

ΠΑΛΑΙΟΝΤΟΛΟΓΙΑ.— **Mollusca and Foraminifera from the Tyrrhenian of Arvi, Crete, with some paleoecological notes**\*, by **G. J. Boekschoten** \*\*. Ἀνεκοινώθη ὑπὸ τοῦ Ἀκαδημαϊκοῦ κ. Μ. Κ. Μητσοπούλου.

#### INTRODUCTION

During research on the Neogene of Crete, Prof. Dr. P. Psarianos (Athens) guided the author to an occurrence of marine Pleistocene on the southern coast of the island. The exposures were studied and some sample material was collected. The identification of the latter posed several problems. First, the Pleistocene fauna contained several reworked Pliocene fossils. Secondly, it became clear that the Pleistocene fossils belonged to quite different ecogroups. Some ideas about the production of fossils by diverse organisms in different biotopes were developed, and an attempt was made to test these ideas with the Cretan material.

In principle, the sediment studied is very suitable for such researches as it was deposited in very shallow water on a rocky coast with many vastly differing biotopes. Such sediments are not often preserved, and the Cretan exposure therefore seems an excellent subject for study. The results, however, are ambiguous, and this for two reasons: the exposure was not investigated thoroughly enough, and there is very little known on the present-day ecology of the organisms involved.

The present report, thus, is to be regarded as a preliminary approach to a problem with which the author hopes to deal more extensively in the future.

#### THE LOCALITY

The village of Arvi is situated on the south coast of Crete, in a large cove between the cliffs that mark the seaward slope of the Diktaean mountains. This cover has a rim of pre-neogene limestones. It is partly filled by Pliocene

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marls that locally contain shells of *Pycnodonta cochlear* (L), *Turritella triplicata* Brocchi, and a rich microfauna. This marine deposit was certainly formed at a depth between 50 and 200 metres (uppermost limit of *Pycnodonta* and lowermost limit of *Turritella*), and the character of the foraminiferal fauna (many *Nodosariidae* and *Lenticulinidae*; no *Elphidium*) points to the lower half of this interval. As far as could be ascertained no coastal Pliocene deposits were preserved in this region.

After the regression at the end of the Pliocene, there occurred several Pleistocene transgressions in Greece.

Curiously enough, the older transgressions are manifested only by wave-cut terraces; deposits of these times are not found, whereas Tyrrhenian strata are common enough.

Perhaps erosion was more active during the Lower Pleistocene than during the upper part of this period. The only Cretan sediments that are probably Lower Pleistocene are the thick deposits of reddish-brown and grey clays, sand and gravel around Ay. Gallini, a village that is situated also on the southern coast of Crete, but about 80 km farther westward. This formation of Ay. Gallini overlies the marine Neogene near Phaneromeni; it is tilted and somewhat broken by tectonic movements of the subsoil. The strata are completely devoid of fossils.

The marine Pleistocene deposits at Arvi were discovered by Pashley (1837); both Spratt (1865) and Raulin (1867) assigned these to the Pleistocene, and Psarianos (1961) narrowed down its age to Tyrrhenian. The latter author described and figured the larger shells from this locality. In the present publication the smaller shells and the foraminifers will be listed and some paleoecological comments will be made.

The material consists of shell-samples collected by the author, and of loose shells collected by Prof. Dr. G.H.R. von Koenigswald, Drs. T. Freudenthal and Mr R.R. van der Ploeg on several visits to the locality. The best exposure is situated some 200 metres W of the village along the dirt road to Vianos which runs along the beach there. In the cliffs yellow-white sands are exposed with numerous shells which are all disarticulated; the loose valves lie with their convex side upward. The shells are found in washed-out lenses; the sand in between contains a fair amount of shell debris and shows a coarse lamination. The deposit is typically a fossil sandy beach.

Some fissures are filled with gypsum. This gypsum is certainly derived from the thick strata of gypsum that underlie the marine Pliocene. The former are exploited further eastward (see Papastamatiou, 1958). Apparently the gypsum was remobilised in post-Tyrrhenian times.

#### THE MACROFAUNA

In this section, the fossils obtained from the sieve fraction larger than 0.5 mm in diameter are discussed.

#### Lamellibranchiata

##### *Suspension-feeders, burrowing in sand.*

+	100	<i>Glycimeris violascens</i> (Lam)
+	70	<i>Corbulomya mediterranea</i> (Costa)
+	40	<i>Venus gallina</i> L
+	40	<i>Loripes lacteus</i> (L)
+	30	<i>Divaricella divaricata</i> (L)
	17	<i>Cardium tuberculatum</i> L
	7	<i>Cardium exiguum</i> Gmelin
	5	<i>Jagonia reticulata</i> (Poli)
	3	<i>Mactra corallina</i> L
	3	<i>Donax trunculus</i> L
	2	<i>Pitar chione</i> (L)
	1	<i>Lembulus pella</i> (Lam)
	1	<i>Venerupis decussata</i> (L)
	1	<i>Solen</i> sp.

This group is numerically the most important (see table 1) as might be expected in a malacofauna which is fossilized in a sandy matrix. Many species are typically indicators of the sandy beach zone. Among these are *Corbulomya mediterranea*, *Venus gallina*, *Donax trunculus*, *Pitar chione* and *Venerupis decussata*.

*Glycimeris* is found on sandy bottoms only, but is by no means restricted to coastal sands alone.

***Suspension feeders, attached to substratum.***

- 5 *Arca pulchella* Reeve
- 3 *Arca noe* L
- 1 *Arca lactea* L
- 1 *Arca tetragona* (Poli)
- 1 *Chama gryphoides* L
- 1 *Corbula gibba* (Oliv)
- 1 *Hiatella arctica* (L)
- 1 *Musculus marmoratus* (Forbes)

This group is represented by few specimens but many species. Some of these (*Arca*, *Chama*) are more or less restricted to rock and gravel environments; others occur on coquinas (*Corbula*), and *Musculus* is found on tunicates. Although the coast near Arvi is decidedly rocky and the Tyrrhenian deposit was formed in an embayment between rocky coasts, the number of rock-dwelling shells is insignificant.

***Selective bottom feeders, belonging to the infauna.***

- 12 *Angulus planatus* (L)

This group is very unimportant as might be expected on the submerged shore of an island, which is a poor producer of detritus. In other environments, selective bottom feeders play an important part (for instance in the Wadden Sea).

*Carnivorous lamellibranchs*

These were not met with in the Arvi samples.

**Gastropoda*****Algal browsers and detritus feeders.***

- + 50 *Bittium reticulatum* (da Costa)
- 9 *Rissoa* cf. *lia* Monterosato
- 6 *Cerithium vulgatum* Brug.
- 5 *Tricolia pullus* (L)
- 4 *Gibbula varia* (L)

- 3 *Alvania cimex* (L)
- 3 *Rissoa monodonta* Bivona
- 1 *Acmaea Virginea* (Müll)
- 1 *Caecum trachea* (Monterosato)
- 1 *Patella coerulea* L
- 1 *Rissoa violacea* Desm
- 1 *Rissoina bruguieri* Payraudeau
- 1 *Skeneopsis planorbis* (Fabr)
- 1 *Torinia* sp.

By far the most common gastropod is *Bittium reticulatum*. This animal feeds on the algal microvegetation occurring on leaves of larger plants and on shells. Therefore, it is not limited to rocky shores as was pointed out a.o. by van Straaten in his study on the Arcachon basin (1956)<sup>1</sup>.

*Acmaea virginea* is likewise a species occurring on the foliage of plants. *Caecum* and *Skeneopsis* feed on diatoms and are independent of the occurrence of rocks. The other species cited above are more or less typical for the littoral zone of rocky coasts.

### **Carnivores**

- 3 *Murex trunculus* L
- 3 *Retusa subcylindrica* (Brown)
- 3 *Retusa truncatula* (Brug)
- 3 *Natica* sp.
- 2 *Natica lactea* (Guild)
- 2 *Nassarius mutabilis* (L)
- 2 *Nassarius incrassatus* (Ström)
- 2 *Strombus bubonius* Lam
- 1 *Conus mediterraneus* Brug
- 1 *Diodora graeca* (L)
- 1 *Epitonium* sp.
- 1 *Triphora perversa* (L)

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1. The species is common in the Dutch Eem deposits, which consist mainly of sand devoid of stones. This points to the existence of dense vegetation on the bottom of the former Eem lagoon.

This group is very heterogeneous, comprising relatively unspecific carnivores that are able to dig (*Natica*) or to consume carrion (*Nassarius*) and specialistic carnivores, that are restricted to a narrow range of prey animals (*Triphora*). *Diodora graeca* and *Triphora perversa* are predators of sponges and ascidians.

The *Natica* species are typically adapted to burrowing for prey in sandy bottoms. The other carnivores cited are largely indifferent with regard to their substratum, as far as is known.

#### **Parasites.**

3 *Turbonilla lactea* (L)

1 *Chrysallida obtusa* (Brown)

1 *Pyramidellia indet.*

Parasitic gastropoda are nearly always found on animals belonging to the epifauna. As the latter element is notably scarce in the present malacofauna, the meagre number of parasitic Gastropoda is not surprising.

#### THE MICROFAUNA

In this section, the fossils obtained from the sieve fractions 0.1 and 0.5 mm are discussed.

#### **Skeletal remains of Metazoa.**

Besides bivalves and gastropods, a skeleton fragment of a Chiton species was found. Moreover, three fragments of a balanid were obtained. Ostracoda are well represented, both in number of shells and in number of species. A common species is *Hemicytherideis elongata* (Brady). Especially abundant are small *Spirorbis* tubes, all with flattened sides which formerly adhered to some vegetal substratum. It is known that *Spirorbis*-larvae die off when they do not find some suitable hard substratum on which they can settle. *Spirorbis*, thus, is a good indicator for the presence of firm substratum on the bottom of the sea. Bryzoa from another part of the sea bottom epifauna; they are well represented in the wash residues, but were not studied in detail. Echinid spines were also present.

**Foraminifera.**

The sand from Arvi is rich in Foraminifera, both reworked and from Tyrrhenian times. The fossil species are readily recognised by their state of conservation; they tend to be filled with a yellowish matrix, identical to the Pliocene marls of Arvi. The following heavily fossilized forms were found:

- 9 *Globigerinoides triloba* (Reuss)
- 5 *Lenticulina* sp.
- 4 *Orbulina universa* d'Orb.
- 3 *Nodosaria* sp.
- 2 *Globigerinoides bisphaerica* Todd
- 1 *Globulina gibba* d'Orb.
- 1 *Lenticulina costata* (F. et M.)

The supposedly Tyrrhenian association of benthonic foraminifers consists of:

- + 120 Miliolidae gen. et spec. indet.
- 103 *Ammonia beccarii* (L)
- 32 *Elphidium crispum* L and *macellum* F. et M.
- 25 *Neoconorbina terquemi* (Rzehak)
- 17 *Quinqueloculina agglutinans* d'Orb.
- 11 *Cibicides* sp. with flattened adherent shells
- 7 *Cibicides*, completely adherent («*Gypsina*»)
- 5 *Cibicides* sp. with free-grown shells
- 5 *Massilina secans* (d'Orb.)
- 5 *Quinqueloculina reticulata* d'Orb.
- 4 *Massilina rugosa* Sidebottom
- 4 *Quinqueloculina striata* d'Orb.
- 3 *Bulimina aculeata* d'Orb.
- 3 *Planulina ariminensis* (d'Orb.)
- 2 *Gyroidina neosoldanii* Brotzen
- 2 *Peneroplis pertusus* (Forskål)
- 2 *Polymorphina* sp.
- 1 *Amphistegina radiata* (F. et M.)
- 1 *Lagena* sp.
- 1 *Lenticulina vortex* (F. et M.)

- 1 *Melonis pompilioides* (F. et M.)
- 1 *Parrina* sp.
- 1 *Textularia sagittula* Defr.
- 1 *Uvigerina nodosa* d'Orb.

The benthonic Foraminifera cannot be subdivided into different ecotypes as their biology is virtually unknown. It may be supposed, however, that all species feed by ingestion of food particles on or quite near to the sea bottom.

The Foraminifera were identified by making use of the publications of Sidebottom (1904-1909), Longinelli (1956), Parker (1958) and Hofker (1960). The study of Le Calvez and Le Calvez (1958) gives ecological details also. Foraminifers are known empirically to occur in certain environments. Nearly all found here are typical for near-coast, shallow open sea water. Some thrive on sandy bottoms such as the *Ammonia*, the *Elphidium* and a part of the *Quinqueloculina* species. Others are restricted to very shallow water with many algae and/or hard rock exposures. Amongst these the *Massilina* species, the *Peneroplis* and the *Amphistegina* may be cited. Others again are less specific, but are mainly found on algae; part of the Miliolidae and the *Quinqueloculina* species, the adherent forms of *Cibicides* (which, however, occur also on shells, hydroids a.s.o.). It can be estimated that there are about 160 forams in the present collection which live in moving sands, against about hundred preferring an environment with solid substratum.

The following pelagic foraminifers were found:

- 5 *Globigerina bulloides* d'Orb.
- 6 *Globigerinoides sacculifera* (Brady)

The presence of some pelagic foraminifers in the undoubtedly very shallow deposits at Arvi is not surprising, as the southern coast of Crete is very steep; there is no shelf, and the bottom of the sea rises steeply near the coast.

#### DISCUSSION

The ecological results of the foregoing paragraphs are summarized in table 1.

Some limitations of this investigation should be made clear. Only one sample (weighing approximately 2 kgs) was analysed quantitatively. This

sample was taken from a shell-rich bed, exposed on the cliff 200 m West of the village Arvi. Probably, this bed is the washed-out residue of a thicker

T A B L E 1

ECOGROUPS FROM THE ARVI MALACOFUNA

Ecogroup	Burrowing suspension feeders	Epibiontic suspension feeders	Selective bottom feeders	Browsers on algae and detritus	Carni- vores	Parasites	Total
Number of specimens	320	13	12	87	24	5	461
Percentage	69	3	3	18	6	1	100

stratum of sand, and it is fairly certain that selection of the fossils by the eroding currents took place. The heavy shells of *Glycimeris* and the light and small *Corbulomya* shells will have reacted quite different to these circumstances. Differentiation between foram tests of diverse forms is also probable. These factors presumably blurred the quantitative portion of each ecological group within the thanatocoenosis. They certainly do not enhance the reliability of the following discussion.

It is clear, that the fauna lived at a depth of at most ten metres (*Corbulomya*) (Van Straaten, 1960). The overwhelming majority of the mollusca belongs to the infauna of the sandy bottom; second place is taken by the shells living on weeds and algae. The shell derived from a rocky habitat are numerous in species but nearly negligible in quantity. The foraminifera are less easily grouped according to different habitats, but it seems that the forms occurring commonly on rock grounds or on algae are numerically better represented than equivalents among the mollusca. Before going into this, it must be stressed that transport of empty shells may have had a confusing effect on the composition of the Arvi fauna. At the sand-producing mouths of the torrents near to Arvi other conditions may have prevailed than in the Arvi Tyrrhenian embayment that derived its sand from this source. Foraminifera are much more liable to be reworked and transported than Mollusca (see for instance, Murray, 1965).

The Mollusca are less easily transported and reworked, because of their size and weight. But it is clear that most of them were transported at least

small distances, because all lamellibranchs were found as loose valves.

Yet, the composition of the malacofauna seems to indicate less clearly the abundant presence of bare rock and luxuriant growth of algae and *Posidonia* on the bottom of the Tyrrhenian sea than the microfauna does. It seems possible, even, that the character of the foraminiferal assemblage was altered by the influx of forms common at river mouths. This would underline its original bare-rock-algae character still more, as it is improbable that mollusca were transported as extensively alongshore.

Several factors can be held responsible for this phenomenon. One of them is the smashing of brittle shells in the surf zone. *Solen* shells, for instance, are particularly easily destroyed. The removal of brittle shells from an association may shift its average characteristics. In this particular case, it would be the rock-dwelling association that increased relatively because rock-dwelling forms tend to be heavier and stronger shelled than the sand infauna.

The duration of life of each shell-bearing animal is an important factor in ascertaining the shell production. Nothing is known on the life-span of foraminifers in nature, and only few data are available on Mollusca. A recent summary of this subject was given by Comfort (1956). There are some interesting examples of gastropods that graze on marine plants which die off each autumn (*Rissoa membranacea*; *Skeneopsis planorbis*). Generally, it seems that marine grazing mollusca have a shorter span of life than the active carnivorous mollusca. Of the former many more juvenile shells are found (e.g. *Bittium*) than of the latter (e.g. *Conus*). This rule is not without exceptions, however, as *Patella* has a life-span of fifteen years (Comfort, 1956).

An important factor is the extent of bottom-surface which each benthonic shell-bearing animal needs. This affects directly the shell production per unit of surface. Again it turns out that little is known on the factors that determine the surface area required by an individual foraminifer. Probably wide variations occur, as the density of living foraminifer occurrences varies also widely. It is notable, that dense concentrations of living foraminifers occur off river mouths (Phleger, 1964). Dr. Vaas (Ierseke; personal communication) offered an ingenious explanation for this phenomenon. Off river mouths, large quantities of nutrient-rich clay suspensions become flocculated first and are deposited afterward. These small flocks of clay seemingly are an excellent substratum for bacterial growth, and it is possible that the proliferation of foraminifera in this environment is due to the presence of enormous quan-

tities of bacterial food. This feature of estuarine environments was hinted at a.o. by Ferguson Wood (1964, pp. 91-92).

Generally, as put forward by Faure-Fremiet (1951), the occurrence of marine Protozoa is mainly governed by the presence of suitable food. In food-rich environments then, a much larger number (and consequently a higher shell production) of foraminifers per surface unity can be expected. Such environments are characterised by a high proportion of living foraminifers in the total shell quantity; a situation which cannot be easily reconstructed from the fossil record, as the microfaunal content is determined much more by sedimentological processes (sedimentation, non-deposition or erosion) than by ecological relations. Moreover, the seasonal variations within the benthic microflora are reflected by seasonal variation in abundance of the foraminifers also (see Murray, 1965). Some indication, whether there was a dense foraminifer population on the bottom of a not-too-old former sea, can however be obtained.

There are certain Opisthobranchia that specialize in feeding on Foraminifera. These have developed a muscled stomach, armed with horny plates, which can crush foraminifers. Conspicuous Mediterranean foraminifer predators are many *Philine* species (Pruvot-Fol, 1954), that occur in appreciable numbers off the mouths of large rivers where dense populations of Foraminifera are living. Other genera (*Retusa*) are known also to feed on Foraminifera<sup>1</sup>. As *Philine* is not found at Arvi, and *Retusa* is scarce, it is improbable that the bottom of the Tyrrhenian sea at that locality supported large numbers of living foraminifers at any time.

The ethology of the Foraminifera is still largely unknown. There are some data on *Elphidium crispum* (L), a species also found at Arvi. Murray (1963) found that *E. crispum* is able to move about in search of food particles, and that movement in some instances is directed and not random. Most Foraminifera have unattached shells but it is questionable whether the living animal often displaces itself actively. It is conceivable that near-coast forms currently found in shifting sediments (*Elphidium*; *Ammonia*) show greater

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1. *Retusa alba* (Kanmacher) feeds on juvenile *Hydrobia* also; possibly the animal takes ostracods. Its presence, thus, does not necessarily point to large numbers of living foraminifers.

activity because of the constant danger of being buried underneath a lamina of newly deposited sediment. On the other hand, there are many instance of Foraminifera which live in turbulent water and respond to this environment by devices which tend to keep the shell in place. A good example is *Cibicides* of which shells are found in various degrees of fixedness; according to Nyholm (1961, 1962) these are the «*Cibicides lobatulus*», the «*Planorbulina mediterranea*» and the «*Gypsina globulus*» stages. All three occur at Arvi. A conspicuous recent adherent foraminifer on Mediterranean rocks is *Miniacina miniacina* (L): this form was not found at Arvi. Other Foraminifera are not encrusting, yet they are shelled in such a way that no locomotion seems possible at all.

Examples are most *Miliolidae*, *Nodosaria* and related forms, *Reophax*. Some of these have free shells in quiet water, and anchored shells in high-energy environments (*Polymorphina*, *Guttulina*) which are attached to a fixed substratum by so-called fistulose chambers. The occurrence of the latter is a good indication for agitated water.

It is uncertain, which features are indicative of locomotion for such small benthonic organisms as foraminifers. Large shell pores for large pseudopodia, and disk-shaped shells could be such functional adaptations. On the other hand, spined shells (such as in many species of *Bulimina* and *Uvigerina*) point clearly to passivity. Generally, benthonic foraminifers are sedentary or very sluggishly moving animals which feed on the bottom immediately around the shell and on the sea water surrounding it. Thus, their mode of life is probably rather uniform. Such a statement would not hold true for the benthonic Mollusca. There is a large group of molluscs to which the substratum is only important as a medium for shell fixation or protection and not as a food-producing surface. These are nearly all lamellibranchs and some gastropods (*Turritella*) that are filter feeders. Then there is a group of molluscs collecting food by scraping off the substratum. These are the browsing gastropods. Finally, there are carnivorous gastropods.

It is clear that of these three groups of mollusca, the carnivores will need the greatest living surface per specimen as a rule, because their prey is usually some organism that has a discontinuous distribution itself. The herbivorous and detritus-eating Mollusca come in an intermediate position with regard to their living-surface; it is large for large herbivores that scrape algal ongrowth

off bare rocks (e.g. *Patella*) but small for small snails living on the surface of sea weed and algae (e.g. many *Rissoa*'s and *Bittium*). The suspension feeders at last, do not need more room generally, than the diameter of their shell, at least in the coastal realm where there is abundant supply of food-containing oxygenated sea-water. It is clear that specimens of the last mentioned group may occur in many thousands per square metre (e.g. *Corbulomya*; *Cardium*) and that their production of shells is much higher than that of either vegetarian or carnivorous molluscs.

Suspension feeders on the rocky bottom (e.g. *Mytilus*, *Spondylus*) are generally less densely strewn (owing to the difficulties that are to be coped with by their larvae when settling takes place) and have far less opportunity to be buried by sediment and fossilized. A relatively small patch of sand in an area of rocks thus may contain a malacofauna dominated by the unfauna of the sand.

This seems precisely to be the case at the Arvi Tyrrenian, which was probably deposited on the bottom of a cove amidst a rocky environment. It is clear that, without biological data on the mode of living of the Mollusca involved, the absolute abundances of the fossil shells found are liable to be interpreted wrongly. This has been pointed out already by R.G. Johnson (1965) in his study on pelecypod death assemblages of a Californian bay.

Quantitative research on foraminifer abundances is a practice of old standing which has been applied successfully already many times. This might indicate that the fossil production per species is less irregular than that of the Mollusca. This in turn is doubtless connected with their far less diversified modes of living. The Foraminifera from the Arvi sediment give a quantitatively better picture of the environment where they lived than the Mollusca. On the other hand they need not be in situ and the peculiar adaptations of the Mollusca enable the paleontologist to draw a more complete reconstruction.

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#### B I B L I O G R A P H Y

- CALVEZ, J. LE and Y. LE CALVEZ (1958) : Répartition des foraminifères dans la Baie de Villefranche. I. Miliolidae. Ann. Inst. Océan., N.S. Vol. 35, pp. 159-234.
- COMFORT, A. (1956) : The duration of life in mollusca. Proc. Malacol. Soc. London, Vol. 32, pp. 249-244.

- FAURE-FREMIERT, E. (1951) : Ecologie des protistes littoraux. L'Année biologique, Vol. 60, pp. 437-447.
- FORBES, E. (1844) : Report on the mollusca and radiata of the Aegean Sea, and on their distribution, considered as bearing on geology. Rept. 13th Meeting British Assoc. Adv. Science, 1843, pp. 130-193.
- FRETTER, V. and A. GRAHAM (1962) : British Prosobranch. Mollusca. London, Ray Society, Vol. 144.
- HOFKER, J. (1960) : Foraminiferen aus dem Golf von Neapel. Paläont. Zeitschr., Vol. 34, pp. 233-262.
- JOHNSON, R.G. (1965) : Pelecypod death assemblages in Tomales Bay, Calif. Journ. Pal., Vol. 39, pp. 80-85.
- LONGINELLI, A. (1965) : Foraminiferi del Calabriano e Piacenziano di Rosignano Marittimo e della Val di Cecina. Palaeontographia Italica, N.S., Vol. 19, pp. 99-214.
- MASSALA, L. (1959) : Nuovi lembi di Tirreniano del Golfo di Oristano. Rend. Sem. Fac. Sci. Univ. Cagliari, Vol. 29, pp. 95-108.
- MURRAY, J.W. (1965) : Significance of benthic foraminiferids in plankton samples. Journ. Pal., Vol. 39, pp. 156-157.
- MURRAY, J.W. (1965) : On the Foraminiferida of the Plymouth region. Journ. Mar. Biol. Assoc. U.K., Vol. 45, pp. 481-505.
- NESTEROFF, W. (1963) : Recherches sur les sédiments marins actuels de la région d'Antibes. Ann. Inst. Océan. N.S., Vol. 43, pp. 1-135.
- NYHOLM, K.G. (1961) : Morphogenesis and biology of the foraminifer *Cibicides lobatulus*. Zool. Bidr. Uppsala, Vol. 33, pp. 157-196.
- NYHOLM, K.G. (1962) : A study of the foraminifer *Gypsina*. Zool. Bidr. Uppsala, Vol. 33, pp. 201-205.
- PAPASTAMATIOU, J. (1958) : Les gites du gypse et d'anhydrite dans l'île de Crète. Bull. Geol. Soc. Greece, Vol. 3, pp. 146-155.
- PARKER, F.L. (1958) : Eastern Mediterranean Foraminifera. Rep. Swedish Deep-sea Exp., Vol. VIII, pp. 249-283.
- PASHLEY, R. (1837) : Travels in Crete, 2 Vol., London.
- PHLEGER, F.B. (1964) : Foraminiferal ecology and marine geology. Marine Geology, Vol. 1, pp. 16-43.
- PRUVOT-FOL, A. (1954) : Opisthobranches. Faune de France, Vol. 58, Paris.
- PSARIANOS, P. (1961) : Ai tirrinií apotheseis tis Nisou Kritis. Ann. Géol. Pays Hellén., Vol. 12, pp. 12-17.
- RAULIN, V. (1867-1869) : Description physique de l'île de Crète. Paris.
- SAKELLARIOU, H.G. (1957) : Les mollusques vivants du Golfe de Thessaloniki. Ann. Géol. Pays Hellén., 1<sup>e</sup> Sér., Vol. 8, pp.
- SIDEBOTTOM, H. (1904-1909) : Report on the Recent Foraminifera from the coast of the Island of Delos. Mem. Proc. Manchester Lit. Phil. Soc., 1904-1909.
- SPRATT, T.A.B. (1865) : Travels and researches in Crete. London.

- STEUER, A. (1939) : Die Fischereigründe vor Alexandrien. Teil XIX, Mollusca, Thalassia, Vol. 3, n° 4, pp. 1-143.
- STRAATEN, L.M.J.U. VAN (1956) : Composition of shell beds formed in tidal flat environment in the Netherlands and in the Bay of Arcachon (France). Geol. en Mijnb., N.S., Vol. 18, pp. 209-226.
- STRAATEN, L.M.J.U. VAN (1960) : Marine mollusc shell assemblages of the Rhone delta. Geol. en Mijnb., Vol. 39, pp. 105-129.
- TERQUEM, O. (1878) : Les Foraminifères et les Entomostracés-Ostracodes du Pliocène supérieur de l'île de Rhodes. Mem. Soc. Géol. France, 3<sup>e</sup> Ser., Vol. 1, pp. 1-135.
- WOOD, E. and J. FERGUSON (1964) : Marine microbial ecology. London. Chapman and Hall.

## Π Ε Ρ Ι Λ Η Ψ Ι Σ

Περιγράφονται ένταῦθα πλειστοκαινικοί παράκτιοι σχηματισμοὶ ἐκ τῆς περιοχῆς Ἄρβης τῆς νοτιοανατολικῆς Κρήτης. Δεῖγμα ἄμμου πλουσίας εἰς λείψανα ὀστράκων μαλακίων μελετᾶται ὑπὸ τοῦ συγγραφέως, ὅσον ἀφορᾷ εἰς τὸν χαρακτῆρα τῆς ἀπολιθωμένης παλαιοπανίδος, μετὰ πάσης προσοχῆς. Εἰς τὰς ἀβαθεῖς θαλασσίας περιοχάς, οἱ διάφοροι βιότοποι ἐμφανίζουν κατ' ἐξοχὴν κυμαινομένης ποσότητος ὀργανικῶν λειψάνων, ἐξαρτωμένων κυρίως ἐκ τοῦ χρόνου καὶ τῆς ἀποστάσεως, ἔνθα πρόκειται νὰ ἀποτεθοῦν τὰ μελλοντικὰ ἀπολιθώματα. Ὁ τρόπος τῆς διαβιώσεως καθιστᾷ τὰ τρηματοφόρα χρησίμους ποσοτικῶς καθοδηγητικούς ἀντιπροσώπους, πρᾶγμα τὸ ὁποῖον δὲν διαψεύδεται ἐκ τῶν ἀποτελεσμάτων. Παρὰ ταῦτα, τὰ μαλάκια ἐκεῖνα τὰ ὁποῖα παρουσιάζουν ἐνδείξεις δευτερογενοῦς ἀποθέσεως παρέχουν ἀπὸ ἀπόψεως αὐτοοικολογικῆς περισσοτέρας μορφολογικῆς λεπτομερείας. Κατὰ συνέπειαν μερικοὶ παλαιοβιότοποι εἶναι δυνατὸν νὰ ἀναπαρασταθοῦν μετὰ μεγαλυτέρας ἀκριβείας διὰ τῆς χρησιμοποίησεως πρὸς τοῦτο τῶν μαλακίων, ἐπιπροσθέτως δὲ καὶ τῶν τρηματοφόρων.