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INTRODUCTION

Published studies on the oraminifera of the Mediterranean Sea commenced with Batsch (1971) at the end of the 18th Century. His work was followed by that of Fichtel and Moll (1798). D'Orbigny (1826) was the first author to publish in the next century on Mediterranean Foraminifera. These earlier works are not of much value, partly due to the infancy of the foraminiferology of the time, and partly to the absence of distribution data. Jones and Parker (1860), Silvestri (1895, 1898, 1900), and Fornasini (1899a, 1899b, 1900, 1902) further contributed to the earlier efforts in this respect. Sidebottom's continious publications (1904—1909) on the Foraminifera around Delos Island in the Aegean Sea can be considered the first step in the direction of a complete foraminiferal investigation. Colom (1942) published the first comprehensive paper of our times. An equally comprehensive work by Ruscelli (1949) on the Foraminifera of the Ligurian Sea was followed by two papers (Muraour, 1954a, 1954b) on the quantitative distribution of foraminifera near Algiers. Emiliani (1955) was the first to publish the results of the isotopic paleotemperature analyses by means of planktonic foraminifera in Pleistocene sediments of the Mediterranean Sea. In the same year, a detailed study on foraminifera of the Ligurian Sea was completed by Giunta (1955). Parker (1955) studied planktonic foraminiferal populations of the Mediterranean Sea, observing that the Eastern and Western Mediterranean basins and the Aegean basin were characterized by distinct population distributions. She concluded that the populations probably originated from the Atlantic and from native ancestral stock. Parker (1958),

in the most complete foraminiferal study so far of the Eastern Mediterranean basin, studied the taxonomy and quantitative distribution of both planktonic and benthonic foraminiferal populations from 16 long cores from Eastern Mediterranean basin and 60 surface sediment samples from Eastern Mediterranean and the Aegean basins. Among others, she observed an increase in the planktonic/benthonic population ratio of the surface samples with increased depth, which reached 99 percent at about 1300 m. Study of surface sediment samples revealed five benthonic assemblages between 25 m and 3974 m. In contrast, the benthonic foraminiferal populations in the cores were found to be very small compared to the planktonic populations. Core descriptions were followed by systematic descriptions .Foraminifera in the cores taken from Western Mediterranean basin were the subject of an investigation by Todd (1959). Planktonic foraminiferal populations of some submarine cores from the Adriatic Sea were examined by Cita and D'Onofrio (1967) for paleoclimatic investigations. Hooper (1969), in a statistical study, examined Parker's (1958) foraminiferal depth assemblages in the Eastern Mediterranean basin. Employing a Fortran program known as COVAP for factor-vector analysis in the Q-mode, he concluded that 5 depth assemblages were present. But the limits of depth zones differed slightly, and the depth assemblages calculated statistically agreed more closely with the stratification of the water masses assumed for the basin by Pollak (1951). A rather limited foraminiferal study on the phlyogenetic relationships between the genera of foraminiferal familiy Soritidae in the Aegean Sea was completed by Sellier de Cirrieux in 1970. Reiss, Merling-Reiss and Moshkovitz (1971) studied the planktonic foraminiferal populations from the southern continental shelf and slope of Israel. Statistical methods were employed by the authors in an attempt to reconstruct the paleogeographic changes in terms of geochronology. Finally, Glaçon, Vergnaud, Leclaire and Sigal (1973), in an investigation on paleogeographic history of the Tethy Sea, studied the presence of two planktonic foraminiferal species in the Mediterranean Sea.

In view of the paucity of investigations on Foraminifera of the easternmost Mediterranean Sea, the present study of benthonic and planktonic foraminifera of the continental shelf of Lebanon was initiated. The continental shelf along central Lebanon is only a few miles wide, becoming wider to the north and south. The gentle dip of the shelf suddenly increases at about 125 meters. This depth is accepted by the author as the continental shelf/slope break in the study area. The central part of continental shelf of Lebanon is cut by several submarine canyons (Tejirian, 1970; Goedicke, 1972). Located in the study area, from north to south, are Jounie, St. George's, and Beirut submarine canyons. Predominant sediments in the area of investigation are brown colored muds, clays, silty muds, sand and, occasionally, coralline algae debris. The only available bottom sediment map (Boulos, 1962) indicates a random distribution of sediments.

METHODS AND MATERIALS

A total of 50 sediment samples for a study of the distribution of Foraminifera were collected from the central continental shelf of Lebanon including St. George's and Jounie Bays and submarine canyons off Beirut.

Figure 1 shows the location of 22 of the 50 samples analyzed to date.

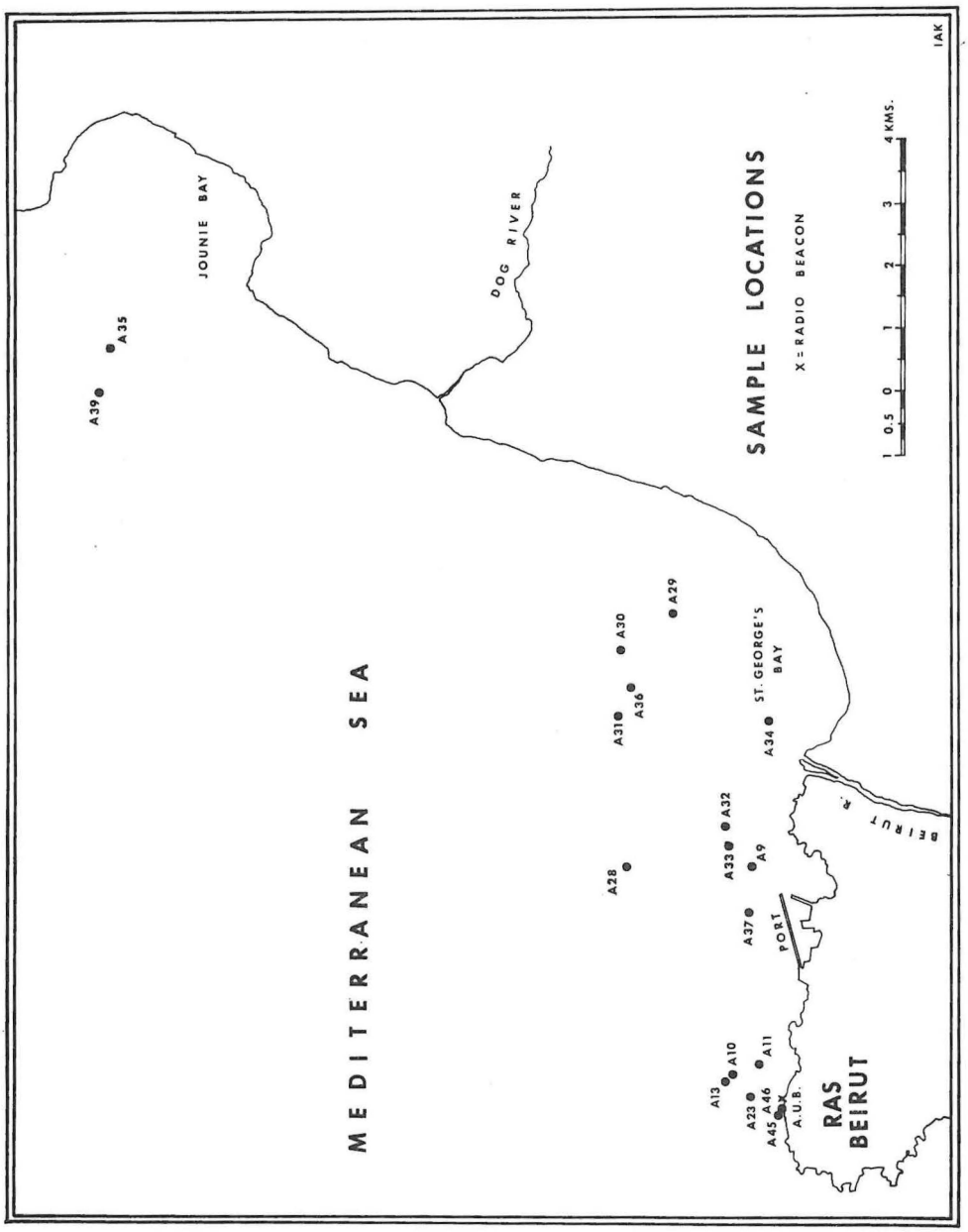

Fig. 1 — Location of sediment samples used for the study of Foraminifera from the central continental shelf of Lebanon.

The sediment samples were collected using either a cone dredge, gravity corer, or by Scuba. The corer could take sediment samples up to 150 cm long, and the cone dredge could collect about 5 kg of surface sediment. The samples ranged in depth from 5 to 440 m. Eight of the 22 samples were obtained by coring from between 42 and 275 m, 8 by dredging between 25 and 440 m, and 6 by Scuba between 5 and 30 m. The cores ranged in depth from 30 to 75 cm. Only the top one cm of the cores have been analyzed in this study. Six hundred g of wet sediment from each cone dredge and Scuba sample was analyzed. Table 1 shows the location, depth and method of collection of the samples.

In the laboratory, the samples were washed with distilled water. Three hundred g of sediment from some samples was treated with 3 percent H_2O_2 to remove clay particles adhering to depressions in the foraminiferal tests. In order to eliminate excessive plant remains, 300 g of one sample was treated with commercial Clorox. As a result of this treatment, over 95 percent of the arenaceous Foraminifera in the sample was destroyed. Prepared samples were examined and photomicrographed by a Leitz Ortholux microscope camera combination.

Table 1. Location, depth and method of collection of sediment samples.

Sample	Location	Depth (m)	Method of Collection
A9	St. George's Bay	25	Dredge
A10	Beirut Canyon	400	Dredge
A11	Beirut Canyon	280	Dredge
A13	Beirut Canyon	440	Dredge
A23	Beirut Canyon	100	Dredge
A28	St. George's Bay	240	Core
A29	St. George's Bay	42	Core
A30	St. George's Canyon	150	Core
A31	St. George's Canyon	275	Core
A32	St. George's Bay	40	Dredge
A33	St. George's Bay	30	Dredge
A34	St. George's Bay	40	Dredge
A35	Jounie Canyon	157	Core
A36	St. George's Canyon	235	Core
A37	St. George's Bay	80	Core
A39	Jounie Canyon	230	Core
A41	Off Aamchit	5	SCUBA
A42	Off Aamchit	10	SCUBA
A43	Off Aamchit	15	SCUBA
A44	Off Aamchit	30	SCUBA
A45	A. U. B. Beach	5	SCUBA
A46	A. U. B. Beach	10	SCUBA

Although the forminiferal distribution pattern on the continental shelf of Lebanon is being investigated at specific level, the preliminary results are considered herein at the generic level. Some of the significant findings at the specific level, however, are included in the present paper.

RESULTS

The examination of samples revealed a very rich foraminiferal fauna. Most of the foraminifera found in the sediment samples are benthonic. The number of benthonic genera was 75 against 4 planktonic genera. About 12 percent of the benthonics were arenaceous forms, while 20 percent were porcelaneous and 68 percent were hyaline genera. A complete list of genera found in the 22 samples of this study is given on Table 2.

Table 2. Genera of Foraminifera recorded from the central continental shelf of Lebanon.

Arenaceous:
Ammobaculites
Ammodiscus
Ammomarginulina
Bigenerina
Clavulina
Cribrostomoides
Eggerella
Glomospira
Haplophragmoides
Reophax
Textularia

Porcelaneous:
Amphisorus
Articulina
Biloculinella
Cornuloculina
Miliolinella
Nubeculina
Ophtalmidium
Peneroplis
Pseudomassilina
Pyrgo
Quinqueloculina
Sorites
Spiriloculina
Spirolina
Triloculina
Vertebralina

Hyaline:
Acervulina
Ammonia
Amphicoryna
Asterigerinata
Astrononion
Bolivinita
Brizalina
Buccella
Bulimina
Cassidulina
Cibicides
Cibicidina
Cymbaloporella
Dentalina
Elphidiella
Elphidium
Epistominella
Eponides
Fursenkoina
Gavelinopsis
Globigerina
Globigerinoides
Globobulimina
Hanzawaia
Hoeglundina
Hyalinea
Lagena
Marginulina
Melonis
Neoconorbina
Neogloboquadrina
Nodosaria
Nonion
Nonionella
Oolina
Orbulina
Pararotalia
Planorbulina
Planorbulinella
Planulina
Pullenia
Rectuvigerina
Reusella
Rosalina
Siphonina
Sphaerogypsina
Sphaeroidina
Spirillina
»Tretomphalus«
Trifarina
Uvigerina
Valvulineria

Some samples collected by means of Scuba diving from near-shore locations (5 to 10 m) were characterized by an abundant *Amphistegina* population which formed about 80 percent of total population. *Peneroplis* was the most abundant porcelaneous genus. In addition, several porcelaneous genera

including *Triloculina*, and *Quinqueloculina* were present. Between 15 and 30 m *Heterostegina* became the dominant genus with about 50 percent frequency followed by *Amphistegina* which formed 30 percent. Below 20 m, diverse hyaline genera appeared. An interesting point was the almost complete lack of arenaceous forms and complete absence of planktonic genera in the samples collected by Scuba diving. Several arenaceous genera such as *Bigenerina, Clavulina, Textularia, Ammobaculites,* and *Reophax* were found, forming from a few to 80 percent of the population in samples collected between 40 and 100 m. At some stations, *Textularia calva* and *Clavulina crustata* formed the major portion of the population. *Elphidium* first appeared at 40 m where, in some samples, about 80 percent of the population was porcelaneous. Species of *Uvigerina* ms first appeared just above 100 m. The planktonics, on the other hand, were first encountered in the sediments collected from 80 m. The dominant species among the planktonic population was the pink variety of *Globigerinoides ruber. Orbulina universa* was also quite frequent. At approximately 100 m, porcelaneous genera were present in great numbers in some samples. In addition to *Triloculina* and *Quinqueloculina, Vertebralina, Peneroplis, Spirolina, Sorites* and *Amphisorus* were frequent porcelaneous genera.

A core (A35) collected from 157 m along the axis of Jounie submarine canyon clearly displayed sediments disturbed by slumping in the canyon Goedicke and Sagebiel (1975). The slumping is believed to be responsible for the presence of displaced nearshore foraminiferal fauna in the deeper portions of the canyon. The bottom portion of the core is composed of clay size particles while progressively coarser particles make up the upper portion. An interesting point about the upper portion of the core is that most of the coarse sediment particles in this section are formanifera along with angular to subangular quartz sand grains. An independent detailed study of this particular core is being conducted by the author.

Foraminifera present in the samples collected from between 150 and 300 m did not show a definite distribution pattern. At these depths, either porcelaneous, arenaceous, or hyaline genera were found to be the dominant group from one location to the other. At the present stage of this investigation such a change appears to be random. Although the benthonics formed overall abundance in the samples around 250 m they contained a quite large population of planktonics, especially *Globigerinoides ruber, Globigerina bulloides* and *Orbulina universa.* At 2 stations, A28 (240 m) and A39 (230 m), corallina algae debris made up about 70 percent of the bottom sediments. Near 300 m (A11), along the axis of the Beirut submarine canyon where angular sand grains formed the bulk of the bottom sediments, hyaline and porcelaneous foraminifera were equally dominant. In addition to nearshore species of *Elphidium,* species of *Triloculina, Quinqueloculina,* and *Pyrgo* were quite frequent. This may be evidence of displacement of the foraminiferal population as well as some of the sediment found at this location. At 300 m, the dominant species in the relatively small planktonic population were *Globigerinoides ruber* (pink variety), *Orbulina universa, Neogloboquadrina dutertrei,* and *Globigerina bulloides.* In addition, a few *Globigerinoides sacculifer* were observed. Below 400 m, hyaline genera were dominant although planktonic/benthonic foraminiferal population ratio continued to increase with increased depth.

DISCUSSION AND CONCLUSIONS

Nearshore microfauna on the continental shelf of central Lebanon is dominated by *Amphistegina* and *Heterostegina* species. Arenaceous and planktonic foraminifera are absent in the samples collected from 5 to 30 m. A strong relationship between the sediment type and the arenaceous foraminifera is indicated between 40 and 100 m. This relationship is strongest for some arenaceous species. *Textularia calva* and *Clavulina crustata* were, for example, quite abundant in silty to fine sandy sediments. Examination of some stations revealed concentration of some genera. This fact is believed to reflect postmortem selective transportation and deposition. The relationship between the type of the bottom sediments and the foraminiferal genera seems to be random between 150 and 300 m. This observation coupled with the fact that nearshore foraminifera and coralline algae appeared at the deeper parts of this interval may indicate downslope movement of sediments in the study area. Core A35 collected from 157 m strongly supports this idea. Another explanation for the presence of coralline algae at 230 and 240 m, and the nearshore foraminifera at 280 and 300 m could be the lowering of the sea level in the Mediterranean basin during the last glacial period. The number of samples studied so far does not permit to make a definite selection between two hypotheses.

Planktonic faraminifera which were first found at 40 m generally showed a continuous increase with increased depth. This is in agreement with the conclusion of other workers for various parts of the present and past oceans (Bandy. 1956; Parker, 1958; Waller and Polski, 1959; Stehli, 1966; Kafescioglu, 1971). The only exception was observed at 280 m where the relative abundance of planktonic foraminifera drastically decreased, probably due to the artificial concentration of benthonics brought to deeper levels by downslope movement of sediments. Beyond this depth the distribution of foraminifera resumed its normal pattern with predominant hyaline forms and planktonics increasing with depth.

SUMMARY

The distribution of benthonic and planktonic Foraminifera on the continental shelf of Lebanon was investigated. A total of 22 short core, dredge, and Scuba samples, ranging in depth from 5 to 440 m. from the narrow continental shelf and three submarine canyons that bisect the study area were examined. A very rich foraminiferal population was found and a total of 75 genera were identified. A normal distribution pattern for Foraminifera was observed between the shore and 150 m, and again beyond 280 m. The depth interval between 150 m and 280 m is believed to have been disturbed by sediment movement. A strong relationship between the arenaceous foraminifera and the type of bottom sediments was clearly indicated.

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KRATAK SADRŽAJ

Istraživano je rasprostranjenje bentoskih i planktonskih foraminifera kontinentalnog šelfa Libanona. Ukupno su analizirana 22 uzroka dobivena pomoću geološke sonde, dredže i autonomnih ronilaca (SCUBA). Uzroci potječu iz uskog kontinentalnog šelfa i triju podmorskih kanjona koji presijecaju istraživano područje. Zabilježena je vrlo bogata populacija foraminifera i determinirano je ukupno 75 rodova. Foraminifere su normalno bile rasprostranjene od obale do dubine od 150 m i ponovno ispod 280 m dubine. Za dubinski interval, od 150 do 280 m, se vjeruje da je bio poremećen pomicanjem sedimenata. Jasno je izražen odnos između arenacejskih foraminifera i tipa sedimenata dna.