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7. THE *STILOSTOMELLA* EXTINCTION[1]

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ABSTRACT

A faunal boundary found at the base of the Brunhes Chronozone at Sites 658 and 659 confirms previous observations from several locations in the Atlantic Ocean and may be classified as a supraregional "extinction event." Several benthic foraminifer species typical of the Pliocene disappear near the Brunhes/Matuyama boundary, thus marking the upper limit of a faunal zone (faunal unit). Improved chronological dating indicates that the disappearance of these species occurs over a period of about 100,000 yr.

INTRODUCTION

Up to now, deep-sea benthic foraminifers have rarely been used for biostratigraphic purposes in the Quaternary. This is due to the extended stratigraphic range of many species as well as to the difficulty in deciding whether morphological variations observed represent phylogenetic changes or reversible modifications. However, Lutze (1979) tentatively subdivided the Neogene at Deep Sea Drilling Project (DSDP) Site 397, located off northwest Africa, into six faunal units, NB1 to NB6 (Lutze, 1979, fig. 7, p. 425).

Lutze's NB5/6 boundary appeared to be a major faunal break correlative with the Brunhes/Matuyama boundary and was characterized by the extinction of several Pliocene species and genera: *Stilostomella, Orthomorphina*, and *Plectofrondicularia* disappear almost simultaneously with *Pleurostomella brevis* and *Ellipsoglandulina laevigata*. Since then, Caralp (1984) has confirmed this faunal boundary as far north as the Goban Spur (Ocean Drilling Program [ODP] Sites 548 and 549, north of the Bay of Biscay).

In this manuscript, we verify the biostratigraphic use of the genera and species mentioned above to subdivide the Quaternary stratigraphically at Sites 658 and 659. These sites not only extend the area of investigation 1000 km to the south of DSDP Site 397, they also provide sections deposited under different ecological conditions. An improved chronological time scale established by Sarnthein and Tiedemann (this vol.) permits a precise dating of the extinction level and the evaluation of the faunal boundary synchronism (Fig. 1).

MATERIAL AND METHODS

Sites 658 and 659 are located on the continental slope of northwest Africa (Fig. 2 and Table 1). Site 658 is situated beneath the permanent upwelling cell west of Cap Blanc at 2263-m water depth. Site 659 is located further offshore on the Cape Verde Plateau at 3081-m water depth, therefore documenting a "nonupwelling" record. Samples from "Meteor" core 13519 were also reexamined. This gravity core was taken from the Sierra Leone Rise (2862-m water depth), which is separated from the continental margin by the Kane Gap deep-water passage. Pleistocene faunal fluctuations at this site have been described by Schröder (1981).

From Sites 658 and 659, 148 samples were analyzed to determine the stratigraphic ranges of the genera and species mentioned above: 130 samples from Cores 108-658A-1H to -33H and 18 samples from Cores 108-659A-3H and -4H. The size of the samples varied from 10 to 20 cm^3 wet sediment, and they usually contained more than 200 benthic foraminifers in the >250-μm fraction.

Based on detailed oxygen isotope and paleomagnetic data, Sarnthein and Tiedemann (this vol.) provided a time scale for the Quaternary sequence of Site 658. Sedimentation rates at Site 659 were calculated from paleomagnetic data on the Brunhes/Matuyama and Matuyama/Jaramillo boundaries (Ruddiman, Sarnthein, et al., 1988). Sedimentation rates at Sites 548 and 549 established by Pujol and Duprat (1983) were used to calculate the extinction date given by Caralp (1984). The sedimentation rates of Meteor core 13519 are based on oxygen isotope and paleomagnetic stratigraphy published by Herterich and Sarnthein (1984).

Determinations were generally restricted to the genus level; species determinations require additional taxonomic work, which is currently under way. Figure 3 documents the genera and species discussed.

RESULTS

At Site 658 *Stilostomella* disappears at 94.77 m below seafloor (mbsf), 4 m above the Brunhes/Matuyama boundary, which corresponds to an age of 649,500 yr. The extinction of *Plectofrondicularia* occurs at 91.94 mbsf and has an estimated age of 620,700 yr (Table 2). At Site 659 the termination of *Stilostomella* occurs 814,000 yr ago, while *Plectofrondicularia* does not occur in the time span observed (Table 3).

The last appearance of *Orthomorphina* occurs at 98.54 mbsf and has an age of 728,400 yr at Site 658. The extinction of *Orthomorphina* at Site 659 occurs at 822,000 yr ago. The different genera and species do not disappear simultaneously at one site, as is shown in Figure 1. It is important to note that the extinction of taxa mentioned is earlier at Site 659 than at Site 658.

DISCUSSION

If we assume that the chronological base is objective and correct, we can deduce a time-transgressive upper boundary for the faunal unit (Table 1). The total time span between the last appearance of *Stilostomella* from Site 659 to Site 658 is about 160,000 yr. The extinction interval of this genera from Site 549 to Site 548 also spans about 160,000 yr. Although the above sites are located at different water depths, Sites 519 and 397, which are from different areas off northwest Africa but in similar water depths, only show a lag time of 30,000 yr.

The same orders of magnitude appear for the last appearance of *Orthomorphina* and *Plectofrondicularia advena*, whereas the last appearance of *Pleurostomella* is restricted to a period of less than 100,000 yr. However, these genera do not appear at all sites.

The question remains if the observed disappearance of typical Pliocene species (and of entire genera?) is the expres-

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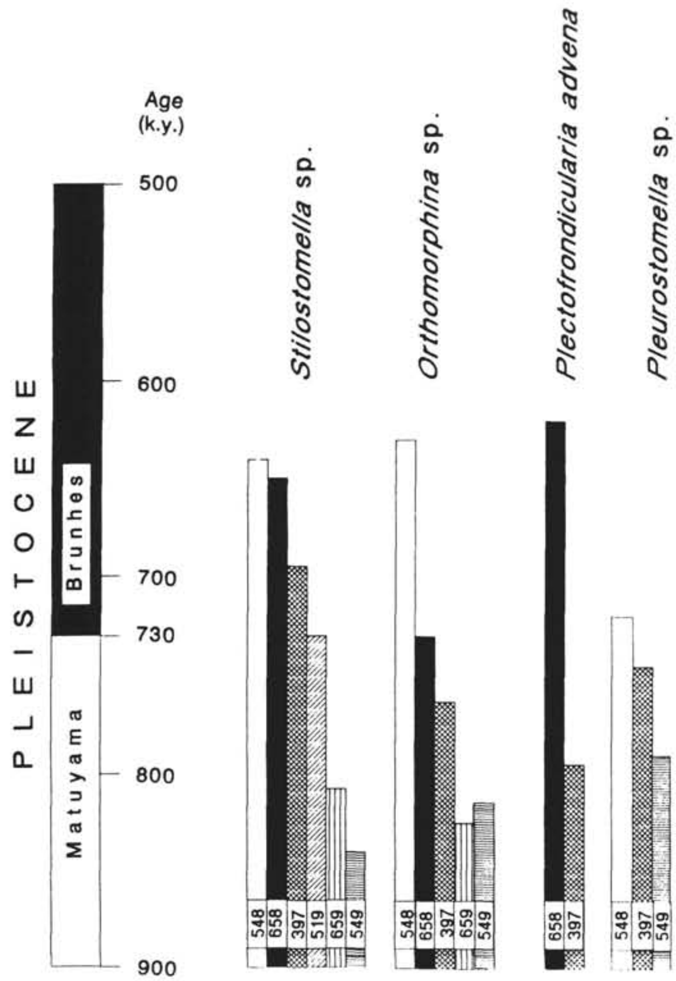

Figure 1. "Extinction" dates of foraminifer index species at the Brunhes/Matuyama boundary. Data represent a combination of several core sites.

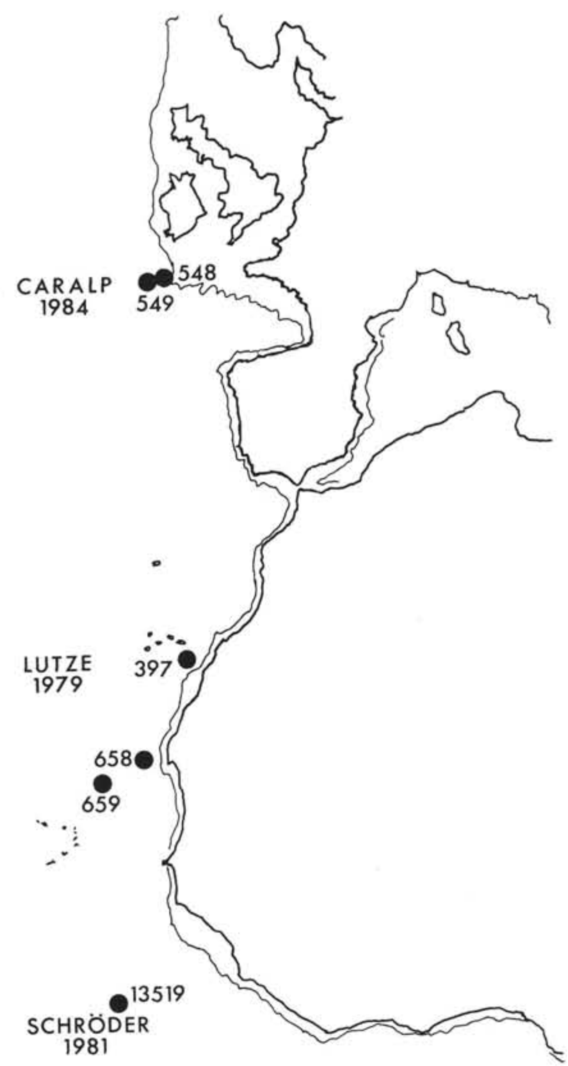

Figure 2. Location of the sites at which the discussed faunal break was observed.

sion of an ocean-wide extinction event. In the literature, the genera considered here have been classified as "recent" (Loeblich and Tappan, 1964). However, we have been unable to find records of stained specimens of these species or of unstained material from sites unaffected by faunal mixing (i.e., as in the redeposition of eroded Pleistocene *Stilostomella* at canyon fans in Southern California; pers. observ,). In more than 1000 samples from the eastern North Atlantic, we have never observed living *Stilostomella, Orthomorphina*, or *Plectofrondicularia* suggest an ocean-wide rather than regional event.

In the well-known *Foraminiferi/Padani* (Dondi and Barbieri, 1982), a treatise on benthic foraminifer ranges in the Neogene of Italy, these species become extinct in the middle of the (undivided) Pleistocene. This further supports the hypothesis that the phenomenon we have observed is an ocean-wide extinction event marking the upper boundary of a biozone (faunal unit).

A last question remains as to the underlying reason for such an event. We have recorded a much earlier disappearance at sites far from the shore and away from areas of high productivity (Table 1). This suggests that these species had been affected by some environmental changes and progressively reduced their geographic distribution. They may have survived for prolonged periods in certain areas with more favorable ecological conditions. Comparing the water depth and distance to shore for the different sites in the northeast Atlantic, a trend may exist toward a somewhat extended period of last appearances at shallower water depths.

Table 1. Termination of *Stilostomella* sp. at various sites.

Site	"Extinction" date (yr ago)	Water depth (m)
DSDP 548	643.000	1256
ODP 658	649.500	2263
DSDP 397	697.000	2900
M 12519	730.000	2862
ODP 659	814.000	3081
DSDP 549A	813.000	2535

There is no evidence for a time-transgressive latitudinal migration of this extinction event. However, our own studies in these regions clearly show that the distribution patterns of fossil and recent benthic foraminifers reflect complicated ecological conditions that are not yet fully understood (Lutze and Coulbourn, 1984; Lutze et al., 1986). Therefore, it would

Table 2. Data base, Hole 658A.

Core, section, interval (cm)	Depth (mbsf)	Age (k.y.)	*Stilo-stomella* (N)	*Ortho-morphina* (N)	*Plectofron-dicularia* (N)	*Pleuro-stomella* (N)	Total
108-658A-							
1H-1, 70–75	0.83	4.1	—	—	—	—	246
1H-1, 102–104	1.13	5.5	—	—	—	—	249
1H-2, 70–75	2.33	11.4	—	—	—	—	144
1H-2, 102–104	2.61	12.8	—	—	—	—	55
1H-3, 70–75	3.68	17.4	—	—	—	—	436
1H-3, 102–104	3.95	18.5	—	—	—	—	394
1H-4, 70–75	5.04	22.7	—	—	—	—	552
1H-4, 80–82	5.12	23.0	—	—	—	—	147
3H-2, 72–75	14.88	111.5	—	—	—	—	120
3H-3, 102–104	16.38	123.8	—	—	—	—	660
3H-4, 102–104	17.87	133.3	—	—	—	—	206
3H-5, 102–104	19.38	142.3	—	—	—	—	136
3H-CC, 16–21	21.13	158.6	—	—	—	—	650
4H-1, 70–75	22.58	174.4	—	—	—	—	366
4H-2, 70–75	23.99	187.1	—	—	—	—	425
4H-3, 70–75	25.49	198.5	—	—	—	—	254
4H-4, 70–75	26.99	210.9	—	—	—	—	251
4H-5, 70–75	28.49	219.1	—	—	—	—	280
4H-6, 70–75	29.99	224.9	—	—	—	—	394
5H-1, 70–75	32.08	233.8	—	—	—	—	267
5H-2, 70–75	33.58	240.2	—	—	—	—	219
5H-3, 70–75	35.08	247.5	—	—	—	—	420
5H-4, 70–75	36.58	257.0	—	—	—	—	406
5H-5, 70–75	38.08	270.1	—	—	—	—	424
5H-6, 70–75	39.57	281.4	—	—	—	—	334
6H-1, 70–75	41.58	293.9	—	—	—	—	458
6H-2, 70–75	43.08	301.5	—	—	—	—	179
6H-3, 70–75	44.53	308.8	—	—	—	—	401
6H-5, 70–75	46.04	316.7	—	—	—	—	286
6H-6, 70–75	47.55	324.7	—	—	—	—	176
6H-7, 70–75	49.04	332.2	—	—	—	—	168
6H-7, 98–100	49.31	333.4	—	—	—	—	125
6H-9, 15–20	49.77	335.3	—	—	—	—	209
6H-9, 33–35	49.94	336.0	—	—	—	—	104
7H-1, 70–75	51.07	340.8	—	—	—	—	788
7H-2, 70–75	52.58	349.6	—	—	—	—	274
7H-3, 70–75	54.07	358.3	—	—	—	—	836
7H-4, 70–75	55.58	367.1	—	—	—	—	326
8H-1, 70–75	60.58	405.0	—	—	—	—	247
8H-2, 70–75	62.08	419.6	—	—	—	—	220
8H-2, 144–146	62.80	426.0	—	—	—	—	221
8H-3, 26–28	63.12	427.8	—	—	—	—	178
8H-3, 70–75	63.58	430.5	—	—	—	—	242
8H-4, 70–75	65.08	441.8	—	—	—	—	270
8H-5, 70–75	66.58	454.9	—	—	—	—	368
8H-6, 70–75	68.07	467.9	—	—	—	—	300
9H-1, 70–75	70.07	480.4	—	—	—	—	236
9H-2, 60–65	71.33	487.0	—	—	—	—	153
9H-3, 70–75	72.71	494.2	—	—	—	—	157
9H-4, 70–75	73.90	500.4	—	—	—	—	166
9H-5, 70–75	75.40	508.2	—	—	—	—	207
9H-6, 70–75	76.90	515.8	—	—	—	—	272
10H-1, 70–75	79.57	528.9	—	—	—	—	354
10H-2, 70–75	81.07	536.2	—	—	—	—	580
10H-3, 12–16	81.99	543.3	—	—	—	—	462
10H-4, 70–75	84.07	563.0	—	—	—	—	110
10H-5, 70–75	85.49	574.0	—	—	—	—	206
10H-6, 60–65	86.81	583.6	—	—	—	—	160
11H-1, 70–74	89.04	599.7	—	—	—	—	551
11H-3, 70–74	90.58	610.9	—	—	—	—	220
11H-4, 70–74	91.94	620.7	—	—	1	—	*
11H-5, 70–74	93.37	631.0	—	—	—	—	218
11H-6, 70–74	94.77	649.5	3	—	1	—	283
11H-7, 70–74	96.16	667.9	4	—	6	—	276
11H-8, 68–72	97.55	721.0	4	—	1	—	192
11H-CC	~97.80	~723.0	6	—	10	—	*
12H-1, 70–74	98.54	728.4	1	1	1	—	150
12H-2, 70–74	99.30	1575.0	5	1	4	—	253
12H-3, 70–74	100.18	1581.0	1	3	5	—	185
12H-4, 70–74	101.90	1592.7	6	4	6	1	233
12H-6, 70–74	104.43	1616.0	—	2	4	—	168
12H-8, 70–74	107.43	1637.1	8	1	1	1	*
13H-1, 72–75	108.09	1643.9	5	4	9	—	220
13H-3, 72–75	110.17	1669.0	2	7	6	2	232
13H-5, 56–59	112.92	1702.1	1	1	3	1	128

Table 2 (continued).

Core, section, interval (cm)	Depth (mbsf)	Age (k.y.)	*Stilo-stomella* (N)	*Ortho-morphina* (N)	*Plectofron-dicularia* (N)	*Pleuro-stomella* (N)	Total
14H-1, 70–74	117.65	1759.0	4	—	—	—	197
14H-4, 67–71	121.13	1800.9	5	2	3	—	221
14H-6, 70–74	124.01	1834.7	4	1	5	—	122
15H-2, 72–76	127.97	1874.8	4	5	—	—	164
15H-5, 75–78	131.73	1912.8	1	2	2	—	183
15H-7, 72–75	134.40	1939.9	—	4	6	—	111
16H-2, 70–74	137.87	1972.0	6	—	1	—	206
16H-3, 70–74	139.37	1985.8	1	1	1	—	152
16H-6, 70–74	143.83	2027.0	5	2	7	—	234
17H-1, 70–74	146.07	2058.4	—	1	9	—	172
17H-3, 60–64	148.77	2096.2	1	—	7	—	172
17H-5, 70–74	151.73	2137.7	1	1	2	—	160
19H-1, 70–74	155.77	2304.0	4	2	3	—	195
19H-5, 66–70	160.15	2355.0	3	1	4	—	92
19H-7, 66–70	162.54	2382.9	—	—	2	—	266
20H-1, 61–65	165.18	2411.1	1	3	4	—	186
20H-3, 70–74	168.24	2442.8	—	10	2	—	216
20H-7, 70–74	170.30	2464.1	1	1	—	—	198
21H-1, 70–74	174.71	2509.9	—	4	—	—	98
21H-4, 66–70	177.26	2536.3	1	—	2	1	232
21H-8, 65–69	181.01	2575.2	—	—	9	—	52
22H-3, 50–54	185.96	2626.5	1	3	1	—	151
22H-5, 60–64	187.84	2646.0	1	—	3	1	214
22H-7, 56–60	189.90	2667.4	—	2	7	2	152
23H-1, 70–74	193.77	2707.5	—	—	1	1	229
23H-3, 61–65	196.09	2731.6	2	—	7	2	179
23H-9, 70–74	200.05	2772.7	—	—	8	4	175
24H-3, 70–74	204.53	2819.1	—	4	4	3	134
24H-5, 63–67	206.77	2842.4	—	—	4	—	49
24H-7, 83–87	209.11	2866.6	—	1	—	—	130
25H-1, 70–74	212.65	2903.3	4	—	—	—	162
25H-3, 70–74	215.29	2930.7	1	59	—	2	176
25H-6, 69–73	218.46	2960.9	1	1	2	—	242
26H-1, 46–50	222.03	2990.4	—	3	3	1	222
26H-4, 54–58	224.46	3010.6	—	2	—	—	180
26H-7, 69–73	227.61	3036.7	—	3	7	—	118
27H-1, 70–74	231.74	3070.9	1	1	2	—	211
27H-4, 59–63	235.1	3099.5	—	—	2	1	202
27H-7, 70–74	238.40	3126.1	—	—	2	—	203
28H-2, 70–75	242.77	3162.3	—	—	1	—	209
28H-4, 70–75	245.72	3186.8	—	—	2	—	119
28H-6, 67–71	248.45	3209.4	1	—	1	1	190
29H-3, 72–76	252.41	3242.2	—	2	1	—	187
29H-5, 72–76	255.13	3264.8	3	2	1	—	246
29H-7, 72–76	257.69	3286.0	11	1	2	—	282
30H-1, 68–72	260.25	3307.2	1	3	1	—	253
30H-4, 70–74	263.13	3331.1	—	—	—	—	203
30H-6, 70–74	265.75	3352.8	17	—	1	—	217
31H-2, 70–74	271.19	3397.8	—	—	—	—	273
31H-3, 63–67	272.52	3408.8	14	2	2	—	60
32H-1, 68–72	279.25	3464.5	—	—	1	—	200
33H-1, 70–74	288.77	3543.1	4	—	—	—	217
33H-2, 70–74	290.27	3555.5	—	1	—	1	256
33H-4, 70–74	292.70	3575.6	4	2	1	1	243

Note: Total = total number of benthic foraminifers; * = not determined.

be rather speculative to hypothesize any particular hydrographic change that may be responsible for this faunal extinction event.

CONCLUSIONS

The last occurrences of *Stilostomella* and affiliate taxa appears to have occurred gradually during a time span of more than 160,000 yr, preceding and subsequent to the Brunhes/Matuyama boundary. The extinction of taxa that are rare or even sporadic probably reflect gradual ecological deteriorations. However, correlations from different locations indicates a distinct faunal unit within the Pleistocene, which is not necessarily objective to catastrophic faunal fluctuations.

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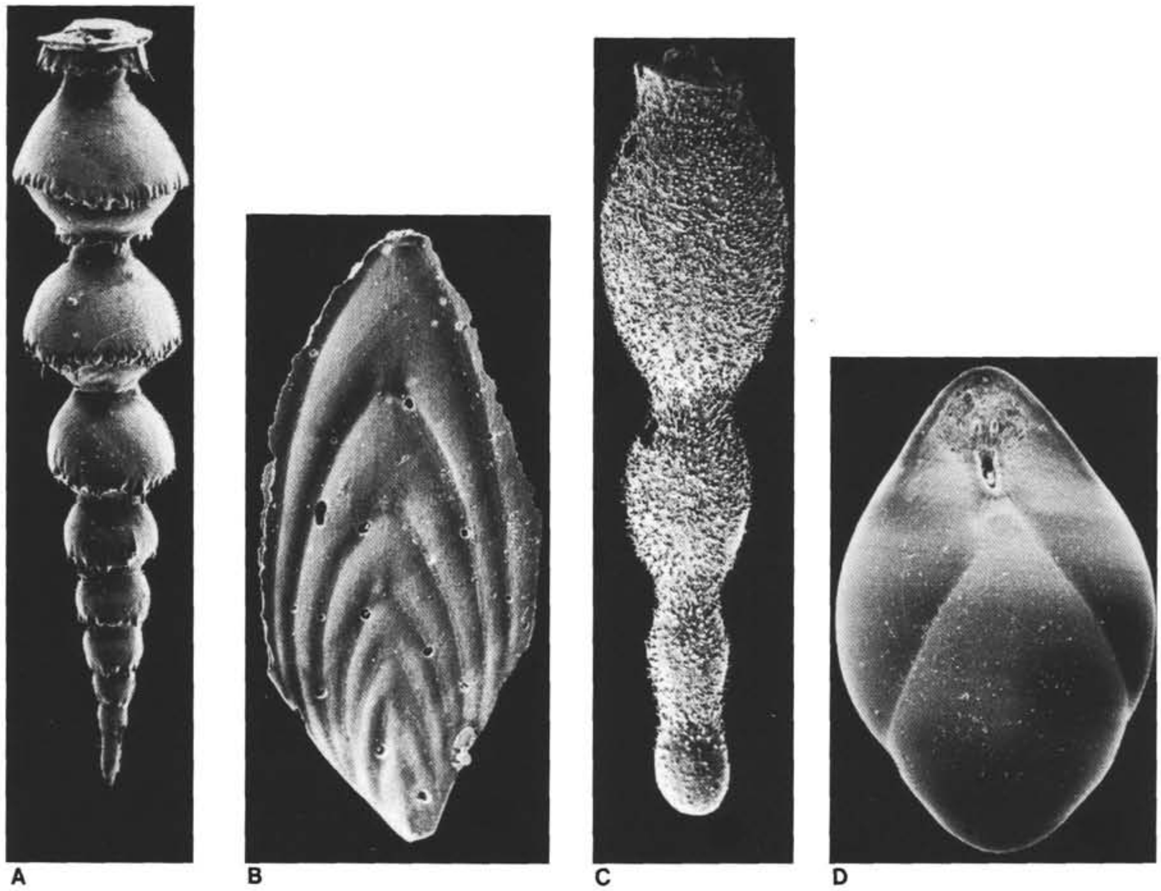

Figure 3. Figures of the species discussed. **A.** *Stilostomella* sp. **B.** *Plectofrondicularia advena.* **C.** *Orthomorphina* sp. **D.** *Pleurostomella brevis.*

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Table 3. Data base, Hole 659A.

Core, section, interval (cm)	Depth (mbsf)	Age (k.y.)	*Stilo-stomella* (N)	*Ortho-morphina* (N)	*Pleuro-stomella* (N)	Total
108-659A-						
3H-1, 70–75	19.53	608.5	—	—	—	774
3H-2, 70–75	21.03	646.8	—	—	—	297
3H-3, 70–75	22.53	695.0	—	—	—	450
3H-3, 102–104	22.83	700.9	—	—	—	*
3H-3, 130–132	23.11	706.5	—	—	—	*
3H-4, 70–75	24.03	724.7	—	—	—	747
3H-4, 130–132	24.61	741.0	—	—	—	*
3H-5, 70–75	25.53	774.0	—	—	—	998
3H-5, 102–104	25.83	782.4	—	—	—	*
3H-5, 130–132	26.11	790.2	—	—	—	*
3H-6, 74–79	26.96	814.0	29	—	—	891
3H-6, 102–104	27.23	822.3	9	1	—	*
4H-1, 70–74	29.02	877.0	8	1	—	297
4H-1, 102–104	29.33	886.5	3	—	—	*
4H-1, 130–132	29.61	895.0	—	—	—	*
4H-2, 70–74	30.50	921.7	2	1	—	504
4H-3, 70–74	32.00	965.4	9	2	—	594
4H-4, 66–71	33.47	1016.3	5	2	1	866

Note: Total = total number of benthic foraminifers; * = not determined.