

Marine Holocene foraminifera and ostracoda from Kalloni Bay, Lesvos Island, Greece

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ABSTRACT — *The foraminifer Elphidium and the ostracod Loxoconcha dominate the bay microfauna and are characteristic of the euryhaline and shallow water environment of Kalloni Bay. General bay, upper and lower bay biofacies have been recognized.*

RIASSUNTO — [Foraminiferi e ostracodi marini olocenici della Baia di Kalloni, Isola di Lesbo, Grecia] — *Il golfo di Kalloni è di ambiente neritico ed il suo contenuto in sale è sottoposto a cambiamenti e di conseguenza la sua microfauna riflette queste condizioni.*

Sono state riconosciute le seguenti biofacies, caratterizzate dalle seguenti specie di foraminiferi ed ostracodi:

- 1) *Golfo intero*: *Elphidium spp.*; *Loxoconcha spp.*
- 2) *Alto golfo*: *Discorbis*, *Anomalina sp.*; *Carinocythereis spp.*
- 3) *Basso golfo*: *Quinqueloculina spp.*; *Bosquetina sp.*

INTRODUCTION

Kalloni Bay is the larger of the two natural bays of Lesvos Island, Greece, in the Aegean Sea. The particularly distinctive feature of Kalloni Bay with respect to Lesvos, and in fact the entire Aegean Sea, is the quality and quantity of its fishery. The most recognizable examples are sardines and clams.

Equally interesting is the geology of both the island and Kalloni Bay. The island of Lesvos is composed of two geologic portions, both different in origin and composition (Prager, 1966; Jones, 1968). In the southeastern portion, older (Paleozoic?) metamorphic rocks occur, while the western and northeastern portion is occupied by a volcanic assemblage. Kalloni Bay is surrounded by volcanic rocks, while metamorphic rocks encircle Yeras Bay.

Kalloni Bay is shallow (10 meter average depth) with a smooth bottom, tending to be deeper and more irregular toward the mouth. Several streams, mostly intermittent, enter the bay. The immediate impression is that the bay is undergoing deposition from the surroundings, with the narrow entrance being kept open by currents. Tassos and Hopkins (1972) in their preliminary study established the uniqueness

of Kalloni Bay and described certain current regimes, and Tassos (1977) described the holocene sediments of the Bay.

THE ESTUARINE NATURE OF KALLONI BAY

Depending on the physical character of circulation, there are three marginal types of estuaries: the river-dominated, the tide-dominated, and wind-dominated estuary (Oostdam, 1971).

In Kalloni Bay, the river-dominated type could be named density-dominated for the following reasons. Density differences are the result of river flow in the bay during the wet season. During the dry season, rivers do not flow, but density differences can be created as a response to salinity and temperature changes caused by evaporation and differential heating. Therefore, the term river-dominated type can be replaced by density-dominated with the recognition of the following subdivisions: temperature-dominated and salinity-dominated.

The calculated and measured current velocities indicate that Kalloni Bay is also a wind-dominated estuary during most of the year. The tidal ef-

fect can be significant in the case of wind absence. The thermohaline currents can also play an important role, especially during neap tides and calm sea.

Under favorable conditions currents can reach velocities up to 25 or 30 cm/sec in the entrance channel of Kalloni Bay.

FIELD PROCEDURES

Thirty one (31) stations were made and 24 bottom samples were collected for this study.

The location of each station was obtained from compass readings and/or self-positioning from prominent onshore features or permanent buoys. Depths were reckoned by marking on the lowering lines.

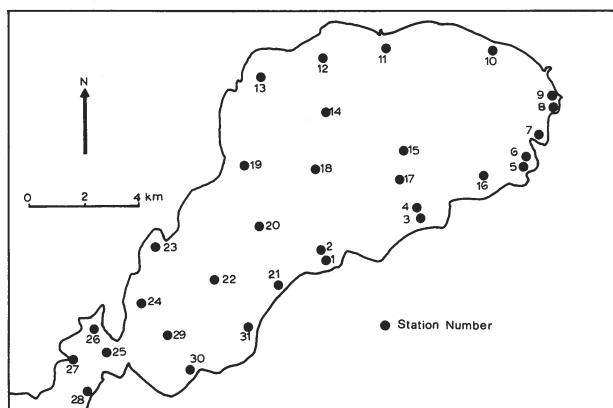
A Rigosha and Co. LTD grab sampler was used for the collection of the bottom samples. Due to the lack of penetration in sandy bottoms and lack of sample retention in the muddy sediments, attempts to take Phleger cores in the area were unsuccessful.

Text-fig. 1 shows the sampling locations.

LABORATORY PROCEDURES AND RESULTS

The coarse fraction method developed by Shepard and Moore (1960) for the study of the recent sediments of the NW Gulf of Mexico was generally followed. Some adjustments in the method were necessary. The special characteristics (high mud content, polymodal) of the Kalloni Bay sediments were considered when these modifications were made.

Each sample was described under the binocular microscope.



Text-fig. 1 - Sampling stations in Kalloni Bay.

After description, the entire sample was dispersed, and the material finer than 0.044 mm (4.5ϕ) was removed by wet sieving. Due to the presence of much mica that can remain in suspension longer than a grain of the same volume and of a more or less spherical shape, the 0.088 mm (3.5ϕ), instead of the 0.062 mm (4.0ϕ), was chosen as the boundary between sand and mud.

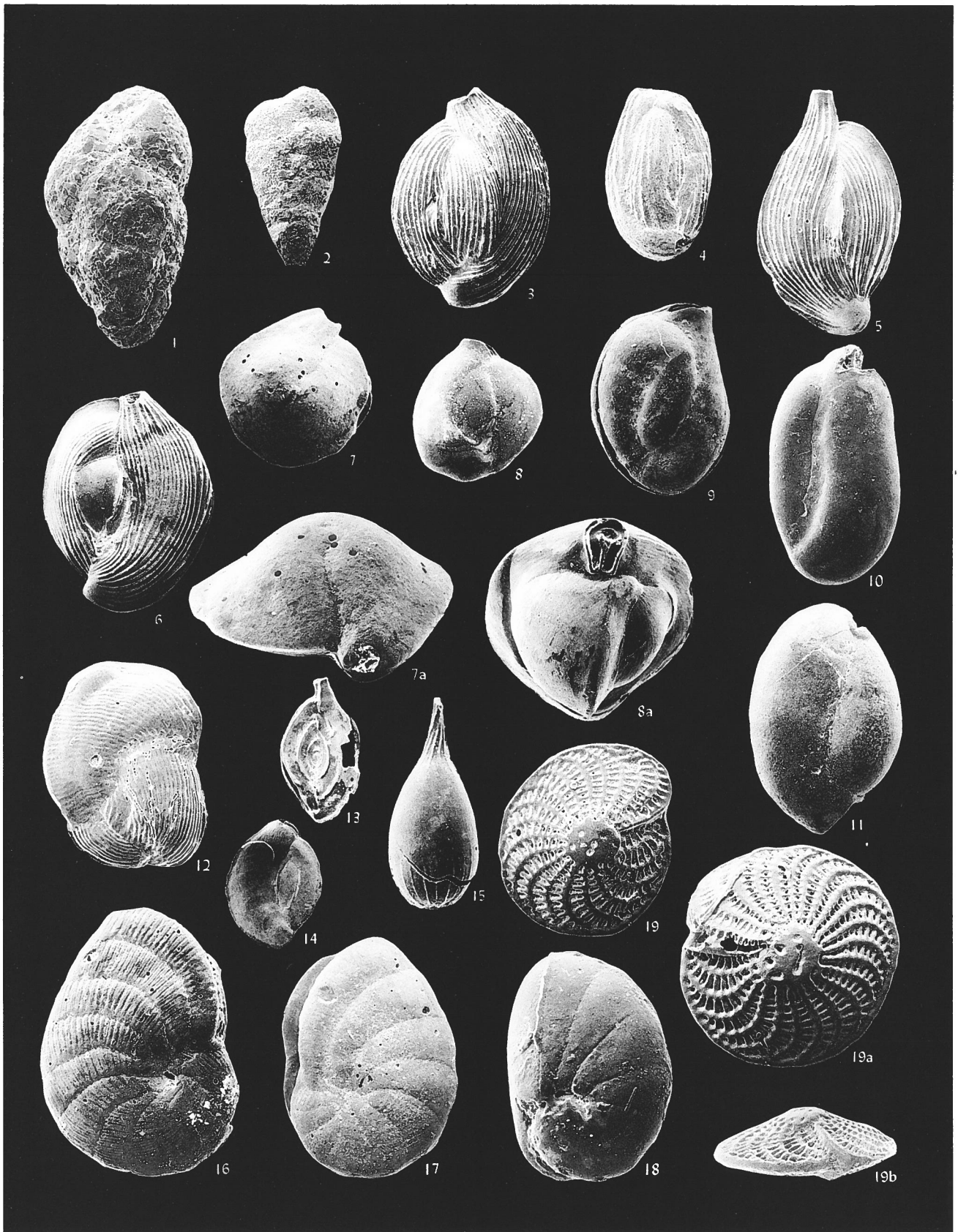
The coarse fraction was dry sieved into sieves of 6, 16, 30, 70, 170, and 325 U.S. Standard Sieve Mesh Numbers. When aggregates were present in appreciable numbers, the sample was dispersed again.

Three constituents are considered as diagnostically important in this study in determining the sediment facies of Kalloni Bay: 1) terrigenous minerals (quartz, feldspar, ferromagnesians, mica), 2) mud, and 3) shells. Foraminifera and Ostracoda, even in the

EXPLANATION OF PLATE 1

Foraminifera of Kalloni Bay, Lesvos Island, Greece.

- Fig. 1 - *Ammotium* sp, side view, x 46.
- Fig. 2 - *Textularia* sp., side view, x 31.
- Fig. 3 - *Quinqueloculina* sp. 1, side view, x 25.
- Fig. 4 - *Quinqueloculina* sp. 2, side view, x 25.
- Fig. 5 - *Quinqueloculina* sp. 3, side view, x 25.
- Fig. 6 - *Quinqueloculina* sp. 4, side view, x 25.
- Figs. 7, 7a - *Triloculina?* sp. 1. 7) Polar view, x 50; 7a) equatorial view (tilted 76°), x 81.
- Figs. 8, 8a - *Triloculina* sp. 2. 8) Side view, x 25; 8a) apertural view, x 45.
- Fig. 9 - *Triloculina* sp. 3, side view, x 24.
- Fig. 10 - *Triloculina* sp. 4, side view, x 25.
- Fig. 11 - *Triloculina* sp. 5, side view, x 23.
- Fig. 12 - *Vertebralina* sp. side view, x 50.
- Fig. 13 - *Massilina* sp. 1, side view, x 24.
- Fig. 14 - *Massilina* sp. 2, side view, x 10.
- Fig. 15 - *Lagena* sp. side view, x 43.
- Fig. 16 - *Nonionella* sp. 1, side view, x 45.
- Fig. 17 - *Nonionella* sp. 2, side view, x 105.
- Fig. 18 - *Nonionella* sp. 3, side view, x 100.
- Figs. 19, 19a, 19b - *Elphidium* sp. 1. 19, 19a) Polar view, x 30; 19b) equatorial view, x 30.

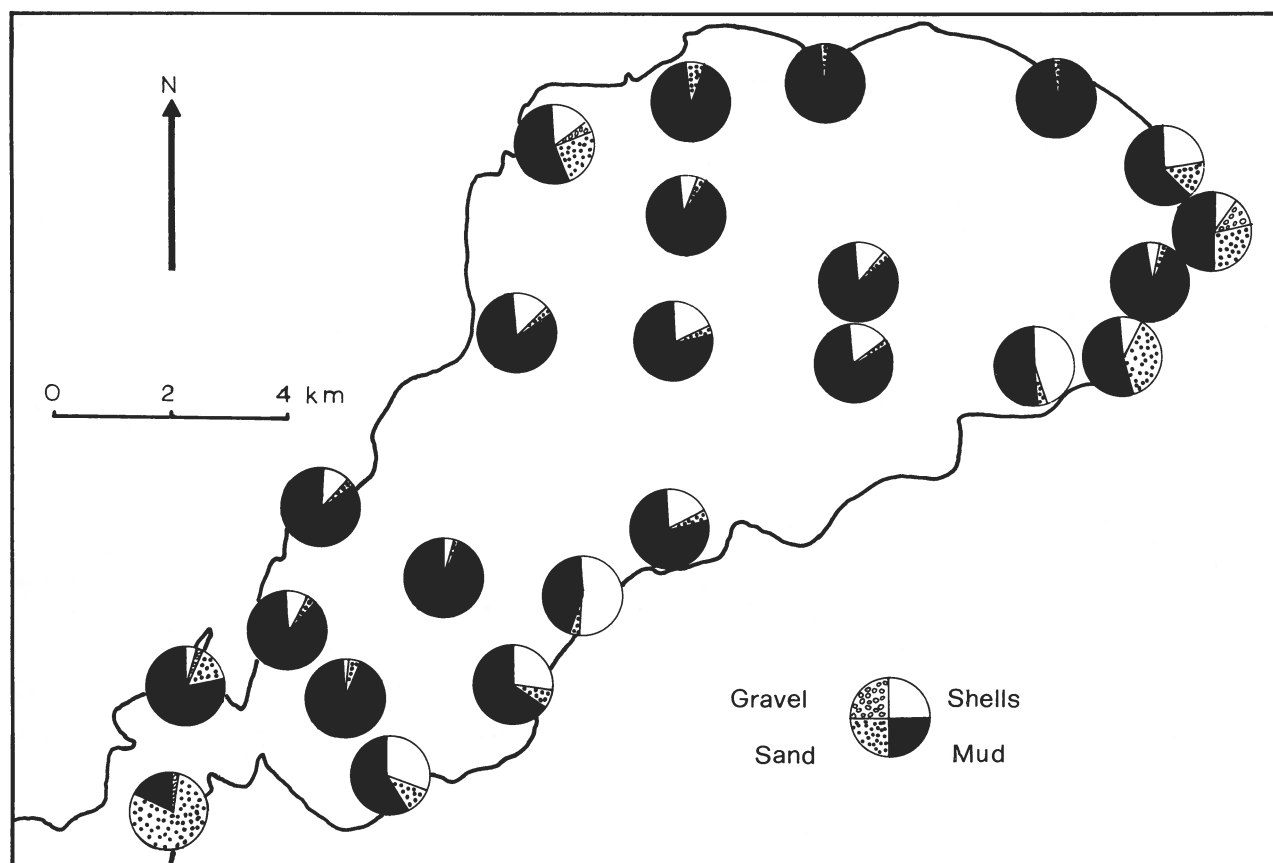


case where they represent over 90% of the fractions between 1/8 mm (3.0 ϕ) 1/2 mm (1.0 ϕ) rarely exceed 1% of the total sample weight (Shepard and Moore, 1960). The same is true for other constituents such as rock fragments, authigenic minerals (pyrite, glauconite, phosphatic grains), echinoids, diatoms,

bryozoans, wood fragments, plant fibers, aggregates, and others.

Nevertheless, the latter constituents are important environmental and water-movement indicators. For that reason they are considered separately.

The approximate weight per cent of the shells

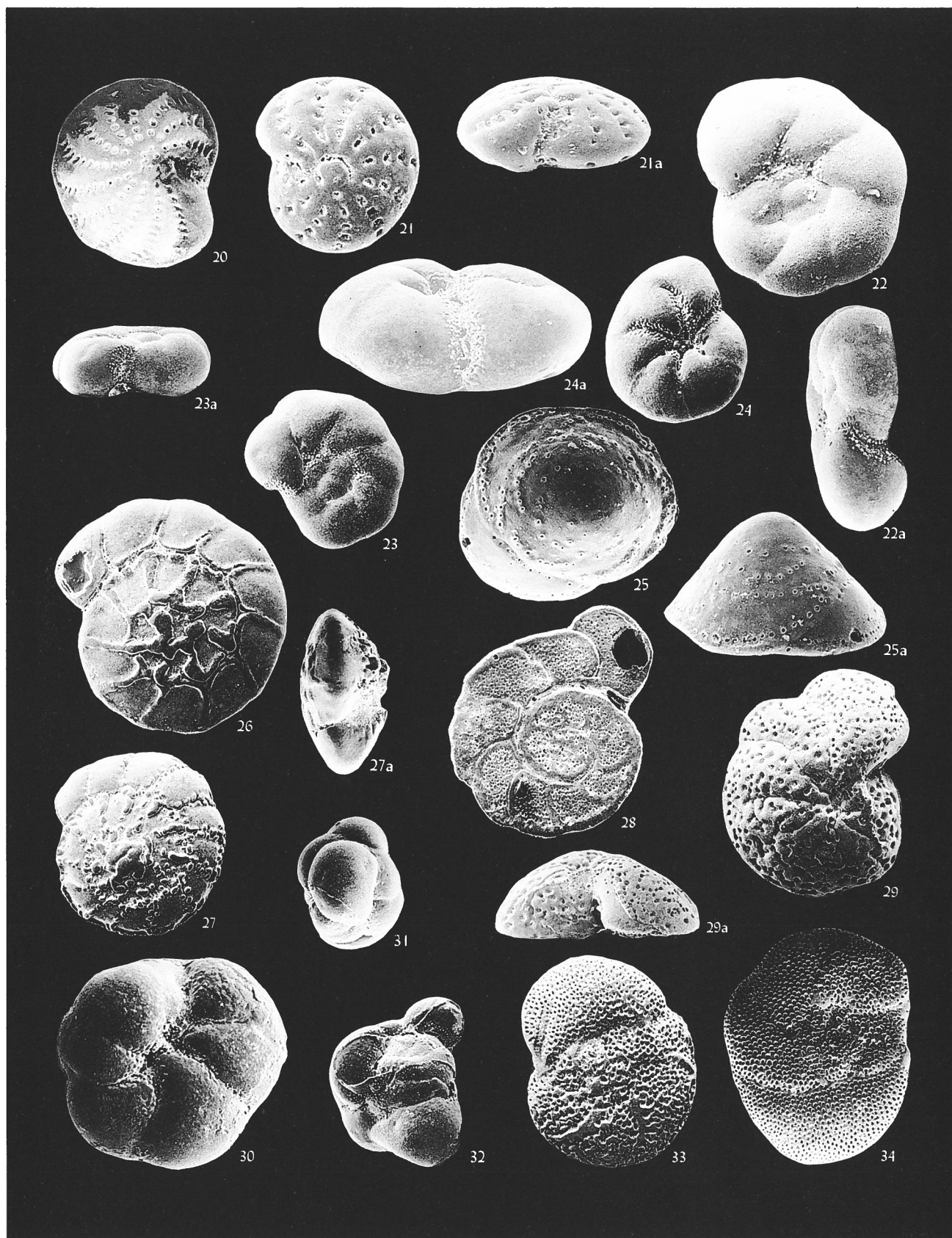


Text-fig. 2 - Shell, gravel, sand and mud content in the bottom samples of Kalloni Bay.

EXPLANATION OF PLATE 2

Foraminifera of Kalloni Bay, Lesvos Island, Greece. (continued)

- Fig. 20 - *Elphidium* sp. 2, polar view, x 50.
 Figs. 21, 21a - *Elphidium* sp. 3. 21) Polar view, x 100; 21a) equatorial view, x 93.
 Figs. 22, 22a - Discorbid sp. 1. 22) Polar view, x 60; 22a) equatorial view, x 60.
 Figs. 23, 23a - Discorbid sp. 2 ? 23) Polar view, x 50; 23a) equatorial view, x 50.
 Figs. 24, 24a - Discorbid sp. 3. 24) Polar view, x 53; 24a) equatorial view, x 90.
 Figs. 25, 25a - *Eponides* sp. 25) Polar view, x 100; 25a) equatorial view, x 100.
 Fig. 26 - *Ammonia* sp. 1, polare view, x 46.
 Figs. 27, 27a - *Ammonia* sp. 2. 27) Polar view, x 24; 27a) *Ammonia* sp. 1 ? Equatorial view, x 40.
 Fig. 28 - *Cibicides* sp. 1. south polar view, x 50.
 Figs. 29, 29a - *Cibicides* sp. 1 ? 29) Polar view, x 50; 29a) equatorial view, x 40.
 Fig. 30 - *Cibicidella* sp. 1, side view, x 100.
 Fig. 31 - *Cibicidella* sp. 2, side view, x 100.
 Fig. 32 - *Cibicidella* sp. 3, side view, x 100.
 Fig. 33 - *Amphistegina* sp. 1, side view, x 53.
 Fig. 34 - *Amphistegina* sp. 2, side view, x 53.



and of the terrigenous minerals was obtained by direct weighing or visual estimation. Lastly the total shell and terrigenous mineral per cent content for each sample was calculated. The mud content for each sample was determined after subtraction from the total sample of the shells and terrigenous material coarser than 0.088 mm.

Foraminifera and Ostracoda were absent in fractions larger than 2 mm and very rare in fractions below 0.09 mm. The 0.21 mm (2.25 ϕ) was selected for Foraminifera and Ostracoda counts because it was the richer in both of them.

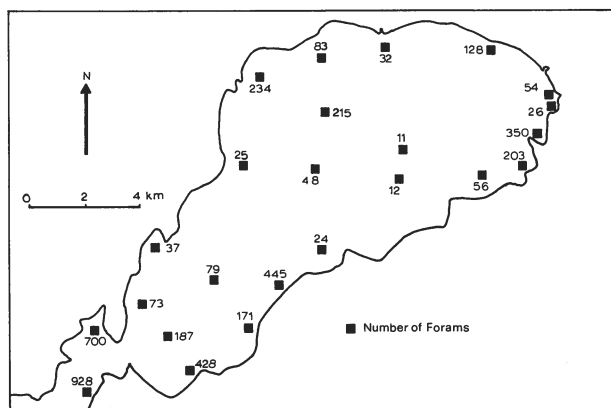
The results of the coarse fraction analysis can be plotted in a pie diagram. Text-fig. 2 shows the shell, gravel, sand, and mud content in each station.

FORAMINIFERA AND OSTRACODA OF KALLONI BAY

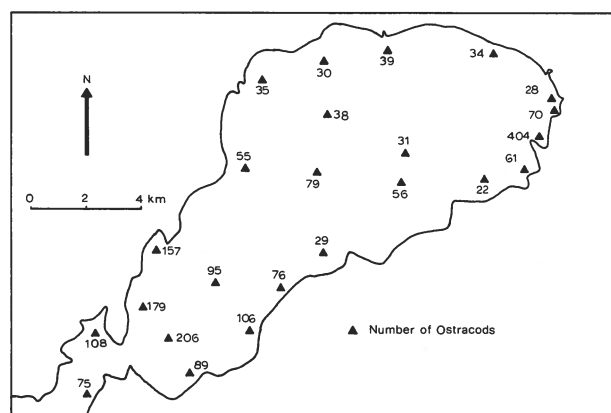
The $-x+70$ mesh fraction (more than 0.21 mm and less than 0.6 mm) has been chosen for Foraminifera and Ostracoda identification and counts because it was the richest.

For each station 0.5 ml of $-x+70$ mesh of dry sediment was picked for microfossils and the different species were identified by Tassos and Swain and counted.

Text-figs. 3, 4 and 5 show the distribution of Foraminifera and Ostracoda, and their ratio, respectively, while Table 1 gives an abstract description of each sample, the total number of Foraminifera and Ostracoda, and the percentage of each one in the different stations.



Text-fig. 3 - Distribution of Foraminifera in Kalloni Bay.



Text-fig. 4 - Distribution of Ostracoda in Kalloni Bay.

EXPLANATION OF PLATE 3

Ostracoda of Kalloni Bay, Lesvos Island, Greece.

Fig. 1 - *Bythocypris* sp., exterior, x 53.

Fig. 2 - *Ilyocypris* sp., exterior, x 27.

Fig. 3 - *Argilloecia* sp., exterior, x 56.

Fig. 4 - *Bosquetina* sp. 1, exterior of right valve, x 25.

Figs. 5, 6 - *Bosquetina* sp. 2. 5) Exterior of left valve, x 27; 6) interior of right valve, x 25.

Figs. 7, 8 - *Pterygocythereis* sp. 7) Exterior of left valve, x 27; 8) interior of left valve, x 27.

Fig. 9 - *Cytheridea* sp. 1, exterior of left valve, x 46.

Figs. 10, 11 - *Cytheridea* sp. 2. 10) Exterior of right valve, x 46; 11) interior of right valve, x 46.

Fig. 12 - *Cytheridea* sp. 3, exterior of left valve, x 45.

Fig. 13 - *Cushmanidea* sp., exterior of left valve, x 45.

Fig. 14 - *Cytherura* sp. 1, exterior of right valve, x 108.

Fig. 15 - *Cytherura* sp. 2, exterior of left valve, x 110.

Figs. 16, 16a - *Paracytheridea* sp. 16) Exterior of left valve, x 55; 16a) ventral view, x 95.

Figs. 17, 17a - *Semicytherura* sp. 1. 17) Exterior of left valve, x 54; 17a) ventral view, x 54.

Fig. 18 - *Semicytherura* sp. 2, ventral view of shell, x 55.

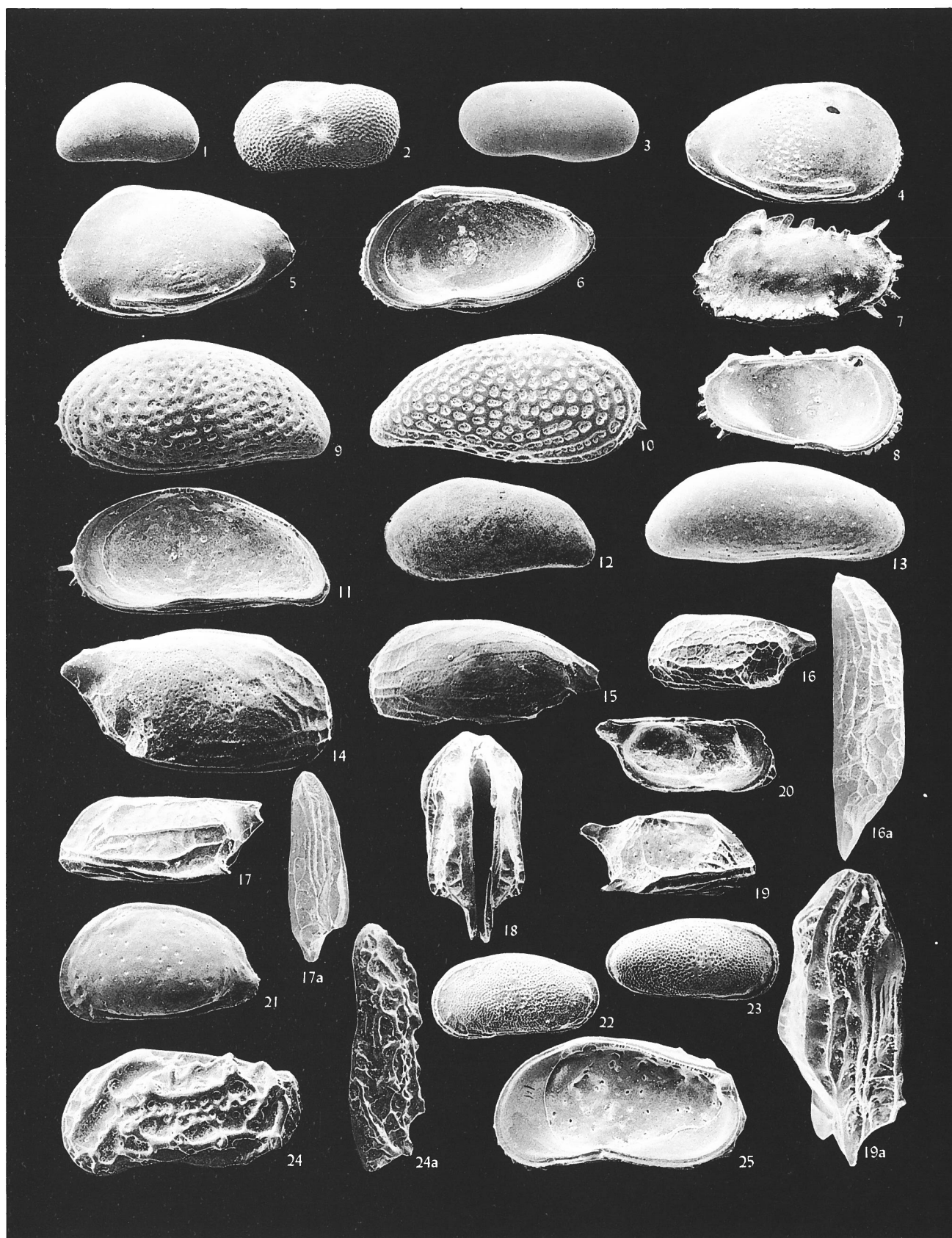
Figs. 19 - 20 - *Semicytherura* sp. 3. 19) Exterior of right valve, x 55; 19a) ventral view (tilted 69°), x 105; 20) interior of left valve, x 50.

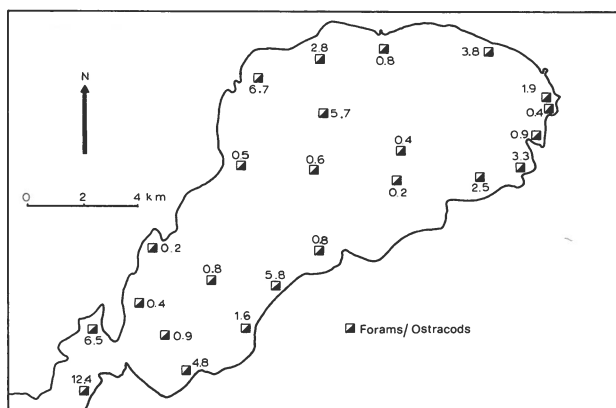
Fig. 21 - *Hemicythere* sp., exterior of left valve, x 52.

Fig. 22 - *Leptocythere* sp. 1, exterior of left valve, x 50.

Fig. 23 - *Leptocythere* sp. 2, exterior of right valve, x 58.

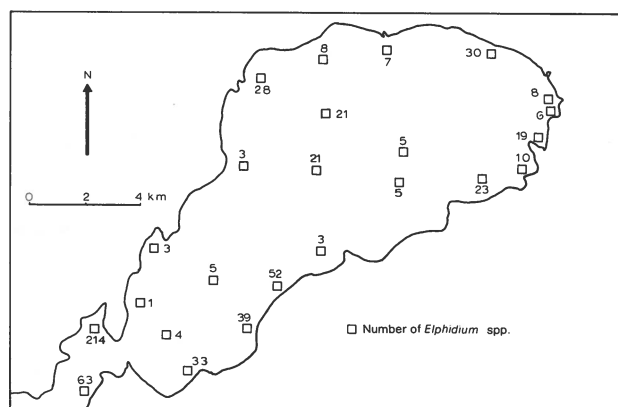
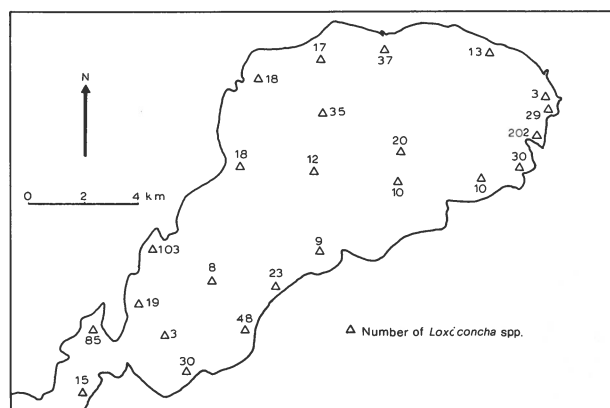
Figs. 24 - 25 - *Callistocythere* sp. 24) Exterior of left valve, x 55; 24a) ventral view (tilted 70°), x 54; 25) interior of right valve, x 54.





Text-fig. 5 - Foraminifera-Ostracoda ratio in Kalloni Bay.

Text-fig. 6 shows the distribution of *Elphidium* spp. while Text-fig. 7 refers to the *Loxoconcha* spp.

Text-fig. 6 - Distribution of *Elphidium* spp. in Kalloni Bay.Text-fig. 7 - Distribution of *Loxoconcha* spp. in Kalloni Bay.

There are several significant points in regard to distribution of Foraminifera and Ostracoda:

1. Most of the specimens were dead shells.
2. Many of the Foraminifera and Ostracoda showed signs of transportation (holes, thinned tests, etc.), and scars from algal growth, especially on Ostracoda.
3. There is a general trend for higher Foraminifera populations in the entrance and in the river mouths. The highest Foraminifera concentrations are observed in the east and west coast of the entrance (Stations 26 and 28).

Ostracoda specimens increase in number in the area just north of the mouth, while the highest concentration of them is observed in a small embayment (Station 7) within the bay. Ostracoda have a more uniform distribution than Foraminifera. The high concentration of both Foraminifera and Ostracoda

EXPLANATION OF PLATE 4

Ostracoda of Kalloni Bay, Lesvos Island, Greece. (continued)

Figs. 26, 27 - *Loxoconcha* sp. 1. 26) Exterior of left valve, x 110; 27) interior of left valve, x 55.

Figs. 28-28b - *Loxoconcha* sp. 2. 28) Exterior of right valve, x 110; 28a) enlargement of middle shell surface showing normal pores and sieve plates, x 268; 28b) enlargement of normal pore, basally knurled seta, and surrounding sieve plate, x 1085.

Fig. 29 - *Loxoconcha* sp. 1 ?, ventral view of shell, x 55.

Fig. 30 - *Loxoconcha* sp. 2 ?, ventral view (tilted 71°), x 46.

Figs. 31, 32 - *Cytheromorpha* sp. 31) Exterior of right valve, x 53; 32) interior of left valve, x 54.

Figs. 33, 33a - *Paradoxostoma* sp. 33) Exterior of left valve, x 50; 33a) ventral view (tilted 81°), x 42.

Fig. 34 - *Carinocythereis* sp. 1, exterior of right valve, x 28.

Fig. 35 - *Carinocythereis* sp. 1 ?, interior of right valve, x 28.

Fig. 36 - *Carinocythereis* sp. 2, exterior of right valve, x 25.

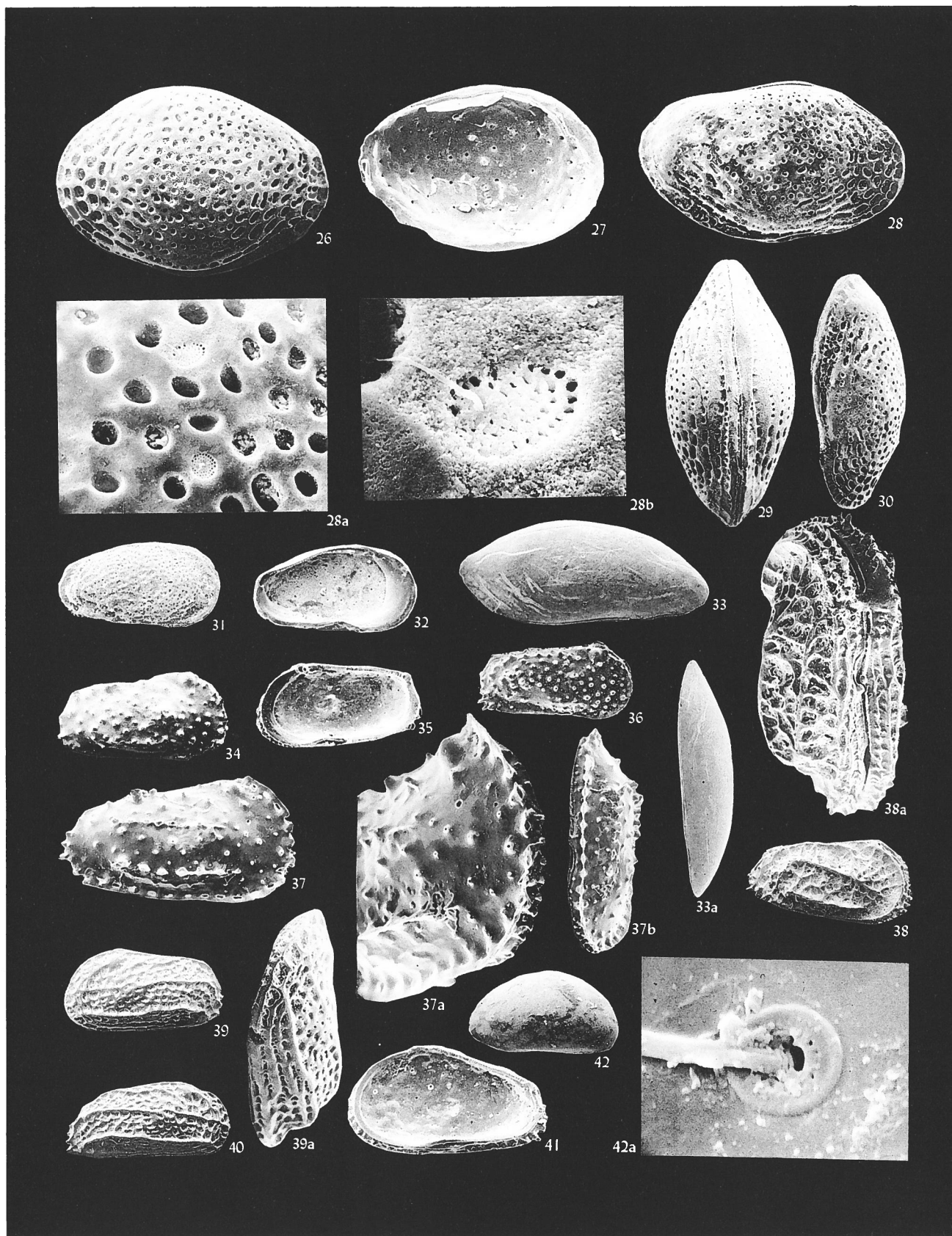
Figs. 37-37b - *Carinocythereis* sp. 3. 37) Exterior of right valve, x 49; 37a) enlargement of mid-anterior (tilted 71°), x 96; 37b) ventral view (tilted 71°), x 46.

Figs. 38, 38a - *Costa* sp. 1. 38) Exterior of right valve, x 28; 38a) ventral view of complete shell (tilted 75°), x 53.

Figs. 39, 39a - *Costa* sp. 2. 39) Exterior of left valve, x 23; 39a) ventral view (tilted 78°), x 55.

Fig. 41 - *Costa* sp. 2 ?, interior of right valve, x 55.

Figs. 42, 42a - *Xestoleberis* sp. 42) Exterior of right valve, x 53; 42a) enlargement of normal pore, basally knurled seta, and surrounding concentric cycle of pores of sieve plate, x 5300.



Station	Description	Total Number	Foraminifera (%)	Ostracoda (%)
2	shM	53	45	55
6	shsM	264	77	23
7	(sh) M	754	46	54
8	shgM	96	27	73
9	shsM	82	66	34
10	M	162	79	21
11	M	71	45	55
12	M	113	73	27
13	sh (g) sM	269	87	13
14	shM	253	85	15
15	shM	42	26	74
16	ShM	78	72	28
17	shM	68	18	82
18	shM	127	38	62
19	shM	80	31	69
21	ShM	521	85	15
22	(sh) M	174	45	55
23	shM	194	19	81
24	shM	252	29	71
26	(sh) (g) sM	808	87	13
28	(g) mS	1003	93	7
29	(sh) sM	393	48	52
30	ShsM	517	83	17
31	shsM	277	62	38
Total		6647	Ave. 57%	Ave. 43%

Tab. 1 - Sample classification, total number of Foraminifera and Ostracoda, and percentages of total number at each station. (Symbols: (sh)= 1-5% slightly shelly; sh= 5-30% shelly; Sh= 30-80% very shelly; SH= 80-100% shells; M= mud; m= muddy; S= sand; s= sandy; g= gravelly; (g)= slightly gravelly).

Station	Sand-Mud	Foraminifera	Ostracoda	F-O
2	0.06	24	29	0.8
6	0.73	203	61	3.3
7	0.04	350	404	0.9
8	0.63	26	70	0.4
9	0.19	54	28	1.9
10	0.01	128	34	3.8
11	0.02	32	39	0.8
12	0.07	83	30	2.8
13	0.45	234	35	6.7
14	0.01	215	38	5.7
15	0.01	11	31	0.4
16	0.05	56	22	2.5
17	0.01	12	56	0.2
18	0.01	48	79	0.6
19	0.01	25	55	0.5
21	0.04	445	76	5.8
22	0.02	79	95	0.8
23	0.03	37	157	0.2
24	0.02	73	179	0.4
26	0.16	700	108	6.5
28	4.54	928	75	12.4
29	0.16	187	206	0.9
30	0.18	428	89	4.8
31	0.13	171	106	1.6

Tab. 2 - Sand-mud ratio, number of Foraminifera and Ostracoda present, and Foraminifera-Ostracoda ratio.

around the entrance could be a result of transportation or of more favorable conditions for their growth in that area.

The fact that almost all the specimens are dead (quite common in other marine areas also) suggests that either they were dead at the sampling time or that they have been transported from somewhere else. Swain (personal communication, 1975) thinks that the former most likely is happening. According to him, there are evidences from other locations showing that Foraminifera and Ostracoda can only be transported for several tens or at the most several hundreds of meters.

An attempt to correlate their abundance with the sand-mud ratio was unsuccessful. (See Tab. 2). The implication is that if Foraminifera and Ostracoda grow in the bay, their distribution is mainly controlled by currents, temperature, and salinity. The substratum is of subordinate importance, since it is fairly uniform in size and organic matter content.

The following biofacies have been recognized in the bay:

I. General Bay

Common:
Elphidium spp. *Loxococoncha* spp.

II. Upper Bay

Common:
Discorbids *Carinocythereis* spp.
Anomalina sp.

Present:
Ammonia sp. 1, 2 *Cytheridea* spp.
Eponides sp. *Cushmanidea* sp.
Pterygocythereis spp.

Minor:
Ammotium sp. *Costa* spp.
Triloculina spp. *Semicytherura* spp.
Massilina sp. 1 *Bosquetina* sp. 1, 2

III. Lower Bay

Common:
Quinqueloculina spp. *Bosquetina* sp.

Present:
Triloculina spp. *Cytheridea* spp.
Ammonia sp. 1, 2 *Cyprideis* sp.
Massilina sp. 1, 2 *Pterygocythereis* spp.
Ammotium sp.
Nonionella spp.

Minor:
Textularia sp. *Cytherura* sp. 1, 2
Eponides sp. *Semicytherura* spp.
Discorbids *Callistocythere* sp.
Cibicides sp. *Hemicythere* sp.
Argilloecia sp.
Xestoleberis sp.
Costa spp.

Among the Foraminifera, found in Kalloni Bay, most groups such as *Elphidium* and Discorbids have typical shallow water forms, while *Cytheridea* and *Cushmanidea* represent some of the shallow-water Ostracoda forms. Also, among the Ostracoda, *Loxococoncha*, *Carinocythereis*, and *Cyprideis* have mesohaline forms, which implies that they can adjust to salinities from 0.5‰ to above 32‰. Genera that are more likely to be found in deeper waters are *Quinqueloculina*, *Triloculina*, *Nonionella*, *Ammonia*, and others from the Foraminifera. From the Ostracoda, the most common deep water forms are *Bosquetina*, *Pterygocythereis*, *Argilloecia*, and *Bythocypris*. Nevertheless, these forms can adapt to shallower waters.

In the core v10-46 (depth 69 m), approximately 40 km southeast of Kalloni Bay, the following genera of Ostracoda have been found: *Bairdia*, *Buntonia*, *Callistocythere*, *Carinocythereis*, *Costa*, *Cytherella*, *Cytheridea*, *Cytheropteron*, *Henryhowella*, *Leptocythere*, *Loxococoncha*, *Pterygocythereis*, *Trachyleberis*, and *Xestoleberis* (Puri, Bonaduce, and Gervasio, 1969).

Foraminifera and Ostracoda found in the surface sediments of Kalloni Bay are shown in Pls. 1-2 and 3-4, respectively.

CONCLUSIONS

We have here a typical shallow warm euryaline water microfauna. If during the Paleozoic and Mesozoic we had similar faunas for the most parts of Tethys, the implication will be that we are dealing with a rather shallow epicontinental sea, and not with a deep ocean which many models use as a basic assumption.

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