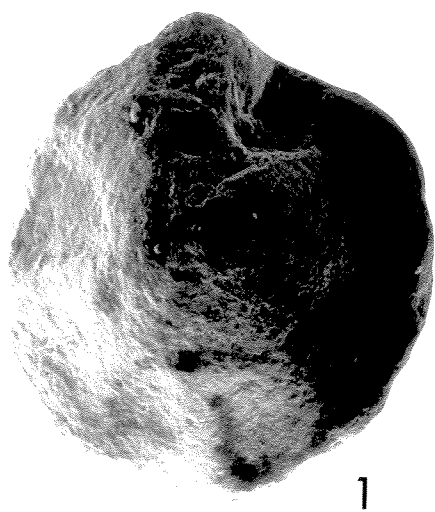


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## Explanation to Plate 2

- Figure 1-3. - Epistomina caracolla caracolla (Roemer).  
 1, from COST B-2: 12,310-40 feet, umbilical view, 147X; 2, from COST B-2: 12,310-40 feet, edge view, 114X; 3, from COST B-2: 12,310-40 feet, spiral view, 120X.
- 4-5. - Epistomina ornata (Roemer). 4, from COST B-2: 11,920-50 feet, spiral view, 122X; 5, from COST B-2: 11,920-50 feet, umbilical view, 106X.
- 6,9. - Epistomina chapmani (Parker and Jones). 6, from COST B-2: 11,890-920 feet, edge view, 120X; 9, from COST B-2: 11,890-920 feet, umbilical view, 72X.
7. - Lenticulina subalata (Reuss). From COST B-2: 11,920-50 feet, side view, 100X.
8. - Lenticulina muensteri (Roemer). From COST B-2: 11,860-90 feet, side view, 142X.

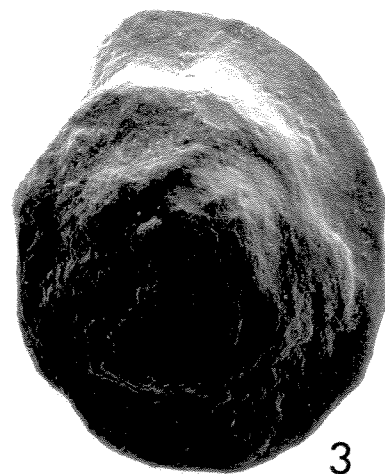




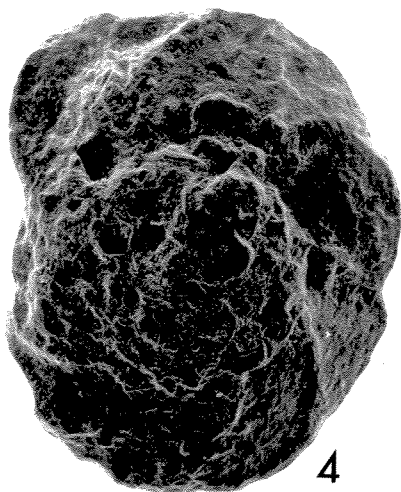
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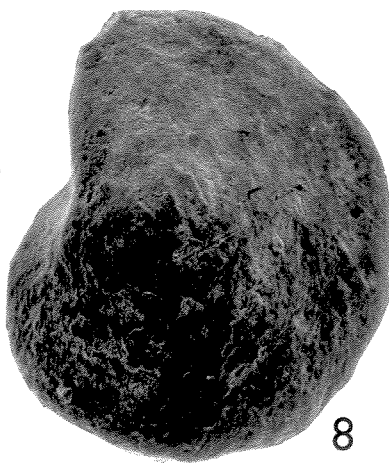
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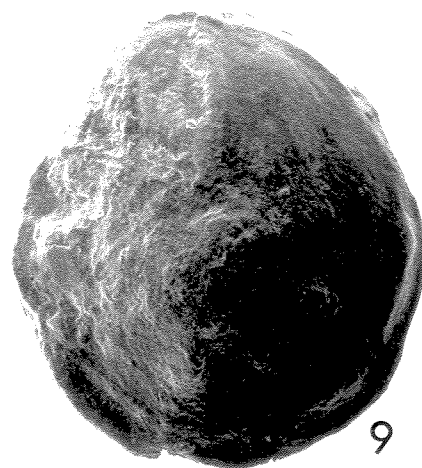
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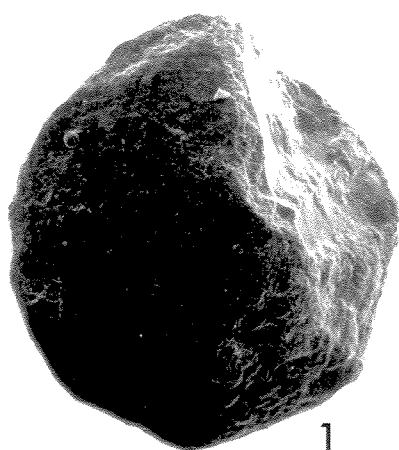
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## Explanation to Plate 3

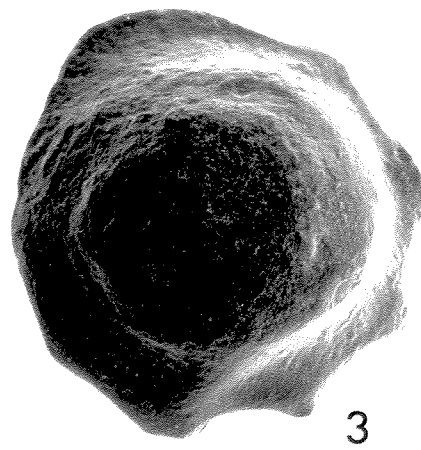
- Figure 1-3. - Epistomina parastelligara (Hofker).  
 from COST B-2: 13,070-80 feet, umbilical  
 view, 106X; 2, from COST B-2: 13,080-90  
 feet, edge view, 97X; 3, from COST B-2:  
 13,080-90 feet, spiral view, 106X.
- 4-6. - Epistomina uhligi (Uhlig). 4, from  
 COST B-2: 13,090-100 feet, umbilical  
 view, 138X; 5, from COST B-2: 13,090-100  
 feet, edge view, 123X; 6, from COST B-2:  
 13,090-100 feet, spiral view, 123X.
- 7-8. - Lenticulina praegaultina Bartenstein,  
 Bettenstaedt, and Bolli. 7, from COST B-2:  
 11,920-50 feet, side view, 90X; 8, from  
 COST B-2: 11,920-50 feet, edge view, 74X.
9. - Lenticulina nodosa gibber (Espitalie and  
 Sigal). From COST B-2: 12,520-50 feet,  
 side view, 106X.
10. - Lenticulina nodosa nodosa (Reuss). From  
 COST B-2: 11,740-70 feet, side view, 115X.



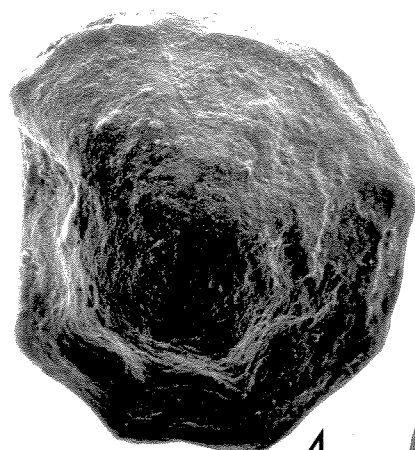
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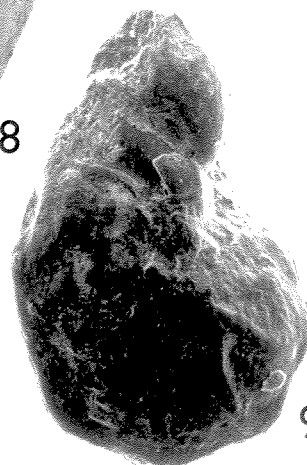
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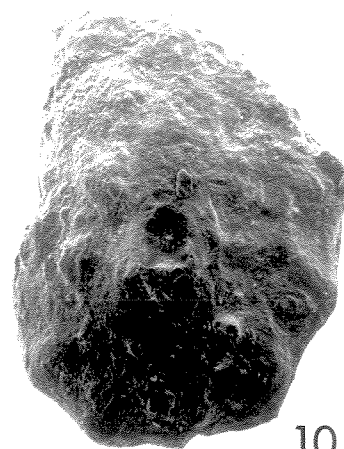
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## VITA

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