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PALEOECOLOGICAL ASPECTS ON FORAMINIFERA ASSEMBLAGES OF THE SECTION ARMENOPETRA (VIANNOU AREA, CRETE ISLAND)

(Fig. 1)

Abstract: The coastal parts of the Viannou area are covered by Neogene deposits rich in macrofauna and microfauna assemblages (Dermitzakis—Geograides-Dikeoulia, 1970). The studied section Armenopetra is located about 1 km east of Keratokampos village (Viannou area).

The section consists of a continuous sequence of about 70 meters which can be divided into two formations. The lower formation consists of well stratified calcareous sediments, from white to grey marls alternating with sandy bioclastic limestones, whereas the upper one consists of white to greyish marls, marl breccias and sandstones.

The purpose of this paper, is to present the paleoecological aspects of foraminifera assemblages of the section Armenopetra. An attempt will be made on the correlation of data from Planktonic and Benthonic foraminifera in order to conclude their ecological conditions during the sedimentation. Special attention is given on the paleoecological observations of Benthonic foraminifera which were determined for the first time in the section.

Резюме: Прибрежные части области Вианноу покрыты неогеновыми отложениями богатыми ассоциациями макро- и микрофауны (Дермицакис — Георгиадес-Дикеоулиа, 1979). Исследованный район Арменопетра расположен в расстоянии около 1 км на восток от с. Кератокампос (область Вианноу).

Район состоит из непрерывной последовательности длиной около 70 метров, которую можно разделить на две формации. Нижняя формация состоит из хорошо напластованных известковых осадков, с белых до серых мергелей чередующихся с песчаными биокластическими известняками, тогда как верхняя состоит из белых вплоть до сероватых мергелей, мергельных брекчий и песчаников.

Целью этой статьи дать палеоэкологические аспекты ассоциаций фораминифер района Арменопетра. Будет сделана попытка корреляции данных о планктонных и бентонных фораминиферах для того, чтобы сделать выводы об их экологических условиях во время седиментации. Особое внимание уделено палеоэкологическим исследованиям бентонных фораминифер, которые были впервые определены в этом районе.

Lithostratigraphy

In the section Armenopetra the local upper part of Ammudhares Formation is exposed, Fortuin (1977). This formation is characterized in the lower most 10 meters (Fig. 1) from thick-bedded white-greyish sandy marls with abundant mollusc fauna. Then follow 11.5 meters of white-greyish marls with marl-

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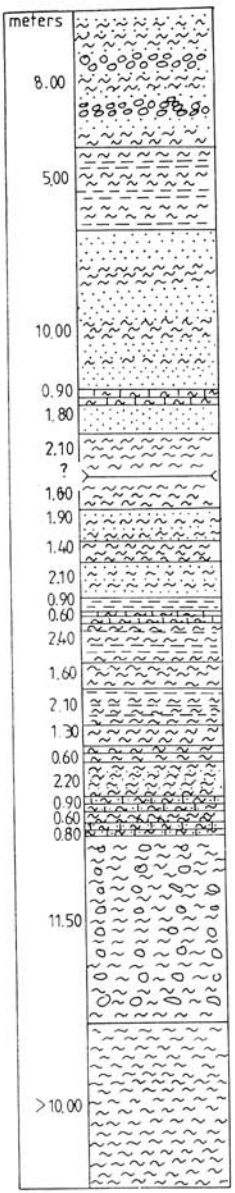

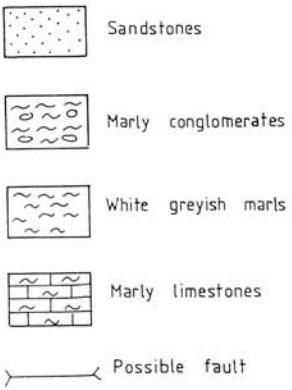

Fig. 1. Lithostratigraphic column of the section Armenopetra

pebbles and reworked elements which become in the higher part increasingly bioclastic and conglomeratic including molluscs as *Pycnodonta navicularis*.

This is overlayed by 21 m thick of alternating sandy marls, marly limestones and sandy calcarenites. In the calcarenites is observed a lamination and an indistinct; positive gradation. Whereas within homogeneous marls some burrows with mollusc fauna were observed.

The upper part of the section with a thickness of about 27 meters characterizes the local base of the Myrtos formation (Fortuin, 1977). The sediments consists from heterogenous sediments, mainly white greyish marls, breccias, sandstones. The marls contain rich mollusc fauna of Pectinidae which has been described from Dermitzakis and Georgiades-Dikeoulia (1979). The sedimentary features of the upper part of Armenopetra section point to an initial period of high in a shallow environment.

Biostratigraphy, Chronostratigraphy and Paleoecology

In a previous paper (Dermitzakis and Georgiades-Dikeoulia, 1979) we studied the planktonic foraminifera in correlation with the Mollusc

associations. In this paper we add the studied assemblages of benthonic foraminifera in order to correlate the results with those of the planktonic foraminifera.

The lower formation consists of well stratified calcareous sediments. The occurrence of *Globorotalia dalii* in this formation, a taxon appearing almost simultaneously with *Globorotalia conomiozea* allows the attribution of this formation to the biozone *Globorotalia conomiozea* of Zachariasse (1975), which cover the Late Tortonian-Messinian time span. Among the accompanying fauna *Globigerinoides extremus, Globorotalia suterae, Globorotalia scitula, Neogloboguadrina acostaensis, Globigerina decorapetra* etc. dominate. This fauna is very abundant in the lower part of the formation and decreases in the upper part. This confirms that during this period a faunal influence by the Atlantic was continuous apart from a temporal interruption during the Messinian. These faunal assemblages correlating with similar of other regions of the Mediterranean area show tropical water, low energy sedimentation for the lower part and unfavourable conditions of environment for the upper part.

The associations of benthonic foraminifera from the samples of the lower formation indicate a marine environment and contain numerous benthonic species. The most common ones are the follows:
Anomalina alazamensis spissiformis CUSHMAN and STAINFORTH, *Asterigerina planorbis* D'ORBIGNY, *Bolivina dilatuta* REUSS, *Bolivina placentina* PADANI, *Bolivina punctata* D'ORBIGNY, *Bolivina tortuosa* BRADY, *Bulimina affinis* D'ORBIGNY, *Bulimina elegans* D'ORBIGNY, *Bulimina marginata* D'ORBIGNY, *Cibicides cicatricosus* SCHW, *Cibicides robustus* PHEGER and PARKER, *Discorbis globularus* D'ORBIGNY, *Elphidium aculeatum* D'ORBIGNY, *Elphidium jenseni* CUSHMAN, *Eponides antillarum* D'ORBIGNY, *Eponides umbonata* REUSS, *Frondicularia advena* CUSHMAN, *Glandulina glaus* D'ORBIGNY, *Glandulina laevigata* D'ORBIGNY, *Gyroidina neosoldanii* BROTZEN, *Lagena quatricostulata* REUSS, *Nodosaria ramphanus* LINNÉ, *Nonion soldanii* D'ORBIGNY, *Nonionella auris* D'ORBIGNY, *Planulina arinunensis* D'ORBIGNY, *Reussela spinulosa* REUS, *Robulus rotulatus* LAMARCK, *Spiroplectammina carinata* D'ORBIGNY, *Trifarina bradyi* CUSHMAN, *Uvigerina peregrina* CUSHMAN, *Uvigerina tenuistrata* REUSS.

The associations that are most open marine one, have been found in the lower formation of the section Armenopetra. These faunas are characterized by high diversities and relative large numbers of planktonic foraminifera. Generally more than 10 planktonic specimens per 100 counted benthonic foraminifera. The most important benthonic consituents are *Bolivina, Bulimina, Cibicides, Elphidium, Nonion* and *Uvigerina*. Another characteristic feature of these associations is that these groups show very little fluctuation in their relative frequencies in the successive samples. Associations largerly made up of these groups are found today in normal marine environments with a muddy substrate, at depths below 100 meters and with bottom temperatures lower than 10 °C (Murray, 1973).

We have better results from a comparison with recent equivalents of the association of the lower formation of Armenopetra section. It appears that benthonic foraminiferal assemblages reminiscent of the ones of Armenopetra, with approximately the same taxa in comparable frequencies, have been, described from tre recent Mediterranea at depths between 200 and 500 meters (Parker,

1958; Chierici et al., 1962). This suggests that the Late Tortonian-Messinian sediments were deposited at depths approximately in the same interval.

The upper formation of Myrtos consists of marls and clays. Among the determined foraminiferal assemblages dominate *Globorotalia margaritae* together with *Globorotalia puncticulata*. This allows the correlation of this formation with the lower part of *Globorotalia puncticulata* biozone which indicate a Pliocene age. Assemblages of *Sphaeroidinellopsis* group, as also *Globigerinoides elongatus, Globigerinoides extremus, Globigerinoides ruber, Globorotalia scitula, Globorotalia crassaformis* etc. have been determined.

These assemblages show new influence by the Atlantic tropical and subtropical waters with range in temperature, salinity and dissolved phosphate.

The change of the fauna during the upper Formation shows that the early tropical aspect of it, diminished during the Pliocene.

The benthonic foraminifera from the upper formation of Armenopetra section, from which five samples have been studied are characterized by not so good preservation and the forms are either etched, worn or vitreous and of light brown colour. They belong in particular to planoconvex representatives of *Cibicides, Anomalina pompilioides, Bolivina, Guttulina, Nodosaria* and *Uvigerina* species. The diversity of benthonics is highly variable and shows fluctuations between close to zero and 25.

From the benthonic foraminiferal associations the most common ones are the follows:

Anomalina pompilioides CALL. and HEMIN., *Bolivina arta* MACFAD., *Bolivina dilatata* REUSS, *Bulimina elegans* D'ORBIGNY, *Cibicides mexicanus* NUTT. *Cibicides robustus* PHLEGER and PARKER, *Dentalina leguminiformis* BATSCH, *Elphidium crispum* LINNE, *Eponides haidingeri* BRADY, *Glaudulina laevigata* D'ORBIGNY, *Guttulina communis* D'ORBIGNY, *Guttulina sigmomorphina* D'ORBIGNY, *Gyroidina soldanii* D'ORBIGNY, *Hopkinsina bononiensis* FORNASINI,*Marginulina crepicosta* SEGUENZA, *Marginulina hirsuta* D'ORBIGNY, *Nodosaria communis* D'ORBIGNY, *Nodosaria ovicula* D'ORBIGNY, *Nodosaria radicula* D'ORBIGNY, *Nodosaria simplex* SILVESTRI, *Nonion granosum* D'ORBIGNY, *Planularia auris augustata* COSTA, *Planulina arimenensis* D'ORBIGNY, *Reusella spinulosa* REUSS, *Robulus costatus* FICHTEL and MOLL, *Robulus cultratus* MONTFORT, *Siphonodosaria vertebralis* BATCH, *Uvigerina flinti* CUSHMAN, *Vaginulina tricarinata* D'ORBIGNY.

An obvious relation exists, between the occurrences of *Globorotalia puncticulata* and *Bulimina elegans*. Both species show a preference in ferromanganese--oxides sediments or rather a tolerance for the environmental factors that caused these sediments.

The combined *Globigerinoides* taxa include some forms that today prefer warmer water: *Globigerinoides sacculiferus, Globigerinoides ruber* and *Globigerinoides trilobus* (cf Cifelli – Smith, 1974; Reiss et al., 1974). The two extinct species *Globigerinoides obliquus* and *Globigerinoides extremus* are generally regarded as tropical-subtropical forms.

Emiliani (1974) analyzed core material from the eastern Mediterranean isotopically and found environmental changes across the glacial/interglacial cycles to be reflected in the morphology of the shells of *G. rubra* populations. His *G. rubra rubra* types, corresponding to our *Globigerinoides ruber* were found

to be restricted to warmer periods and the *G. rubra gomitulus* types, corresponding to our *Globigerinoides elongatus* are predominant at lower temperatures. These latter types are small very compact specimens with very small openings. These observations fit with the observed trend in our section of Armenopetra. Although *Globigerina falconensis* is decribed as bring an ecophenotypic variant of *G. bulloides* occuring especially in subtropical waters (B e – T o l d e r l u n d, 1971) no obvious trend is recorded from bottom to top. *Globigerina bulloides, Globigerina quinqueloba* were combined to form a group with cooler water preference.

Throughout the upper part of the section Armenopetra the diversity of the benthonic foraminiferal assemblages is relatively common and the various groups of taxa distinguished are present in fairly constant relative frequencies throughout the upper part of the section.

Cibicides mexicanus and *Cibicides robustus* are frequent species encountered in the studied samples. Also *Bolivina dilatata, Nodosaria* spp., *Guttulina communis, Planulina ariminensis, Uvigeriva flints, Siphonodosaria vertebralis* are present in most of the samples in appreciable number. *Reussella spinulosa* shows an irregular decrease in frequencies towards the top of the section.

The benthonic foraminiferal assemblages recovered from the upper part of Armenopetra section (belonging to Myrtos formation) indicate primarily an open marine shallow environment in which the marly-clayey sediments were rapidly deposited. The depth at which this process occurred is difficult to be estimate since real depth-indicative taxa are absent. The growing importance of epiphytes recorded from botton to top may possibly be related to an increasing supply from coastal areas or to a development of submarine vegetation in the vicinity. This is in good accordance with frequencies of molluscs associations and especially with large Pectinidae. By means of the preferential depths of the most common species the depth of deposition was estimated to have been between 100 and 200 meters tending to shallow in an upward direction. The increasing quantities of mollusc remains in the younger strata also recorded from the same interval by D e r m i t z a k i s and G e o r g i a d e s - D i k e o u l i a (1979) support this hypothesis.

Compared to the paleobathymetric reconstruction of the Ammudhares Formation (lower part of Armenopetra section) to the Myrtos formation (upper part of the section) seems that the last ones have been deposited in a shallower environment. The more clayey character of the younger formation is thought to have influenced the deviating composition of the benthonic assemblages and as a consequence our paleobathymetric estimate may be too shallow. However, other lines of evidence, such as the changes in lithology, support the idea of shallowing and an approaching hinterland, which supplied the terrigenous fines and organic material in increasing quantities.

It is generally accepted that there was a gradual change from biogenic to more clastic sedimentation in the Middle Pliocene across the island of Crete. Middle to Upper Pliocene sediments are deposited in such clastic facies, spanning a considerable time interval. In combination with the consistently decreasing depth of deposition up into the zone of wave turbulence, it seems most appropriate to infer that rising hinterland was responsible for the ample supply of terrigenous clastic fines. Sea-level oscillations undoubtedly were superimposed.

Conclusion

For the studied section of Armenopetra we arrived to the follows conclusive results about the paleoecology of the two distinct lithostratigraphic Formations which cover the sediments throughout all the section. The lower formation of Ammudhares consists of well stratified calcareous sediments. The cooccurrence of *Globorotalia dalii* with *Globorotalia conomiozea* allows the attribution of this lower part of the section Armenopetra to the biozone of *Globorotalia conomiozea* which cover the Late Tortonian-Messinian time span.

The planktonic foraminiferal assemblages are very abundant in the lower part of the formation and dicrease in the upper part. This confirms that during Late Tortonian-Messinian a faunal influence by the Atlantic was continuous with a temporal interruption during the Messinian. These faunal assemblages correlating with similar of other regions of the Mediterranean area show tropical water, low energy sedimentation for the lower part and unfavourable conditions of environment for the upper part. The most important benthonic constituents are species of *Bolivina, Bulimina, Cibicides, Elphidium, Nonion* and *Uvigerina*. From a comparison with recent equivalents of the association of the older Formation of Ammudhares of Armenopetra section, it appears that benthonic foraminiferal assemblages reminiscent of the ones of Armenopetra, with approximately the same taxa in comparable frequencies have been destribed from the recent Mediterranean at depths between 200 and 500 meters. This suggests that the Late Tortonian-Messinian sediments were deposited approximately at the same dephts.

The upper formation of Myrtos consists of marls and clays. The cooccurrence of *Globorotalia margaritae* with *Globorotalia puncticulata* allows a correlation with the lower part of the biozone of *Globorotalia puncticulata* which indicate a Pliocene age. The planktonic foraminiferal assemblages show new influence by the Atlantic tropical and subtropical waters with wide range in temperature, salinity and dissolved phosphate.

An obvious relation exists between the occurrence of *Globorotalia puncticulata* and *Bulimina elegans*. Both species show a preference in ferromanganese-oxides sediments. *Cibicides mexicanus* and *Cibicides robustus* are frequent species encountered in the studied samples. Also *Bolivina dilatata, Nodosaria* spp., *Guttulina communis, Planulina ariminensis, Uvigerina flinti, Siphonodosaria vertebralis* and *Reussela spinulosa* are present in most of the samples in appreciable numbers. The benthonic foraminiferal assemblages recovered from the upper part of Armenopetra section (belonging to Myrtos formation) indicate an open marine shallow environment in which the marly-clayey sediments were rapidly deposited. By means of the preferential depths of the most common species the depth deposition was estimated to have been between 100 and 200 meters tending to shallow in an upward direction. In combination of deposition up into the zone of wave turbulence, it seems most appropriate to infer that rising hinterland was responsible for the ample supply of terrigenous clastic fines. Sea-level oscillations undoubtedly were superimposed.

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