Relationship between Pliocene marine invertebrate paleocommunities and water depth in the Nicosia Formation, Cyprus

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INTRODUCTION

There have been few paleontological studies of the Pliocene formations of the Mesaoria Basin, Cyprus. The most extensive paleontologic studies of the Nicosia Formation were conducted by Cowper Reed between 1933 and 1940. In a series of four articles, he published species lists and described new species from sites throughout the Mesaoria Basin. However, there has been no analysis of the paleoecology of the communities preserved in the Nicosia Formation sediments. Fossils collected from eight sites in the Nicosia Formation characterize eight separate paleocommunities, ranging from a very diverse paleocommunity represented by 42 species to a paleocommunity that was primarily composed of *Ostrea sp.* and the bivalve *Anadara diluvii* (Figure 1). Sediment samples were collected at each site, and the differences between foraminiferal assemblages supported the previously identified divisions of paleocommunities. Foraminiferal analysis indicates that these marine invertebrate communities were primarily depth controlled.

GEOLOGIC SETTING

The oldest sediments deposited in the Mesaoria Basin during the Pliocene are the calcareous marine silts of the lower to upper Pliocene Nicosia Formation, which uncomformably overlies the marl, chalk, and gypsum beds of the Miocene Kalavasos Formation (McCallum and Robertson, 1990). This unconformity is a result of the Messinian salinity crisis. During the Messinian (late Miocene), the Mediterranean was isolated from the Atlantic due to the interaction of various tectonic, climatic, and eustatic factors, causing a Mediterranean-wide evaporitic event- the Messinian Salinity Crisis (Rouchy and Saint Martin, 1992). The 900 meter-thick Nicosia Formation is thought to represent sediments from the uplifted Troodos that were being deposited into the subsiding basin during the rapid return of open seas to the basin (McCallum and Robertson, 1990).

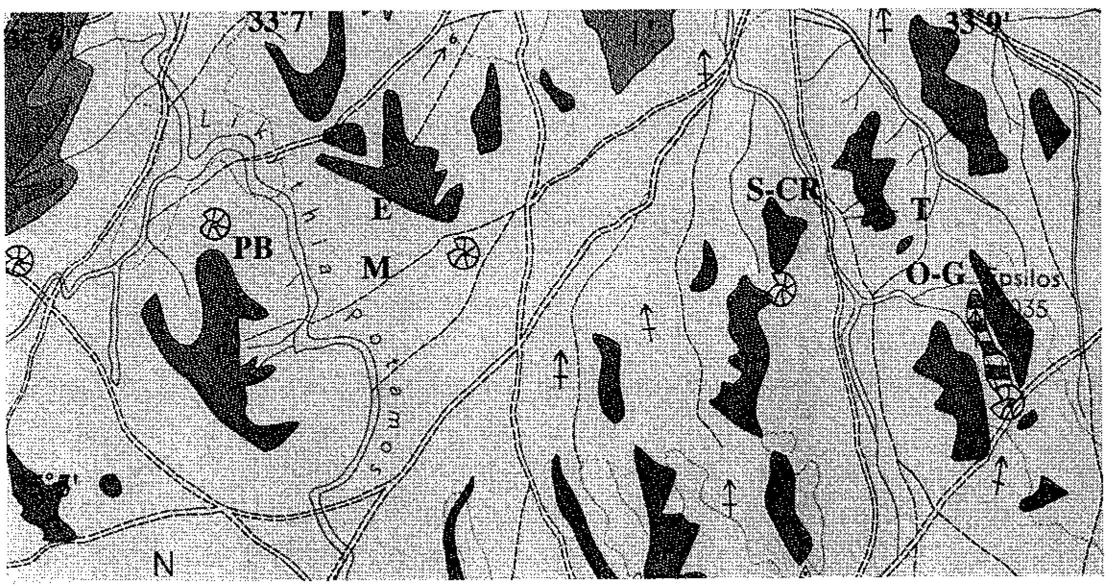

Figure 1. Map of fossil localities, using GPS data; where two sites are located together, they were too close to resolve using GPS. Site abbreviations: PB, Pelican-Brachiopod; M, Mark; E, Ellen; S-CR, Epsilos-Shark and Coral Reef; T, Epsilos-Turritella; O-G, Epsilos-Oyster and Epsilos-Giant.
Formations labeled "I" are the Fanglomerate Series (Pleistocene), and "N" labels denote the Nicosia Formation. Geological map from Bear, 1960. Scale of two inches to one mile.

METHODS

Field Methods. Specimens were collected from 8 sites, south and southwest of Meniko (Figure 1). Total sample numbers vary from 69 to 406 individuals per site, and species number varies from 8 to 42 per site. Sediment samples were taken at each site in order to collect foraminifera samples, which were analyzed by Steven Dornbos and Mark Wilson.

Laboratory Methods. Due to the fact that immediate identification the genus of a fossil was not always possible, a temporary name was assigned to the shell in Cyprus. Identification of the fossils collected was carried out by comparing each specimen to multiple sources of descriptions and photos (Sabelli, 1980; Tornaritis, 1987; Malatesta, 1974). These same sources also provided ecological data about the life habits of each genus or species. Sediment samples (40 ccm) were sieved through the 40, 60, and 80 mesh sizes, and forams were picked from the 60 mesh. All of the 60 mesh fractions were picked clean for each site with the exceptions of Epsilos-Oyster and Pelican-Brachiopod.

Depth Determination. Two different methods were used to obtain depths from the foraminiferal data. Wright, 1977, derived a formula that can be used to calculate the depth directly. The equation is as follows: D=e^ (0.0418P +3.4823), where D is water depth in meters and P is the percent of planktic foraminifera in the sample (Table 1). This equation does not, however, hold if the percent of planktic foraminifera in the sample is less than 5 percent, which is the case for three of the sites in this study. In these cases, the only information yielded from this equation is that these paleocommunities were at less than 40 m. The second method used to determine depth involves plotting the planktic foraminifera percentage on a curve generated by Grimsdale and Morkhoven (1955), and reading off the depth of the water. These results closely correspond to the results from Wright, 1977.

Table 1. Depth of paleocommunities as calculated from Wright, 1977.

	% of Planktonic Foraminifera	Depth		% of Planktonic Foraminifera	Depth
Coral Reef	3.6	<40 m	Epsilos- Shark	18	69 m
Epsilos- Turritella	3.7	<40 m	Epsilos- Giant	20	75 m
Epsilos- Oyster	.87	<40 m	Mark Site	43	196 m
Ellen Site	6.3	42 m	Pelican-Brachiopod	82	1002 m

DESCRIPTION OF PALEOCOMMUNITIES

Coral Reef. The dominant feature at this site is a *Cladocora sp.* reef outcrop that is 9m thick in the center, and extends 50 m horizontally. The reef thins out to a thickness of 0 m from the central thickest area. The preservation at this site is incredible. There were *Cladocora sp.* growths on the left valves of *Spondylus sp.*, as well as *Spondylus sp.* fossils within the reef that we were not able to collect. Overall, of the 42 species represented here, the majority were filter feeders, such as *Spondylus sp., Chlamys sp., Arca noae, Chama carinata* and *C. gryphoides* (Table 2). This paleocommunity had a relatively large number of predators, seen by naticid bore holes in *Antigona (Ventricola) cunctata* individuals collected here as well as a crab claw tip. Some of the benthic foraminifera found at this site are useful in determining temperature and depth ranges, as well as paleoenvironmental information. The temperature ranges that *Ammonia beccarii* and *Rosalina globularis* prefer overlap, constraining the water temperature to 20-25° (Boltovskoy and Wright, 1976). Since *Cibicides lobatulus* is currently found living on vegetation, and there are 6 species of herbivores at this site, there was a large amount of vegetation that left no fossil record (Boltovskoy and Wright, 1976). Also, *Elphidium crispum* has a depth ranging from the inner shelf to 50 m, and *Asterigerina sp.* has a depth ranging from the inner shelf to 70 m (Murray, 1973). This paleocommunity was most likely situated on the inner shelf, and due to the presence of a reef and the large amount of plant life, at less than 20 m in depth.

Epsilos-Turritella. The fossils at this site were very well preserved, with no sorting and very little sign of transport. There was a total of 12 mollusca species collected at this site, with *Turritella tricarinata* accounting for 335 individuals, and 82.5% of all fossils found here (Table 2). The second most common species at this site was *Antigona (Ventricola) cunctata,* an infaunal filter feeder that comprised 10.3% percent of the individuals collected at Epsilos-Turritella. The burrower *Fursenkoina schreibersiana* is found at depths ranging from 20-50 m, and *Turritella tricarinata* is usually found at depths of about 25 m (Murray, 1973; Malatesta, 1974). This paleocommunity was probably located at depths between 25- 40 meters.

Epsilos-Oyster. This fossil bed was dominated by a layer of *Ostrea sp.* shells, all about the same size, well preserved with little breakage, and with only a third of them articulated. It is possible that this assemblage of

Ostrea sp. shells was deposited by a storm deposit. Above this one layer that accounts for 65% of all shells at this site, there are several epi-faunal filter feeders, such as *Spondylus sp., Chlamys sp., Serpulids, Vermetus sp., Chama carinata* and *C. gryphoides* (Table 2). The benthic foraminiferal assemblage at this site is the same as Epsilos-Shark and Coral Reef, and the only difference is the much greater abundance of foraminifera found here. From the paleoenvironmental indicators mentioned in the Coral Reef section as well as the depth information from Wright (1977), it can be concluded that this paleocommunity was situated at in the inner shelf, above 40 meters in depth.

Ellen Site. The most common fossil from this site was *Ostrea sp.* (43.6%), followed by *Glossus humanus?* (23.8%), both filter feeders (Table 2). Terebratulids were also found in this field area. The preservation at this site was not good. Some articulated *Ostrea sp.* were found, and right and left valves of *Glossus humanus?* were commonly found together, but always broken. Therefore, there was limited transport of the fossils in this area. The foraminifera from this field area do not yield any paleoenvironmental information.

Epsilos-Shark. There were patches of *Cladocora sp.* throughout this field area, ranging from 7-12 cm high and 25 cm wide. Also, *Spondylus sp.* and *Chama sp.* left valves were often attached to parts of a clump of *Cladocora sp.* A total of 25 different species were collected from this very well preserved site. The high abundance of herbivores indicates that vegetation was dense (Table 2). Naticid borings were common in fossils from this site. The benthic foraminiferal assemblage at this site is the same as the ones at Epsilos-Oyster and Coral Reef. This paleocommunity most likely inner shelf (Murray, 1973).

Epsilos-Giant. Of the 20 species collected from this area, 22.7% are *Aporrhais sp.*, 18% are *Ostrea sp.*, and 13.3% are *Turritella (Torculoidella) subangulata* (Table 2). There are naticid boreholes on *Antigona (Ventricola) cunctata, Turritella (Torculoidella) subangulata,* and *Cardium echinatum.* Additionally, shell fragments that had been bored by sponges were found at this site. The fossils from this area were well preserved, and articulated *Ostrea sp.*, and *Pecten sp.* were collected. The benthic foraminifera *Elphidium crispum,* with its depth range of inner shelf to 70 m, was collected at Epsilos-Giant, which suggests that this paleocommunity existed at deep end of that range.

Mark Site. There were only 8 species found at this site, primarily *Ostrea sp.* and the bivalve *Anadara diluvii.* The only sign of predators was a turritella with naticid boreholes. As shown in Table 2, this site is predominately populated by filter feeders, with very few deposit feeders, almost no predators, and no herbivores. The preservation of shells at this site was good. The foraminifera from this field area are not diagnostic in terms of paleoenvironmental information. This paleocommunity was most likely located on the outer shelf, deep enough that there was no significant light transmittal. The depth from the foraminiferal data is 196 m, very near the aphotic zone (Boltovskoy and Wright, 1976).

Pelican-Brachiopod Site. This assemblage is the second most diverse, with 37 species. More than half of these are filter feeders, but 9 of the species are predators, which comprise 15.6 % of the individuals found at this site (Table 2). *Cassidaria sp.* preyed on echinoids, and *Epitonium sp.* preyed on sea anemones (Sabelli, 1980). This site was very well preserved, with no signs of sorting or abrasion. The most common fossils found at this site were *Amusium cristatum* (10.7%), a Terebratulid species (8%), and two species of *Turritella* (14%). The foraminiferal data from this site is not helpful in determining depth or paleoenvironment. The depth determined above is most likely the correct depth for this paleoenvironment (Table 1).

CONCLUSIONS

Although the mollucsian paleocommunities from these different sites vary widely, the foraminiferal data seems to group certain foraminiferal assemblages with different depths. There is a definite grouping of foraminiferal species that are found at Coral Reef, Epsilos-Oyster, and Epsilos-Shark. Additionally, the water depth determines the amount of light that reaches the sea floor, which to a large extent determines the amount of vegetation, and thereby the abundance of life forms whose diet consists of herbivores. Therefore, the primary factor in forming different fossils assemblages in the Nicosia Formation was due to water depth.

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Table 2. Comparison between the number of species and the percent of individuals found at each site, divided into ecological niches.

	Filter Feeders		Deposit Feeders	
Community	Number of Species	% Individual Abundance	Number of Species	% Individual Abundance
Coral Reef	21	85.4	0	0
Epsilos-Turritella	7	98.5	1	0.3
Epsilos-Oyster	13	81.8	1	1.8
Ellen Site	12	98.7	1	present
Epsilos-Shark	16	74	1	1.3
Epsilos-Giant	10	59.6	1	22.7
Mark Site	6	97.2	1	1.5
Pelican-Brachiopod	19	72	2	5.7

Table 2. Continued.

	Predators		Herbivores	
Community	Number of Species	% Individual Abundance	Number of Species	% Individual Abundance
Coral Reef	8	5.1	6	7.2
Epsilos-Turritella	4	1.4	0	0
Epsilos-Oyster	3	2.4	3	3.6
Ellen Site	2	present	0	0
Epsilos-Shark	3	4.4	3	17.1
Epsilos-Giant	5	7.8	3	4.7
Mark Site	0	0	0	0
Pelican-Brachiopod	9	15.6	3	2.4