NOTICE CONCERNING COPYRIGHT RESTRICTIONS

BENTHIC FORAMINIFERA OF MIOCENE GEOPRESSURED STRATA OF SOUTHERN LOUISIANA

Barun K. Sen Gupta and Lori T. Lewis

Introduction

Only a meager amount of micropaleontological information has been published on the geopressured and adjacent hydropressured units of the Miocene subsurface column of southern Louisiana. The goal of the present investigation was to utilize quantitative techniques of micropaleontology in order to assess patterns of benthic foraminiferal distribution in these rocks and their paleoenvironmental significance. This report contains a summary of the results and the initial interpretations.

Area and samples

Samples were studied from cores and cuttings obtained from wells drilled by various oil companies in Vermilion, St. Mary, lower St. Martin, Assumption, Terrebonne, and LaFourche Parishes (Fig. 1); the subsurface Miocene section in this area is the thickest in southern Louisiana. The core samples from Vermilion Parish (Parcperdue field: Dow Chemical LeRoy Sweezy Well No. 1) were unsatisfactory in faunal quality; the critical shale intervals were poorly represented. Five core samples from a well in Bay Baptiste field (Terrebonne Parish), however, were found useful. The principal data set was obtained by studying cuttings from seven wells (Fig. 2), numbered as follows:

1: Exxon-Michel 1, Assumption Parish

2: Pan Am SB, St. Martin Parish

3: Calco Melacon, Terrebonne Parish

4: Sun Oil - Miami Corp., St. Mary Parish

FIGURE 1. A location map of the study area (heavy outline). Wells are located in St. Mary, lower St. Martin, Assumption, Terrebonne, and Lafourche parishes.

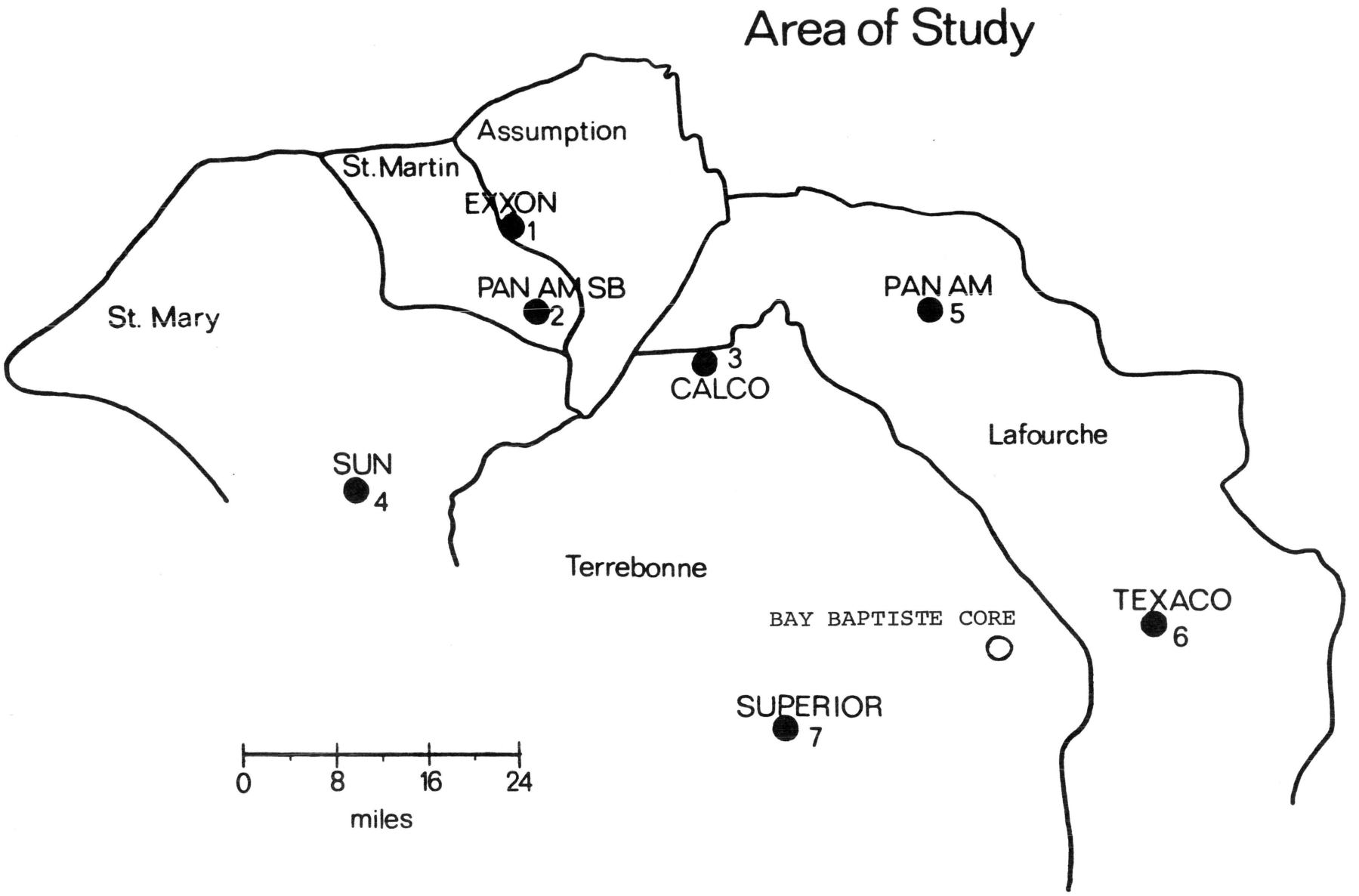


FIGURE 2. Enlarged map of the study area, with well locations.

5: Pan Am 2374, Lafourche Parish

6: Texaco LL&E, Lafourche Parish

7: Superior LL&E, Terrebonne Parish

The tops of the geopressured interval in these wells are at the following depths: well 1 - 11,700 ft.; well 2 - 14,200 ft.; well 3 - 13,200 ft.; well 4 - 16,100 ft.; well 6 - 12,250 ft.; well 7 -17,600 ft. No geopressure was recorded from well 5.

Samples were selected, on the basis of guide species of benthic foraminifera, so that a representative section of the middle and upper Miocene could be studied. These samples mainly represent shale units between stratigraphic depths of 9,000 and 17,000 feet. In all, 37 samples of well cuttings were studied; the faunal data from these samples form the basis of all numerical analyses in the present investigation.

Methods

Wherever possible, 300 or more specimens of benthic foraminifera were removed from the sample (or an aliquot), identified, and counted. Besides computing species percentages in each assemblage, 3 diversity measures were obtained. The parameter S, species richness or simple species diversity, is merely a count of the species present in a sample. The parameter J, the Pielou Index, is given by:

$$J = -\sum_{i=1}^{S} p_i \log p_i \; / \; \log S \; ,$$

where p_i is the proportion of the ith species. This is a measure of evenness and has a value of 1 when all species are present in equal

proportions. Finally, $\overline{H}$, the Shannon-Wiener information function, is given by:

$$\overline{H} = -\sum_{i=1}^{S} p_i \ln p_i$$

The measure incorporates both richness and evenness, and is more strongly influenced by species of average abundances than by extremely abundant or extremely rare species.

Furthermore, a Q-mode cluster analysis was performed, using as variables the 68 species or varieties whose frequencies equal or exceed 1% in one or more samples. The similarity coefficient was measured as a simple distance function, and the dendrogram was obtained by the average linkage method. An additional multivariate analysis is planned; this will be a factor analysis.

Biostratigraphic Background

The subsurface Miocene sediments of Louisiana are of varying thickness and generally consist of sandstones, siltstones, and shales. The stratigraphic zonation is usually based on selected species of benthic foraminifera, common in the shaly intervals. The intervening sandy intervals, generally representing a deltaic environment, are barren or nearly barren of foraminifera. The stratigraphic ranges of the guide species of benthic foraminifera (Fig. 3) vary from very short, as with Marginulina ascensionensis, to very long, as with Bolivina floridana, Cibicides floridanus, and Uvigerina lirettensis, three species that were present during most of the Miocene. For purposes of zonation and correlation, the critical information used by most industry paleontologists in the Gulf Coast is the

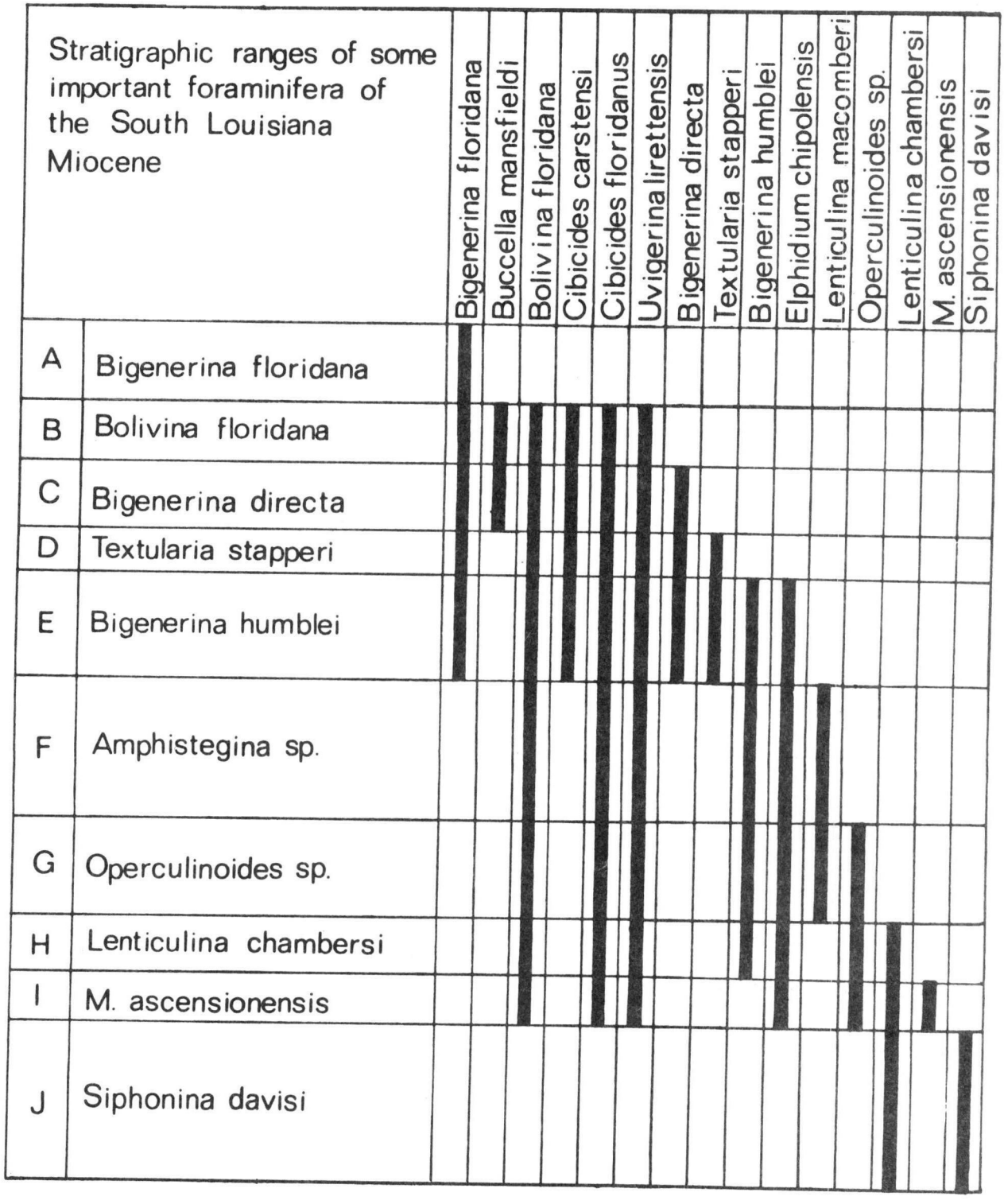


FIGURE 3. Stratigraphic range chart (modified from Rainwater, 1964).

first occurrence (i.e., the "top") of a species in cuttings, going downhole. A regional stratigraphic scheme based on benthic foraminifera is valuable, in spite of the extensive sandy units, because of the presence of many transgressive, marine, shaly beds in the overall regressive sections. The local ranges of key species of benthic foraminifera are restricted by the vertical limits of the transgressive marine units.

Figure 4 is a schematic cross-section of the Miocene transgressive units of southern Louisiana, with their marker foraminifera. The unfossiliferous, sandy, regressive beds in the section can be correlated on the basis of their positions relative to the marine units. Some of the transgressive units, such as the lower Miocene Siphonina davisi and Marginulina ascensionensis shales and the middle Miocene Bienerina humblei and Bigenerina directa shales, are particularly widespread in the Gulf Coast.

The correlation scheme followed in the study area is given in Figure 5. The zones from Siphonina davisi through Lenticulina chambersi are lower Miocene. Those from Operculinoides sp. through Bigenerina directa are middle Miocene. The two uppermost zones, Bolivina floridana and Bigenerina floridana, are upper Miocene.

Results

Composition of Assemblage:

In all, we identified seventy-three species or varieties of benthic foraminifera; some of the characteristic forms are illustrated in plates 1-3. Twenty-six taxa occur at the 10% frequency level, i.e., each of these constitutes 10% or more of the assemblage in one or more samples. These

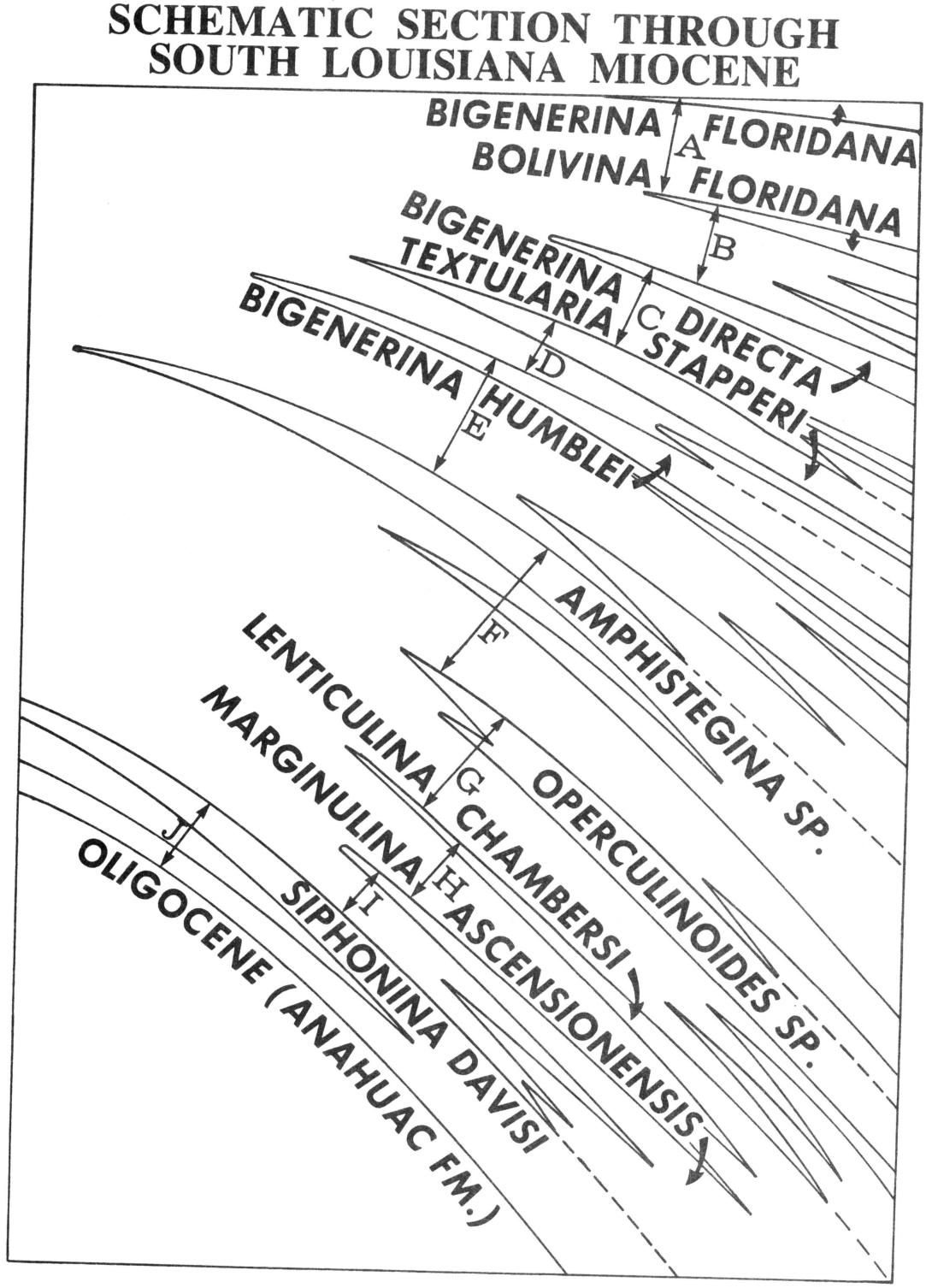


FIGURE 4. Schematic cross section, Miocene transgressive units.

LOUISIANA MIOCENE

CORRELATION CHART

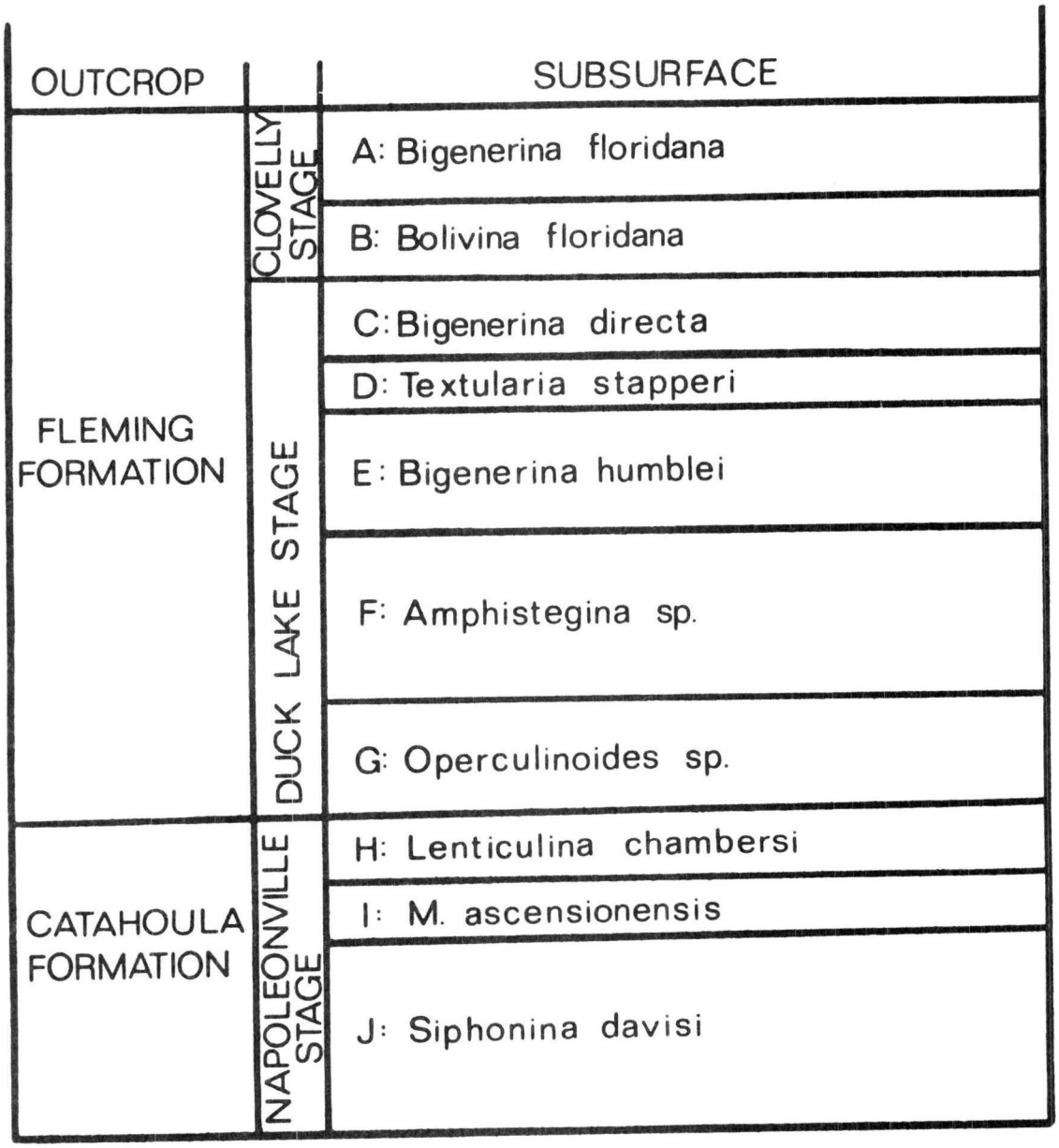


FIGURE 5. Correlation scheme used in the study area (modified from Rainwater, 1964).

taxa are listed below; asterisks indicate the sixteen taxa that are dominant in at least one sample.

Ammonia beccarii *

Bolivina floridana

Bolivina harangensis

Bulimina ovata

Buliminella curta

Cibicides carstensi *

Cibicides 1 *

Cyclammina sp. *

Discorbis crosbei

Discorbis gravelli

Eggerella sp. *

Florilus spissus *

Hanzawaia sp. cf. *H. concentrica* *

Lenticulina americana *

Lenticulina americana, var. *

Lenticulina chambersi *

Lenticulina jeffersonensis *

Lenticulina macomberi

Lenticulina 49 *

Miliolid, unnamed (sp. c) *

Nonionella auris *

Siphonina 1

Textularia articulata

Uvigerina howei *

Uvigerina lirettensis

Uvigerina stephensoni *

The sixty-eight taxa that occur at 1% frequency level are listed in Table 1. Their relative abundance in the samples are given in Tables 2-8.

Species Diversity

The diversity differences among samples are best seen with the Shannon-Wiener index. the curves for the 7 wells are shown in Figure 6. The Pielou Index J varies little among the samples, the range being 0.72 - 0.85; This represents a high equitability. The Shannon-Wiener index $\overline{H}$ shows a greater range, 1.5 - 2.5. Judging by modern analogs, the values represent low to moderate diversity for benthic foraminifera.

The samples from the Texaco LL&E well in southern Lafourche Parish have a diversity trend (Fig. 7) significantly different from that observed in samples from other wells. A sharp peak for S and $\overline{H}$ is observed at 12,500 ft.; J also reaches a high, although not the highest, value at this level. In contrast, particularly low values for all three diversity indices are observed at 10,398 ft. and 10,758 ft.

Cluster Patterns

The dendrogram produced by cluster analysis (Fig. 8) includes only two clusters, designated A and B, that contain more than three samples at a moderate level of similarity. These are essentially chronostratigraphic clusters. Cluster A consists of lower Miocene samples from two wells in the northern part of the study area. Five of these samples are from the Exxon-Michel well (Assumption Parish); the other is the lowermost sample from the Pan Am well (St. Martin Parish). All these samples are dominated by Lenticulina chambersi and Uvigerina howei. Cluster B consists of middle

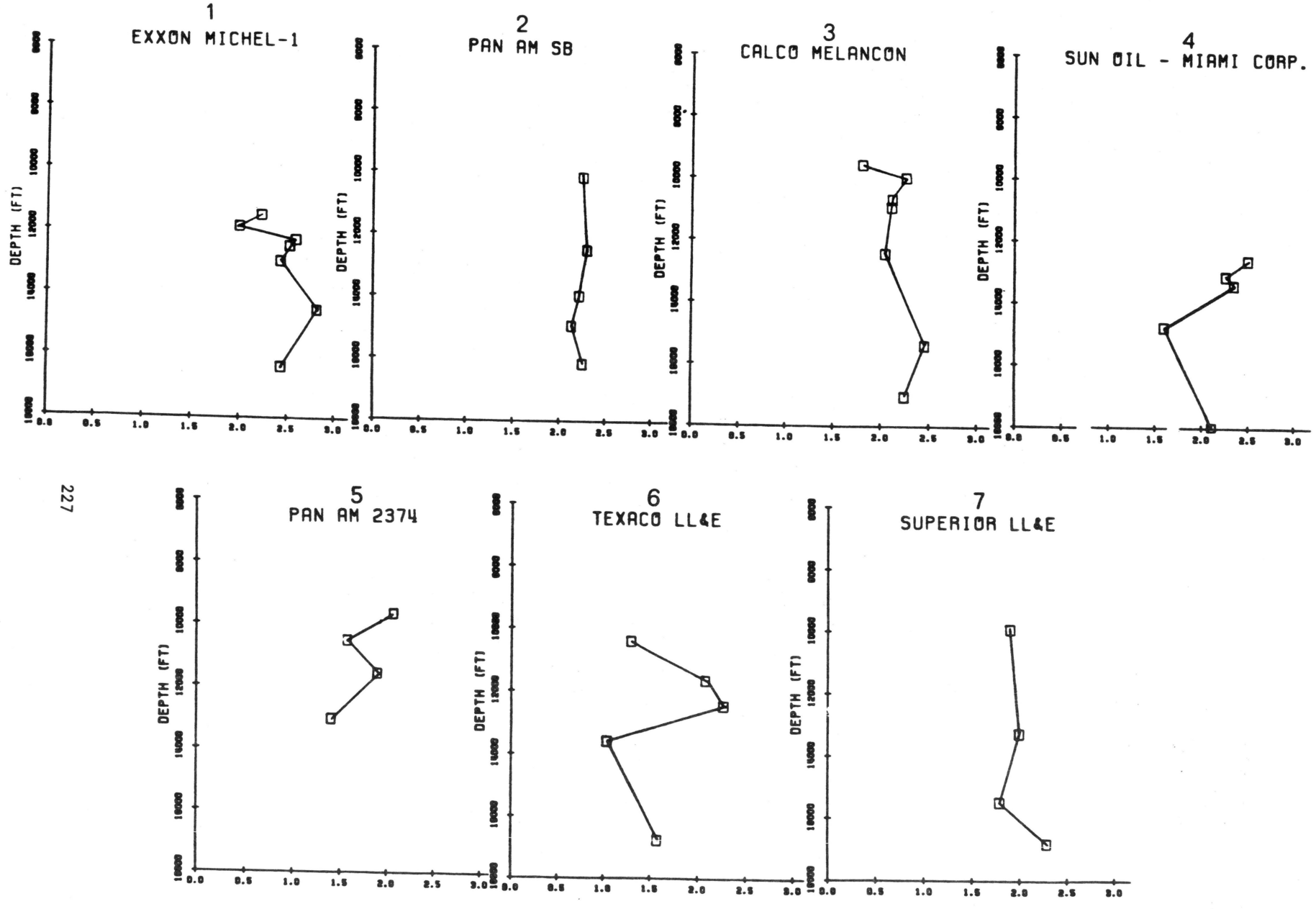


FIGURE 6. Graphs of the Shannon-Wiener indices for the seven study wells.

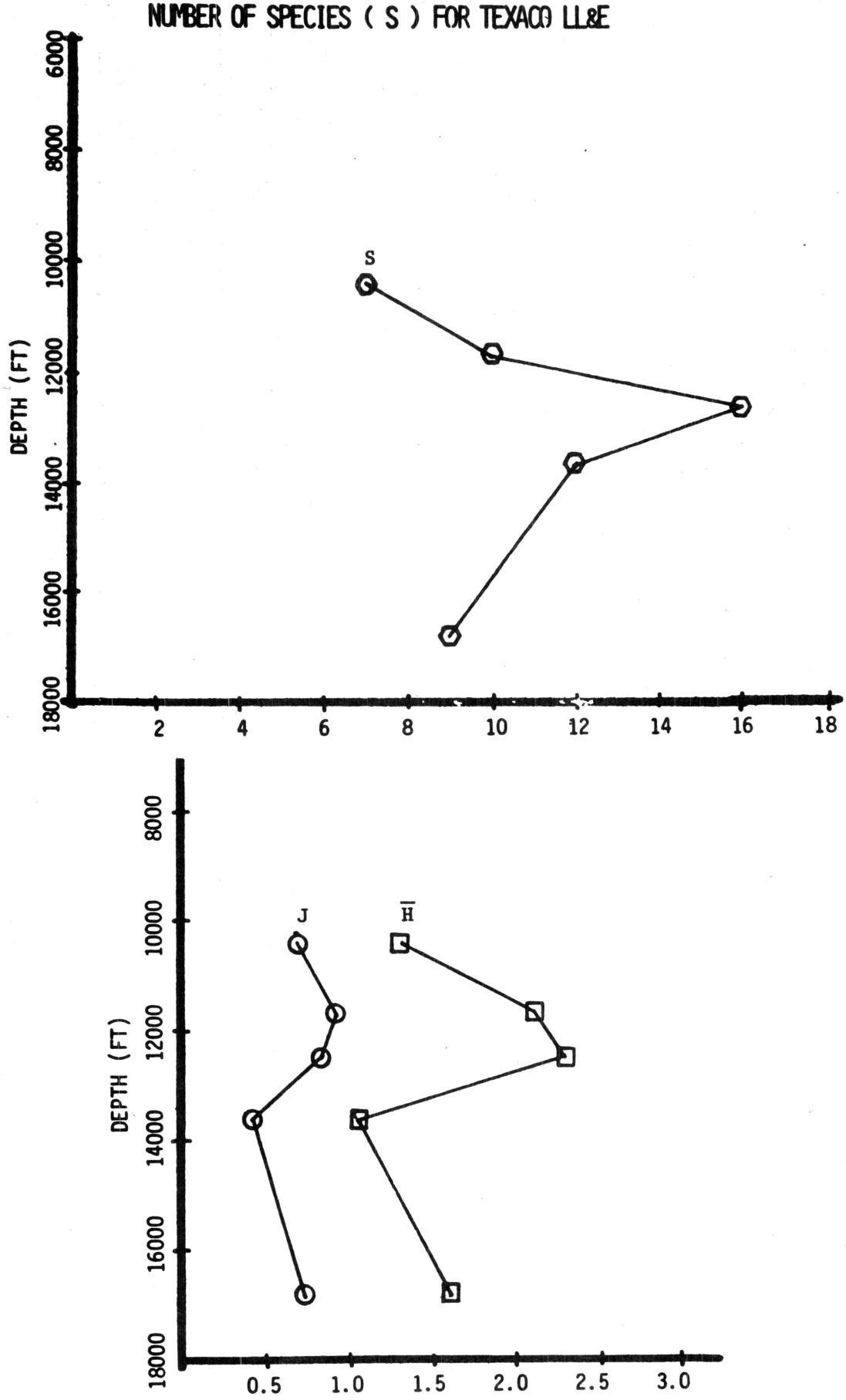


FIGURE 7 : Number of species (top), Pielou, and Shannon-Wiener Index for Tex. LL&E

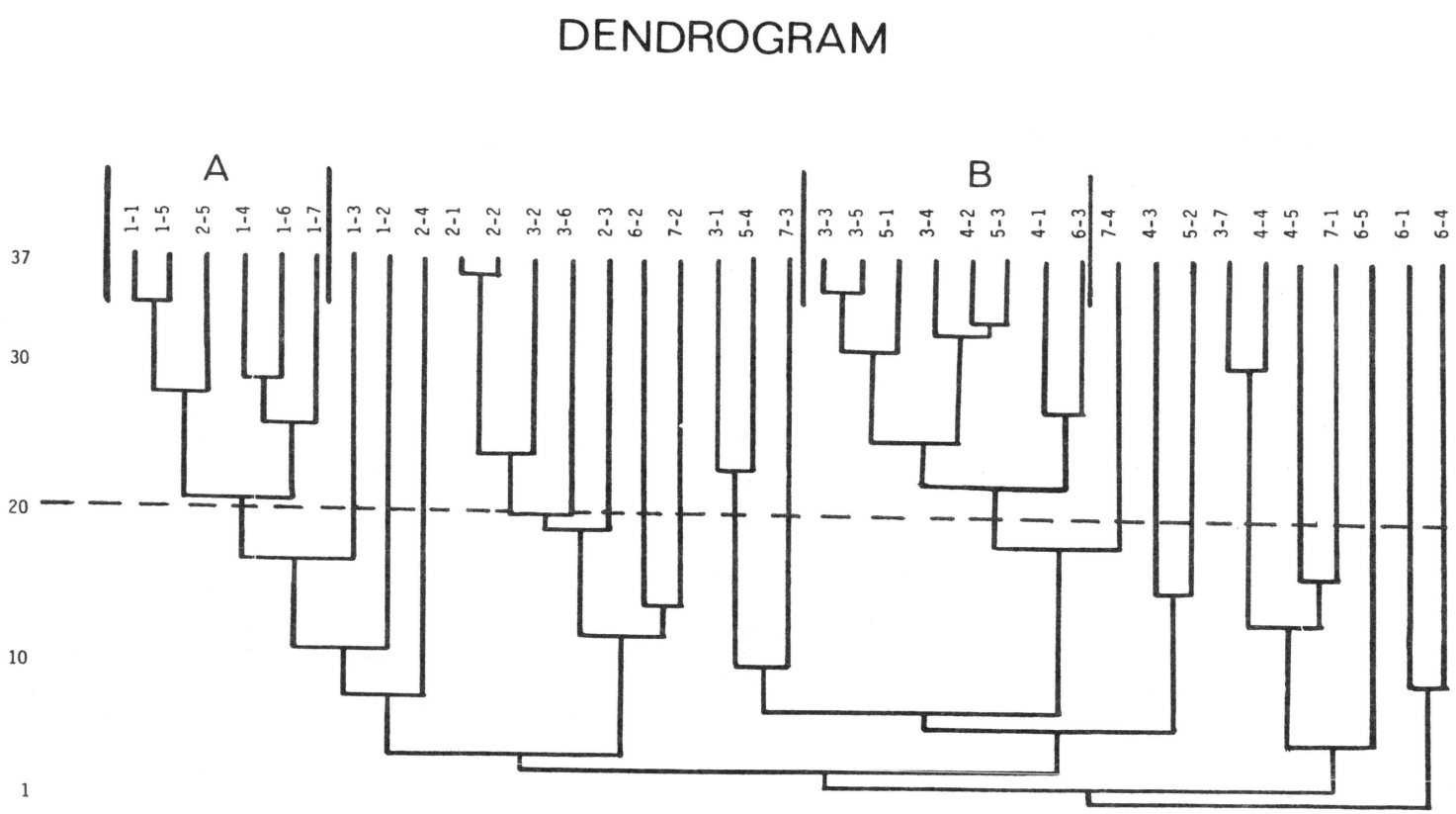


FIGURE 8. Dendrogram produced by Q-mode cluster analysis.

Miocene samples from the central and southern parts of the study area; the assemblages are dominated by Lenticulina americana var. and Uvigerina stephensoni. The chronostratigraphic control on clustering indicates that major faunal similarities and differences can be recognized in spite of downhole contamination of cuttings.

Bay Baptiste Core

In order to assess the magnitude of faunal contamination in well cuttings, five core samples from a well in the Bay Baptiste field (Fig. 2) were studied. The stratigraphic levels of the samples range from 8,000 to 15,000 ft. Overall, faunal compositions and dominance patterns were similar to those found in cuttings obtained from comparable depths in the Texaco LL&E and Superior LL&E wells, located on either side of the cored well. Thus, in our cutting samples, contamination has not obscured the significant faunal elements.

Summary of Paleoenvironment

Judging by modern trends of benthic foraminiferal distribution, the environments represented by the shale units range from the inner shelf to the shelf-edge or beyond. Overall, costate species of Uvigerina dominate about one-half of the samples. Similar species of Uvigerina (e.g., U. peregrina) are now characteristic of middle or lower slope habitats. The associated species in our samples, however, indicate that the characteristic environment of the Miocene uvigerinids of southern Louisiana was somewhat shallower -- outer shelf or upper slope. In contrast, a much shallower (and perhaps, brackish), inner neritic environment is represented by an Ammonia beccarii fauna, present in a few samples.

A so-called "deep water" facies of middle Miocene has been recognized in many Louisiana wells; the fauna is usually referred to as the "Harang fauna" (Pope and Smith, 1948). Several elements of this fauna, such as Lenticulina chambersi, Uvigerina howei, and Cyclammina sp., dominate many of our samples. Furthermore, assemblages of both of the major sample-groups (identified by cluster analysis), representing two different stratigraphic units, have similarities with this fauna, and record outer shelf or upper slope environments.

In the marine section, periodic shoaling of the environment is indicated by pronounced shifts in species dominance and also by diversity changes. For instance, extremely low values of species diversity are observed in the 10,398 ft. and 16,758 ft. samples from the Texaco LL&E well in southern Lafourche Parish. Ammonia beccarii is the unquestionable dominant species in these samples, constituting 42% of the older and 74% of the younger assemblage. The environment is interpreted to be nearshore, probably brackish.

As judged by the benthic foraminifera in our samples, no drastic change in the paleoenvironment can be related to the geopressure-hydropressure boundary in the wells.

Acknowledgment

We are deeply indebted to Shell Oil Company, New Orleans, and especially to Mr. Edward B. Picou, for making available the cutting samples and valuable stratigraphic information. We thank Mr. David Dow, Pennzoil Company, Lafayette, for providing the Bay Baptiste field core samples.

References

Pope, D. E., and Smith, D. J., 1948. The Harang fauna of Louisiana: Louisiana Geological Survey, Geological Bulletin No. 26, 80 p.

Rainwater, E. H., 1964. Regional stratigraphy of the Gulf Coast Miocene: Gulf Coast Association of Geological Societies, Transactions, v. 14, p. 81-124.

TABLE 1. Species List

No.	
1	*Ammonia beccarii*
2	*Bolivina floridana*
3	*Bolivina gladius*
4	*Bolivina harangensis*
5	*Bolivina marginata*
6	*Bolivina marginata multicostata*
7	*Bolivina perca*
8	*Bigenerina humblei*
9	*Bigenerina nodosaria directa*
10	*Buccella* sp.
11	*Bulimina marginata*
12	*Bulimina ovata*
13	*Buliminella curta*
14	*Cassidulina laevigata*
15	*Cassidulina subglobosa*
16	*Cibicides americana*
17	*Cibicides carstensi*
18	*Cibicides* 1
19	*Cibicides* 2
20	*Cyclammina* sp.
21	*Discorbis crosbei*
22	*Discorbis gravelli*
23	*Elphidium* 1
24	*Elphidium* 2

25	Elphidium 3
26	Eggerella sp.
27	Eponides 1
28	Eponides 2
29	Eponides 3
30	Florilus sp. cf. F. byramensis
31	Florilus spissus
32	Florilus 2
33	Fursenkoina pontoni
34	Gyroidina scalata
35	Gyroidina 1
36	Gyroidina 2
37	Gyroidina 3
38	Hanzawaia sp. cf. H. concentrica
39	Lenitculina americana
41	Lenticulina americana, var.
40	Lenticulina chambersi
42	Lenticulina hanseni
43	Lenticulina jeffersonensis
44	Lenticulina macomberi
45	Lenticulina vaughni
46	Lenticulina 49
47	Nonionella auris
48	Planulina palmerana
49	Reophax sp.
50	Siphonina davisi
51	Siphonina 1

52	*Textularia articulata*
53	*Textularia* 1
54	*Textularia* 2
55	*Textularia* 3
56	*Textularia* 4
57	*Textularia* 5
58	*Uvigerina howei*
59	*Uvigerina lirettensis*
60	*Uvigerina stephensoni*
61	miliolid a
62	miliolid b
64	miliolid d
65	species a
67	species c
68	species d (nodosarid)

TABLE 2. Species percentages in the Exxon-Michel-1 well, Assumption Parish.

Sample references (also in dendrogram, fig. 8) - 1-1:11500'; 1-2:11860'; 1-3:12280'; 1-4:12490'; 1-5:12970'; 1-6:14530'; 1-7:16360'.
For species names see Table 1.

Species No.	Sample						
	1-1	1-2	1-3	1-4	1-5	1-6	1-7
41	9	28	7	7	17	12	11
42				1		1	
43	5	22	4	6	3	6	5
58	20	6	11	19	24	10	28
59	1						
60	8		1	12	6		
22	14	9	7	8	14	6	9
16	1		8	9	4	6	6
18	7		1		1	8	3
31	4	10	5	8	5	13	11
30			1	2	1	3	1
47			12	7	4	9	2
61	4	1	1	1		2	9
62						1	2
13	1			1			
11	1				1	1	
12		11	3	2	3	2	4
51	14	4	6	8	5	5	2
50		6	5	3	2	1	

TABLE 2. (Continued)

Species No.	Sample						
	1-1	1-2	1-3	1-4	1-5	1-6	1-7
7	1	1		1	2	2	1
53			1			1	
54							
49	1				1	2	
23				1		3	1
24							1
35					1		2
26			20		1	2	
33		1	3		4	2	1
66							2

TABLE 3. Species percentages in the Pan Am/SB Well, St. Martin Parish.

Sample references (also in dendrogram, fig. 8) - 2-1:10100'; 2-2:12440'; 2-3:13910'; 2-4:14870'; 2-5:16100'. For species names, see Table 1.

Species No.	Sample				
	2-1	2-2	2-3	2-4	2-5
41				3	11
39	18	18	15	6	
40		2	8		
45	5	2			
46			10		
58	4	6		40	23
59	1		3	1	3
60	18	13	26	3	5
22				15	20
38	24	24	9		
18	2	4	2	3	7
31		4	4	3	3
30			2		1
32	5				
61	2	8	1	3	
62	1				
13	1			5	2
12				1	
51	8	10		3	3
50	3		4		

TABLE 3 (Continued)

Species No.	Sample				
	2-1	2-2	2-3	2-4	2-5
6		2	1		
3		1			
52	3		11		
1					10
68		1			
34				1	1
35		1		4	6
36		1			
37		1	3	3	1
26		1			
27		1			

TABLE 4. Species percentages in the Calco Melcancon Well, Terrebonne Parish.

Sample references (also in dendrogram, fig. 8) - 3-1:9580'; 3-2:10000'; 3-3:10690'; 3-4:10960'; 3-5:12460'; 3-6:15390'; 3-7:17049'. For species names see Table 1.

Species No.	Sample						
	3-1	3-2	3-3	3-4	3-5	3-6	3-7
39	2	26	1	5	5	9	7
40	38		16	20	19	1	1
45	9	1	1	3	4		
59	1			3			5
60	5	20	35	31	37	15	38
38	21	13	9	6	17		
18					1	9	
17				1			
31				6			
32	5	1	1		8		5
47	1	1	1				
61						1	
62						1	
63	2	2					
13			2	13	2	15	8
51	8	2	10	1	8	4	11
7					3		
3					1	2	2
4		6	4	1		1	

TABLE 4 (Continued)

Species No.	Sample						
	3-1	3-2	3-3	3-4	3-5	3-6	3-7
5		3	5	4	1	4	4
2		3					
52		4					
55		5					
56			3	1			
1		1	1	2			
68							5
36			1			7	1
37						5	
26	7	5	2			3	
33		4				1	1
14						4	
15							1

TABLE 5. Species percentages in the Sun Oil Well, St. Mary Parish.

Sample references (also in dendrogram, fig. 8) - 4-1:12625'; 4-2:13127'; 4-3:13409'; 4-4:14754'; 4-5:17980'. For species names, see Table 1.

Species No.	Sample				
	4-1	4-2	4-3	4-4	4-5
39	2	10	7		
40	20	15	6	2	
45	5	2	5	2	1
44					12
59	7	9	5	6	
60	20	32	17	55	33
38					20
18	1			2	5
17	10	1	22		1
31					7
32	2	2	9	4	
47					2
62		1		1	
63	1				
64					1
13	7	8	8	4	
51	3	6	5	14	
3	2	1			
4			1		
2	5	5		2	
5	5	6	1		1

TABLE 5 (Continued)

Species No.	Sample				
	4-1	4-2	4-3	4-4	4-5
9	1	1			5
8	1				
49				1	
20	1				
1		1			
68	1				1
26	4	2		5	
14				2	3
65					6

TABLE 6. Species percentages in the Pan Am 2374 Well, Lafourche Parish.

Sample references (also in dendrogram, fig. 8) - 5-1:9633'; 5-2:10500'; 5-3:11565'; 5-4:13020'. For species names see Table 1.

Species No.	Sample			
	5-1	5-2	5-3	5-4
39	4	7	8	
40	19	31	21	48
45			3	
46	11	4		
59	4		13	
60	28	9	37	20
38	14		6	17
18				1
17		42		
32	4	2	1	
61		1	1	3
13	1	2	3	3
51	9	1	2	
2	1		1	
5	1	1	2	
1			1	
37	2			
26		5	2	
14	4	1		

TABLE 7. Species percentages in the Texaco LL&E Well, Lafourche Parish.

Sample references (also in dendrogram, fig. 8) - 6-1:10398'. 6-2:11673'. 6-3:12500'; 6-4:13610'; 6-5:16758'. For species names see Table 1.

Species No.	Sample				
	6-1	6-2	6-3	6-4	6-5
39		20			
40			16	4	
45		9	1	2	
60	1	2	28		25
38	37	16	9	11	
18			7		
17					14
32	4			1	
47		9			
64		5	5		1
13	1		3		4
51			3		
6		7			
3			2		
2	1		8	2	1
52		5			
9				2	
20			2		18
1	42	20		74	
10					2

TABLE 7 (Continued)

Species No.	Sample				
	6-1	6-2	6-3	6-4	6-5
24				2	
68			1		
36			1		
26	7	10			34

TABLE 8. Species percentages in the Superior LL&E well, Terrebonne Parish.

Sample references (also in dendrogram fig. 8) - 7-1:9900'; 7-2:13240'; 7-3:15453'; 7-4:16780'. For species names see Table 1.

Species No.	Sample			
	7-1	7-2	7-3	7-4
39	13	2	4	
40	12	31	22	
45			9	
46	10	27		
60	4			14
38		36	10	14
18				3
32	7	1	6	2
64	3			
63	3		14	3
13				7
51			2	
6	3			
2		2	1	12
52	12			
57	5			
9	6	4		1
49			1	
1	3			
14		7	1	2

TABLE 8 (Continued)

Species No.	Sample			
	7-1	7-2	7-3	7-4
15	1	5		
29	1			
67		5		

Explanation: Plate 1

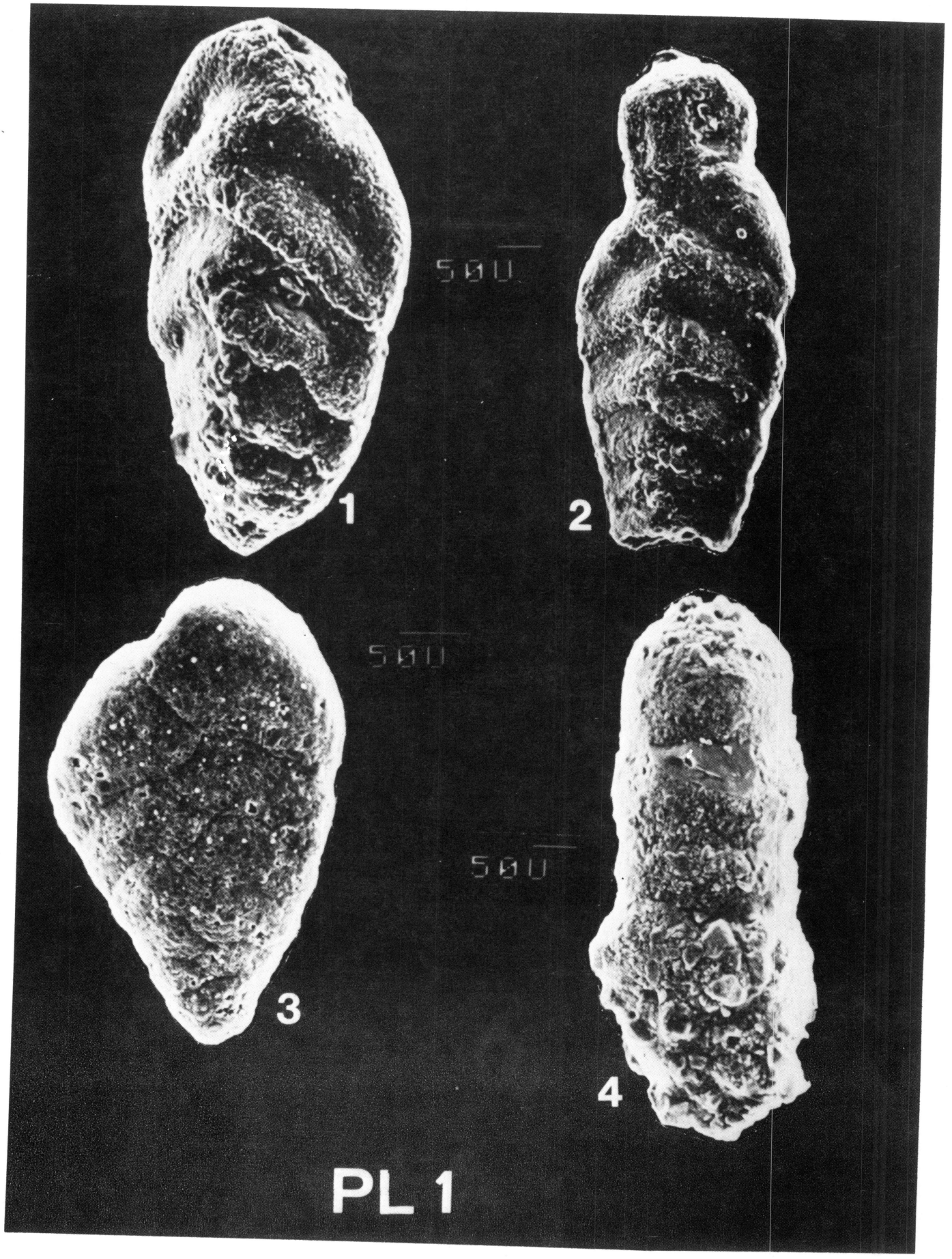
Representative agglutinated species.

Figure

1, 2. *Bigenerina humblei*

3. *Textularia articulata*

4. *Bigenerina directa*

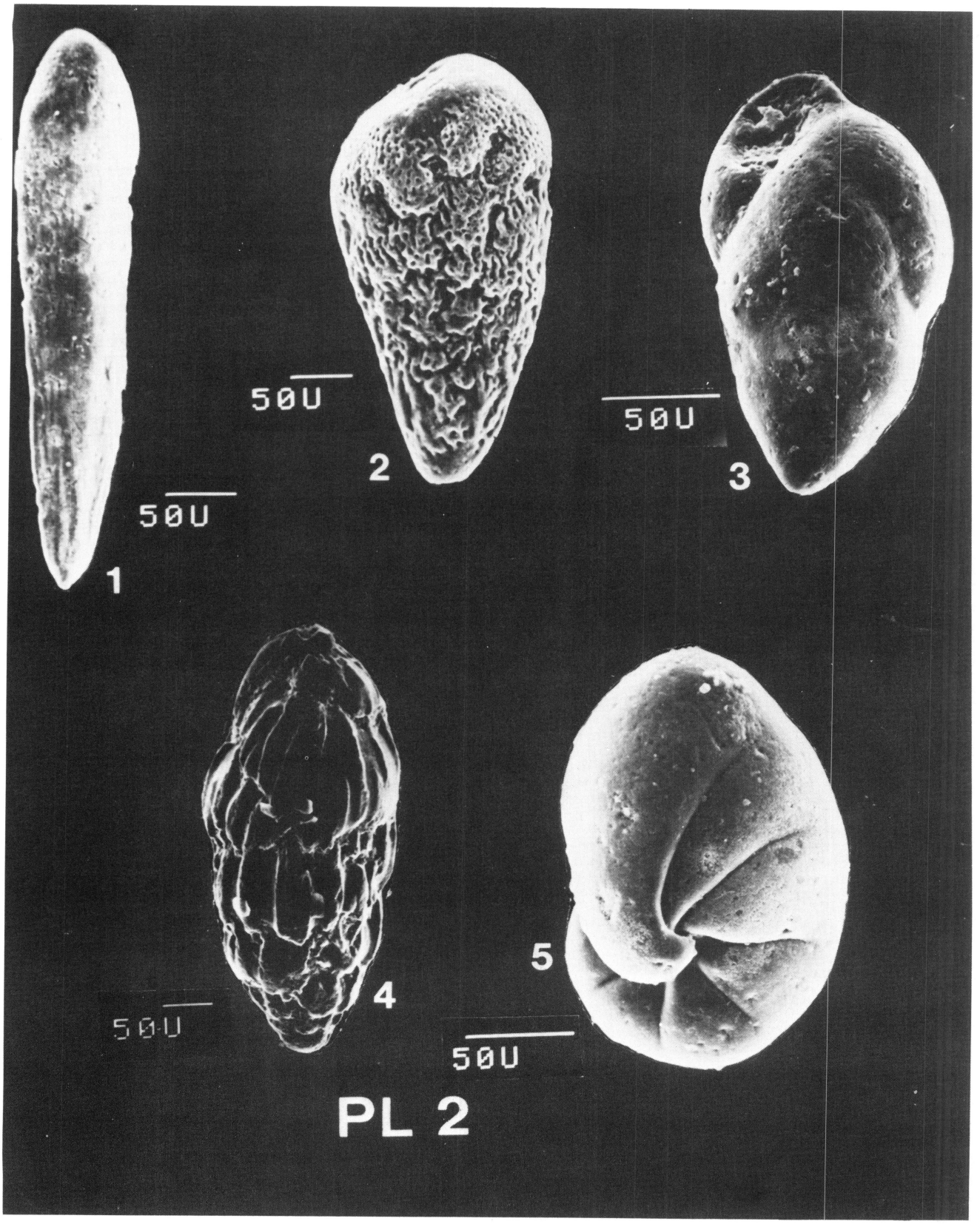

500
1
2
500
3
500
4
PL 1

Explanation: Plate 2

Representative calcareous species.

Figure

1. *Bolivina gladius*
2. *Bolivina floridana*
3. *Buliminella curta*
4. *Uvigerina stephensoni*
5. *Nonionella jacksonensis*

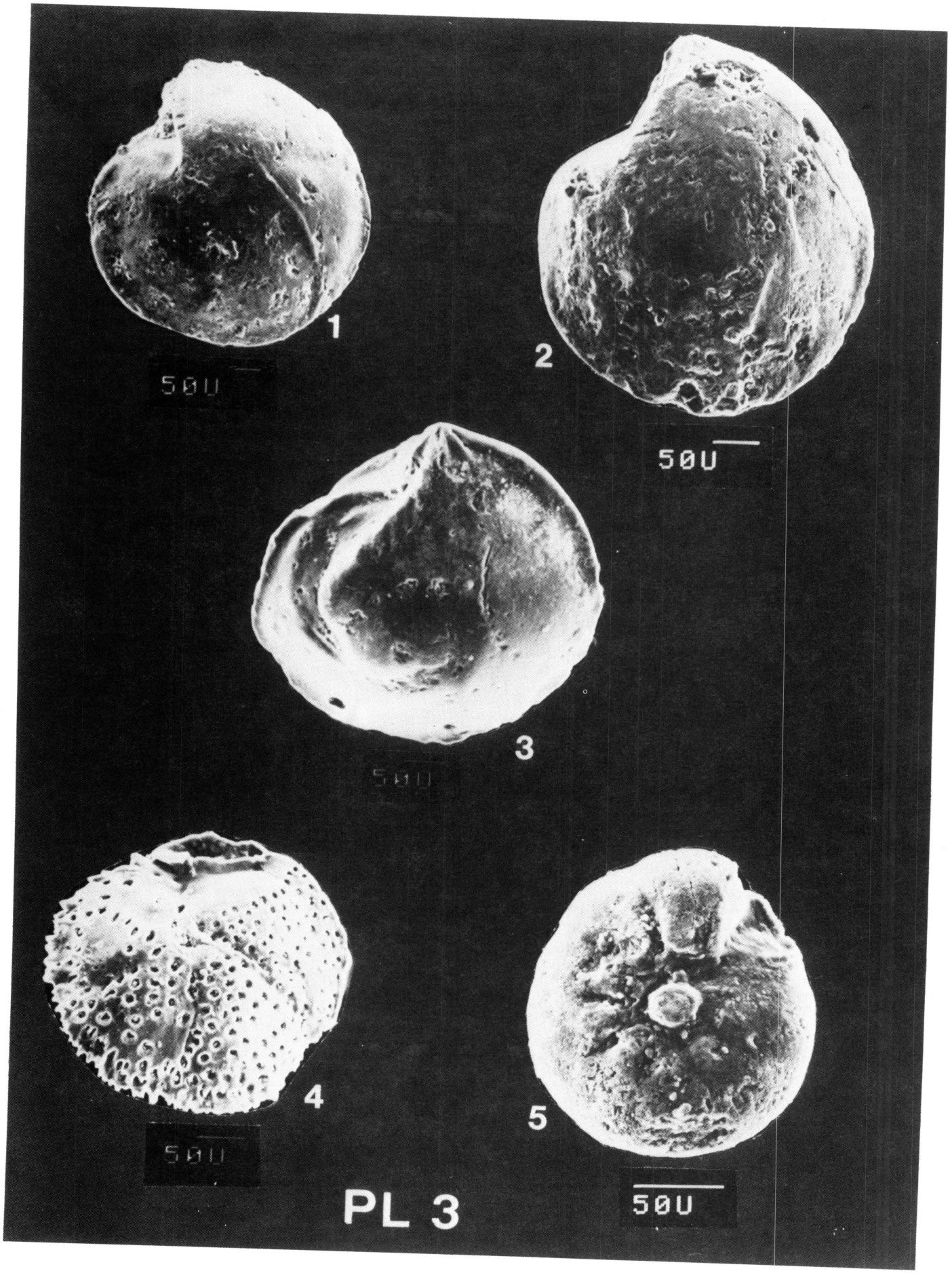

50U
1
50U
2
50U
3
50U
4
50U
5
PL 2

Explanation: Plate 3

Representative calcareous species (continued).

Figure

1. *Lenticulina americana*
2. *Lenticulina americana*, var.
3. *Lenticulina chambersi*
4. *Siphonina davisi*
5. *Ammonia beccarii*


1
50U
2
50U
3
4
50U
5
50U
PL 3