THE OCCURENCES OF PLEISTOCENIC DEPOSITS IN SE SITIA DISTRICT (E. CRETE)

BY

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INTRODUCTION

In the present study we aim to determine the exact geological age of the marine Pleistocenic formations on the coastal zone of the south-eastern shore of Sitia district (East Crete), as also to contribute to the study of the spreading of Tyrrhenian deposits in Greece. Besides which, in this study the morphometrical analysis of the Pleistocenic sandstone-conglomerate cobbles of the positions described is realised as a contribution to the study of the paleogeographic problems of the southeastern side of Sitia district.

The text is divided into three parts. In the first one, the term Tyrrhenian is discussed in general, as also the studies written up to now on the Tyrrhenian deposits of Crete. In the second part the Pleistocenic beds in various places of Sitia region are described and the enclosed fauna is examined. Lastly in the third part, the data of the morphometric study of the cobbles are mentioned and the relative paleogeographic conclusions are extracted.

FIRST PART

The term Tyrrhenian in general

In the year 1880 the Italian geologist G. SEQUENZA first observed the presence of petrified species in certain Mediterranean formations, which today are isolated and live on the atlantic shores of Africa. Based on the fossils, defined by himself, he characterized the enclosing beds as belonging to the Upper Sacharion and separated through a discord from the underlying bed belonging to the Lower Sacharion.

Thus SEQUENZA also underlined stratigraphically the significance of his paleontological discovery, in relation to the fauna, which has disappeared from the Mediterranean sea. So we can say that the stratigraphical definition of the stage later called Tyrrhenian is found in the above mentioned study of the Italian geologist.

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The term Tyrrhenian has been established through the study of A. ISSEL (1914) on the Quaternary of Sardinia, where he characterizes the beds of petrified Strombus with the name Tyrrhenian.

GIGNOUX (1913) described the significance of the disappeared species of tropical proportions in detail, as also the systematic succession of the sedimentation cycle of the beds with Strombus, using ISSEL'S term for the characterization of those beds. Besides which he accepts, that the Senegalese species of Tyrrhenian fauna lie in beds, the height of which is quite low, fluctuating between 0 - 35 m., with certain exceptions, as for instance Calabria, Isthmus of Corinth etc.

DEPERET (1918) discerned two horizons with Strombus in Tunisian Tyrrhenian. These horizons corresponded to the two transgression phases, separated by a regression of the sea. For the first horizon (30 m high) he preserved ISSEL'S term, however he called the lower one (15 m high) — and consequently more recent one —according to the altimeter theory, by the name Monastirian, from the place Monastir in Tunisia.

Although later studies proved that in this region there is a horizon with Strombus, which has been transported to several heights because of tectonic movements, DEPERET'S mistake survived and so prejudicated the necessity of the separation of Tyrrhenian.

Later the separation of Tyrrhenian was defined into T. I and T. II. CASTANY and OTTMAN (1957) identify Tyrrhenian and Monastirian with only one stage, that of Tyrrhenian II. The doubtful appearance of a Tyrrhenian older than T.I. caused new confusion and increased the Tyrrhenian levels to three. QIQUOUT (1949) wrote that Ouljien is a stage posterior to DEPERET'S Monastirian and that both clearly are the most recent deposits with Strombus. He observed the strata of Ouljien in Marocco. BONIFAY and MARS (1959) identify the term Ouljien with Neotyrrhenian. So, according to those authors the term Neotyrrhenian signifies deposits of the interstage Würm 1-Würm 2. The immediately older one, Eutyrrhenian, signifies the deposits of the maximum interglacial Riss-Würm. During Eutyrrhenian the evolution of the Senegalese fauna reached its highest point.

The same authors considered the formations, the ones older than Eutyrrhenian which might enclose Strombus, as a particular substage of Paleotyrrhenian. So they considered Paleotyrrhenian and Neotyrrhenian as the evolution phases of the beginning and the end of a warm fauna evolution which reaches its apogee in Eutyrrhenian. But, while the creation of Neotyrrhenian is especially fine and clear, that of Paleotyrrhenian is less successful. That is because Paleotyrrhenian is related to Tyrrhenian paleontologically, while stratigraphically its limits can't be defined clearly. The creators of the term themselves use it in different

T A B

Terminology and Stratigraphy of marine

PRINCIPAL TERMS	POSSIBLE EQUIVALENCE (Total or Partial)	STAGES	SUB - STAGES
Versilian (A. C. Blanc, 1936)	Flandrian (Dubois, 1924) Grimaldian (Bourcart, 1936)	Versilian	Middle Lower
Neotyrrhenian (Bonifay & Mars, 1959)	Tyrrhenian III Monastirian (Deperet, 1918)	Tyrrhenian	Upper = Neotyrrhenian
Eutyrrhenian (Bonifay & Mars, 1959)	Tyrrhenian II Tyrrhenian (Issel, 1914)		Middle = Eutyrrhenian Lower
Milazzian (Deperet, 1918)	Tyrrhenian I Paleotyrrhenian (Bonifay & Mars, 1959) Milazzian I, II, (Selli, 1949)	Sicilian	Upper Middle { Paleotyrrhenian Milazzian }
Sicilian (Doderlein, 1872)	Sicilian I, II, (Blanc)		Lower=Sicilian (typic.)
Calabrian (Gignoux, 1910)	Emilian (Ruggieri & Selli, 1948) Precalabrian (Selli, 1951)	Calabrian	Upper Middle = Emilian Lower { Calabrian (typic.) Precalabrian }

* This table compiling review data gives a representative example of taxonomic stratigraphy changes, as the subject remains open.

L E 1.

Pleistocene in the Mediterranean *.

MOVEMENTS OF THE SEA	TYPE OF FAUNA	GLACIAL CHRONOLOGY Post - glacial
Present level	Present	Würm IV
Transgression	Cold	Würm III
Regression	Cold Fauna occurences ?	Würm II (Würm)
Phase transgression	Warm	Interstage WI - WII (Würm)
Regression		Würm I (Würm)
Maximum transgression	Warm	Interglacial Riss - Würm
Transgression	Unknown Fauna (cold ?)	Riss
Regression		
Maximum transgression	Temperate warm, temperate	Intergacial Mindel - Riss
Transgression	Cold	
		Mindel
Regression		
Maximum transgression	Temperate	Interglacial Günz - Mindel
	cold	
Transgression	Temperate cold	Günz

(according to several authors, BONIFAY, MARS, SELLI, et al.) without excluding possible ways. BONIFAY (1964) accepts the value of a particular phase or a subdivision, the time limits of which must be placed in the Sicilian cycle and not in the Tyrrhenian one. MARS (1963) retained the term Paleotyrrhenian discerning it however, from Upper Sicilian (Milazzion) likening it to the third post-astian transgression.

In the previous pages is displayed a Table (1) with the views of several researchers, as to the separation and the chronological position of Tyrrhenian, just for information, since the problems concerning this Quaternary stage are many and various and the subject remains open.

Tyrrhenian in Crete Island

Tyrrhenian deposits are largely represented in Greece. Especially in Crete island the certification of the presence of Tyrrhenian beds has multiplied. PSARIANOS (1961) observed the first Tyrrhenian beds with *Natica lactea* and *Strombus* sp. in Arvi area and BOEKSCHOTTEN (1963) certified this once more, mentioning an oral communication of KOENIGSWALD about the discovery of *Strombus bubonius* in Arvi area.

BOEKSCHOTTEN (1963) described a fossiliferous Tyrrhenian westwards off Arvi, between Cape Trachili and Cape Kefala. Among the fossils he mentioned *Natica lactea*.

SYMEONIDIS (1967) attested Tyrrhenian beds eastwards off Hierapetra, at the places Peristeras, Koudounata, Stenaki, Kaki Skala and Koutsounari, as also on the opposite the shore lying islets of Chryssi, Koufonissi and Strongilo. Among the rich fauna collected he mentions, as a characteristic representative of Tyrrhenian, the gastropod *Polynices (Polynices) lacteus* GUILD.

ANAPLIOTIS and GEORGIADOU - DIKEOULIA (1967) noticed Tyrrhenian deposits on the eastern and western shores of Paleochora in SW Crete and, based on the fossil of *Conus testudinarius,* considered the strata Tyrrhenian.

DERMITZAKIS (1969) mentioned Tyrrhenian beds consisting of sandstone - conglomerates with benches of genus Glycymeris and lying discordantly on Neogene marls. Their presence is characteristic near the places Stomios, Gonies, Patella and Ammoudares to the west of Hierapetra. Recently, the gastropod *Strombus bubonius* LK. was found at the localities Giali and Ammudares, respectively east and west of the city of Hierapetra (pers. communication by L. Angelier, France).

KUSS (1970) studied fauna of Mammals in Rethymnon region and stating the shores' morphology, accepts the existence of terraces at a height of 30 m (Tyrrhenian I) and 20 m (Tyrrhenian II). He considered the latter one as created after an intratyrrhenian regression of the sea and a new impulse of it up to the height of 20 m.

KERAUDREN (1970) described certain Cretan shores and mentioned petrified corals and algae on the coasts to the south of Phalassarna. So, based on the petrified flora, he accepts that the terrace of Phalassarna Bay belongs to Eutyrrhenian excluding the presence of Sicilian. In Heraklion he also mentioned that he found littoral formations with fossils which he places in Neotyrrhenian age.

The platform with petrified algae eastwards off Heraklion near the airport is considered by him as Neotyrrhenian. The same author mentions, following GRADSTEIN'S information, a thin dune phase bed near Phaneromeni Bay at the northern coast of Sitia, which he believes Neotyrrhenian. Also GRADSTEIN (1973) described fossiliferous beds belonging to Vai Formation probably equivalent of the Tyrrhenian deposits of the islands Chryssi, Strongylo, Koufonissi.

PAPAPETROU - ZAMANI (1971) found a fossiliferous sandstone on the coast of Phalassarna and the adjoining one of Makri - Teichos and attributes it to Tyrrhenian II.

DERMITZAKIS (1972) studied the area of the peninsula of Gramboussa, certifying the presence of fossiliferous Tyrrhenian beds in the places a) Phalassarna, b) Tigani-Balos, c) Mouchli-Lakkos d) Kavonissi and e) Plaka-Limanaki. There he discovered and described an important number of petrified species, among which the horizon with benches of genus Glycymeris is characteristic.

Below there is displayed a map, on which are noted the places and the authors of the Tyrrhenian beds found up to now (fig. 1).

SECOND PART

Description of Tyrrhenian deposits

The existence of Tyrrhenian strata on the northeastern coast of Sitia had never been mentioned up to now by any of the researchers of Crete Island and this is probably due to the inaccessible and impassable nature of the area examined. The search for new leeward areas for the cultivation of early vegetables as well as the rapid tourist development of the coast led to the necessity of the construction of new roads to the coastal areas, which were inaccessible by land up to now and could only be reached by sea.

Our study covers the northeastern coastal zone of the District of Sitia, where Tyrrhenian strata have been observed at the following places or villages a) Mavros Kolymbos-Koutsouras, b) Makrys Gialos, c) Diaskari coast, d) Langada, e) Kalo Nero, f) Aghios Ioannis Kapsas, g) Atherinolakkos, h) Ambelos Bay, i) Xirokambos Coast (fig. 2).

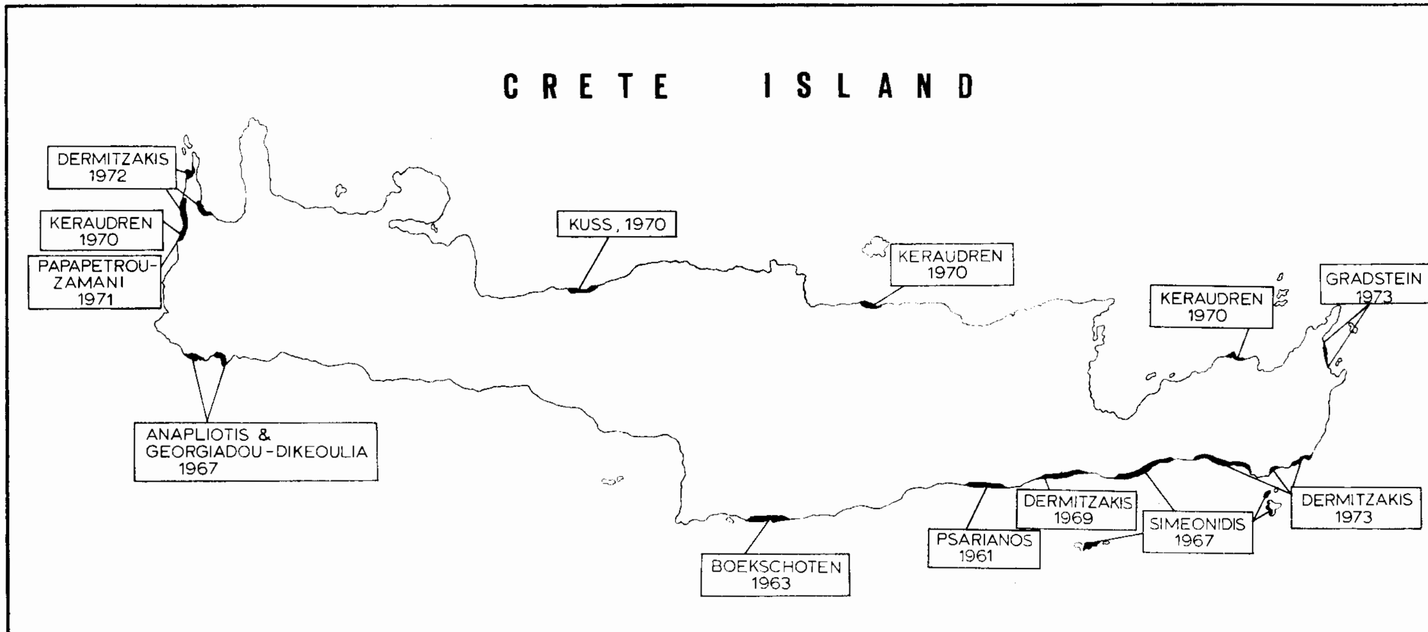

Fig. 1. Map of Crete Island with the places at which Tyrrhenian deposits have been certified.

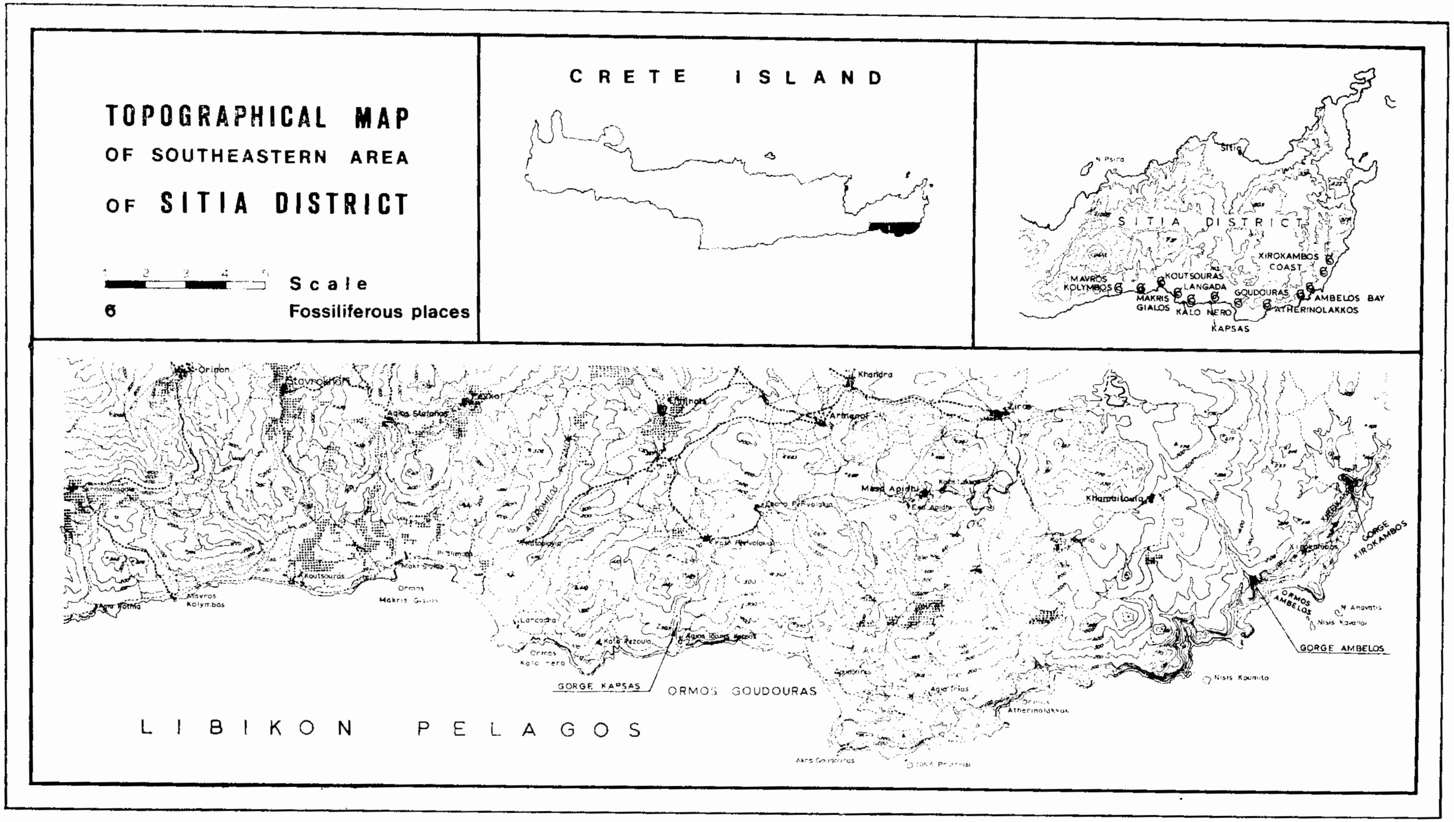

Fig. 2. Topographical Map of the district of Sitia, on which the fossiliferous occurences of Tyrrhenian are noted.

a) Mavros Kolymbos-Koutsouras Region

At Mavros Kolymbos cove and on the adjoining Koutsouras coast the Pliocenic sandstone-marls containing *Spondylus crassicosta* LK. (fig. 3, 4, 5) are unconformably covered by sandstone-conglomerates with large grey and black limestone cobbles and gravels, by flysch sandstones,

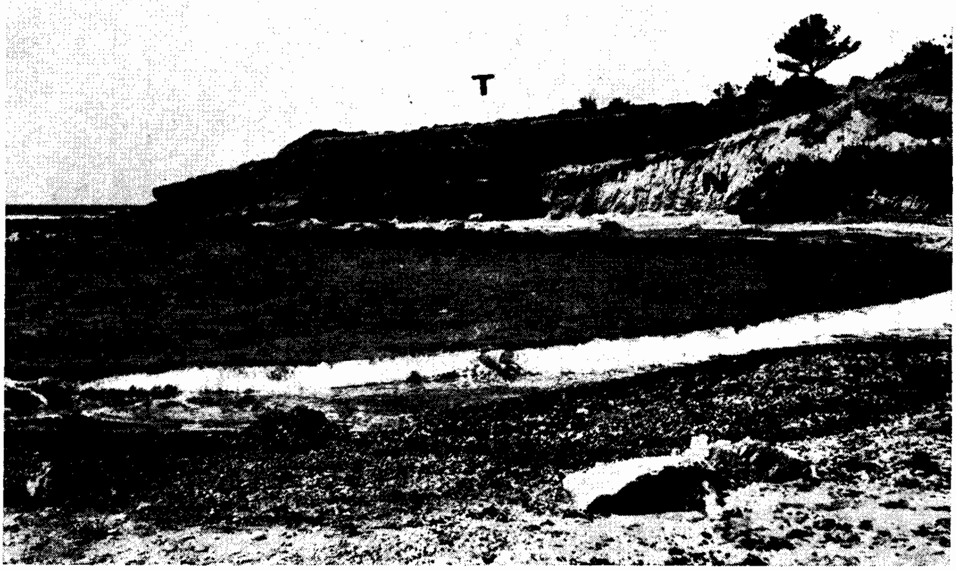

Fig. 3. Mavros Kolymbos region: The sandstone-conglomerates and the sandstones of Tyrrhenian (T) overlie the Neogene marls (N) discordantly.

by igneous rocks cherts, dolomites, etc. Morphometric analysis has been carried out on the cobbles (for details see page 209). The determined indices have shown that the cobbles are of marine origin. This was in fact expected since in several places the presence of enormous *Spondylus gaederopus* L. 10-12 cm in length was certified, as well as of Glycymeris (matrices). Characteristic is also the presence of individuals of the lamellibranchiate *Chama gryphoides* L.

The present fossils lie either within the binding sandstone material of the conglomerate, or within the sandstone horizon lying under the conglomerate. The height of these Tyrrhenian beds reaches 20 m (see fig. 4). In the same area sandstone-conglomerates of Pleistocenic age occur in the form of a terrace and at a height of 40 - 70 m. At some places the height of these sandstone-conglomerates exceeds 90 m. They lie unconformably on Neogene formations or are in touch with the slope

Fig. 4. A view of the Tyrrhenian deposits at the coast of Mavros Kolymbos.

surface of the Mesozoic mountains. Nowhere have fossils been found in them.

The same morphology of the coast goes on up to Koutsouras village (fig. 6), the only difference being that about half of the cobbles of the Tyrrhenian sandstone-conglomerate are of igneous material (diabases etc.) and the binding sandstone material is red-brown in colour. Within the conglomerate settlements of *Lithothamnium* coral bundles and lamellibranchiates *Spondylus gaederopus* L. and *Glycymeris glycymeris* L. are contained.

b) Makrys Gialos Region.

To the east of Koutsouras the small village of Makrys Gialos is located, the beautiful sandy coast of which is surrounded everywhere by

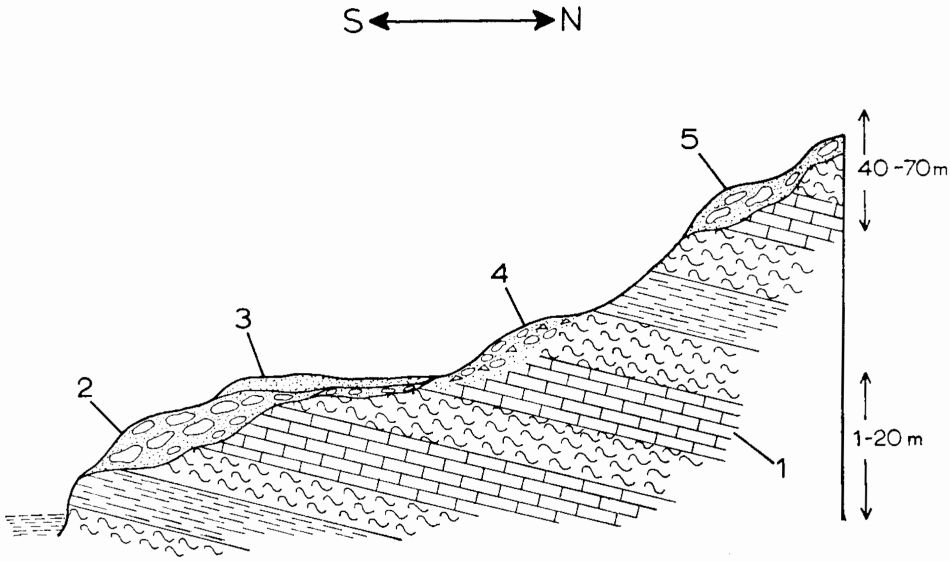

Fig. 5. A section at the place Mavros Kolymbos: 5) Pleistocenic sandstone-conglomerates of marine phase, without fossils at a height 40 - 70 m. 4) Debris of various material 3) Tyrrhenian sandstone material of a deeper marine phase 2) Sandstone-conglomerates of the Tyrrhenian transgression 1) Neogene marls, sandstones and marly limestones.

Fig. 6. Koutsouras beach: The Tyrrhenian sandstone-conglomerates overlie the Neogene horizons with marls discordantly.

sandstone and sandstone-conglomerates lying unconformably on Neogene marls (fig. 7). At the west end of Makrys Gialos Bay the thickness of the alternations of the Tyrrhenian strata reaches 12 m (fig. 8)

6) Towards the interior over the sandstone conglomerates lie tor-

Fig. 7. Eastern edge of Makrys Gialos Bay. The Tyrrhenian sandstone-conglomerates overlie the Neogene marls discordantly.

rential deposits with large cobbles, red or grey sands and red alluvian deposits of various composition.

5) Sandstone-conglomerate with cobbles of limestones, dolomites, diabases and marly sandstones compact material with abundant piles of *Lithothamnium,* probably offlap conglomerate.

4) Rough- grained sandstone, with fragments of fossils and Coral tufts (fig. 9).

3) Horizon of fine-grained, slightly compact sandstone. It is about sediments of a deeper marine phase with the following fossils.

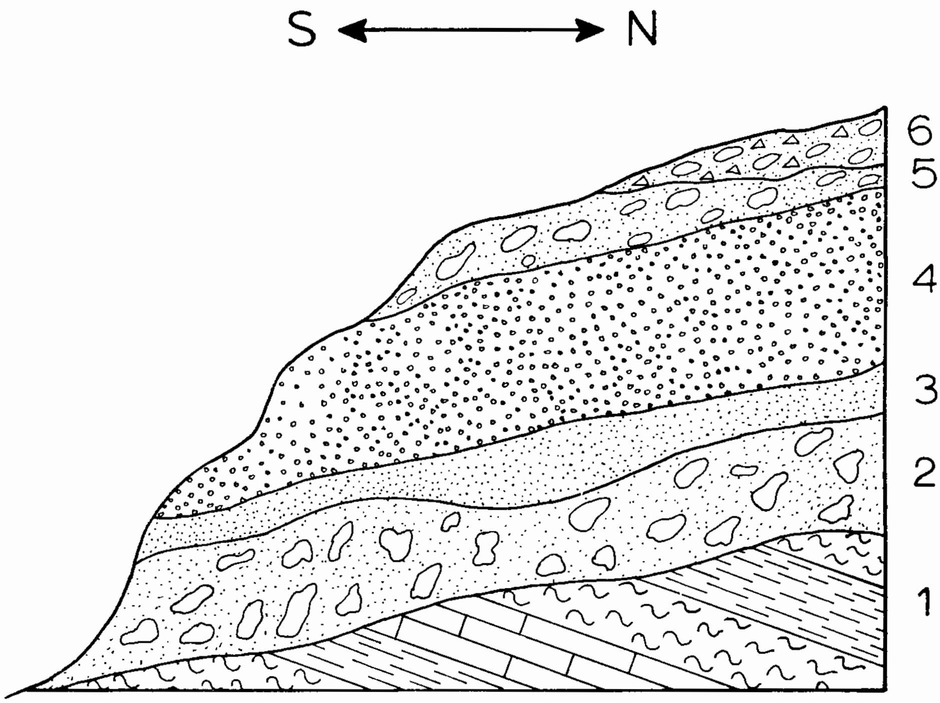

Fig. 8. A section of the western edge of Makrys Gialos Bay: 6) Various transported terrestrial materials 5) Sandstone-conglomerate, probably of regression 4) Sandy material with fossils and coral tufts 3) No compact sandstone sediments of deeper seas with fossils 2) Sandstone-conglomerate of Tyrrhenian transgression 1) Neogene marls and marly limestones.

Lamellibranchiates

Glycymeris (Glycymeris) glycymeris (LINNÉ)
Ostrea (Ostrea) lamellossa BROCCHI
Pina sp.
Cardium (Cerastoderma) edule (LINNÉ)
Venus (Venus) verrucosa LINNÉ
Chlamys (Chlamys) multistriata (POLI)
Lima (Lima) lima (LINNÉ)
Chlamys (Flexopecten) flexuosa (POLI)

Gastropods

Patella (Patella) caerulea LINNÉ
Cerithium (Therithium) vulgatum (BRUGUIÈRE)
Astraea (Bolma) rugosa LINNÉ

Corals

Cladocora cespitosa GUALT.

2) Sandstone-conglomerates in the upper horizons of which occur large individuals of the lamellibranchiate *Spondylus gaederopus* LK. It is about a conglomerate apparently of transgression.

Fig. 9. Coral tufts in the fossiliferous sandstone in the western edge of Makrys Gialos Bay.

1) Alternations of marls and marly limestones underlie in discordance, in which the lamellibranchiate *Pycnodonta navicularis* (BROCCHI) was found.

From the above mentioned and from the comparison of the strata of Makrys Gialos with the Tyrrhenian beds of other places in Crete, we accept that the horizons at Makrys Gialos are of a Tyrrhenian age. The fact of the presence of erosional old strandlines at a height of 12 - 14 m on the sandstone-conglomerates is also worth mentioning. These old strandlines have been created by the sea subsequently, after the deposition of the sandstone-conglomerates. A similar case of characteristic erosion-

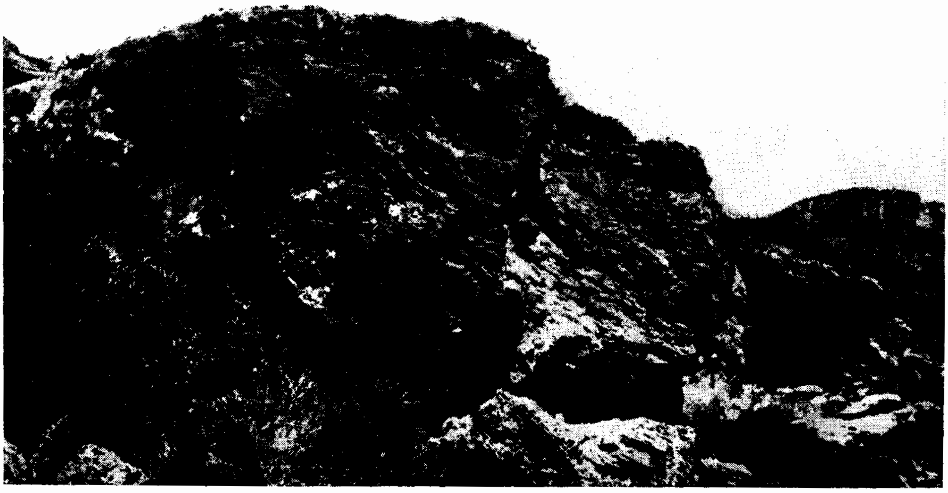

Fig. 10. Old strandlines on the Tyrrhenian sandstone-conglomerates at the place Ag. Saranta, at a height of 12 - 14 m and at a distance of about 800 m from the present-day coast. These old strandlines have been created later, after the deposition of the sandstone-conglomerates.

al old strandlines on Tyrrhenian sandstone-conglomerates was observed at the location Aghii Saranta, about 7 km eastwards off Hierapetra (see fig. 10).

c) Coast of Diaskari

To the east of Makrys Gialos and on the adjoining coast there is the shore of Diaskari. At this place the Tyrrhenian sandstone-conglomerates overlie the marly sandstone horizons and the marly limestones of Neogene age unconformably (fig. 11).

At first sight we have the impression of the presence of two terraces with Pleistocenic sandstone-conglomerates, the first at a height of 2 - 4 m and the second at a height of 18 - 25 m. In fact however, it is

Fig. 11. Coast of Diaskari : Neogene horizons (N) and the overlying deposits of sandstone-conglomerates and sandstones with fossils (T).

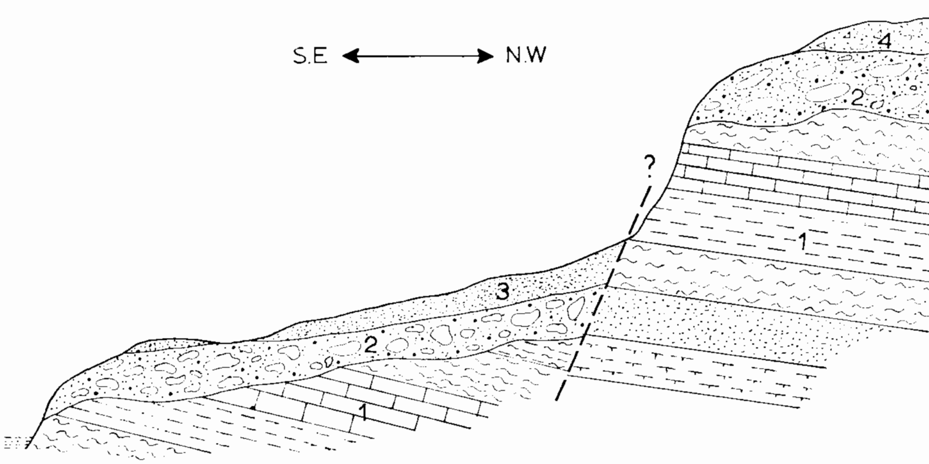

Fig. 12. Section at the coast of Diaskari : 4) Alluvial deposits with various material 3) Horizon of red-brown sandstone with fossils 2) Sandstone-conglomerate with *Glycymeris* 1) Alternations of marls, sandstones and marly limestones of Neogene, underlie discordantly.

only one terrace, separated and detached from its original place probably through a displacement (see fig. 12).

Within the sandstones and the sandstone-conglomerates of Diaskari fossils are found abundant only in individuals and not in species (fig. 13). The presence of plentiful individuals of the enormous lamellibranchiates

Fig. 13. Fossiliferous sandstone-conglomerate from Diaskari region.

Spondylus gaederopus L., *Glycymeris (glycymeris) glycymeris* L., *Glycymeris (Glycymeris) bimaculata* (POLI) is characteristic. In spite of the lack of guiding fossils in the above mentioned formations, we accept that they are of Tyrrhenian age, based on the stratigraphical position, the petrological composition and the comparison of the enclosed fauna with known Tyrrhenian deposits of proven age.

d) Langada region

At the coast of Langada the sandstone-conglomerates reach a height of 8 - 25 m, within which is found a small number of petrified *Spondylus gaederopus* L. and *Glycymeris glycymeris* L. Within intermediate lenses of sandstony red-brown material we found the following fossils: *Chlamys*

(Flexopecten) glabra (LINNÉ), *Thericium (Thericium) lividulum antiquum* MALATESTA, *Conus (Puncticulis) mediterraneus* HWASS, *Lunatia (Lunatia) catena* (DA COSTA) (fig. 14).

Going towards the interior of the place Pilalimata sandstone-conglomerates occur with rough-grained material without fossils, which at

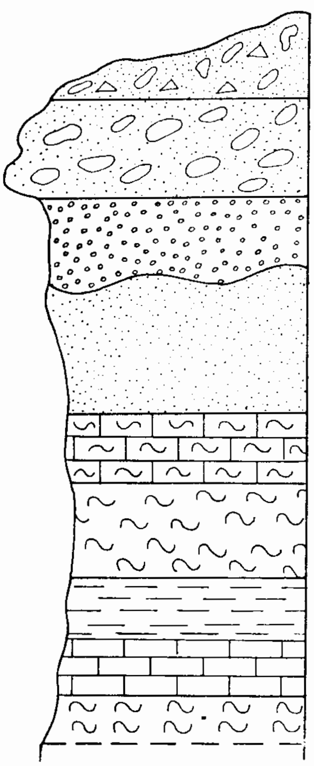

Fig. 14. Section at Langada locality:

1 1) Alluvial deposits

2 2) Sandstone-conglomerate with *Spondylus gaederopous, Glycymeris glycymeris, Chlamys glabra* etc.

3 3) Coarse-grained sandstone

4 4) Discordance

5 5) Fine-grained sandstone

6 6) Marly limestone

7 7) Blue-gray marl

8 8) Alternations of marls and marly limestones.

a height of 110 m overlie unconformably the marly sandstone horizons of Miocene. The age of the Tortonian of the underlying beds is proved through the presence of the following fossils:

Pecten (Flabellipecten) besseri ANDRZ
Pycnodonta navicularis (BROCC.)
Chlamys solarium LK.
Chlamys multistriata POLI
Amussium cristatum (BRONN)

From the above fossils the species *Pecten (Flabellipecten) besseri, Chlamys solarium,* are characteristic of Tortonian deposits. As for the overlying unconformably sandstone-conglomerates in the form of covers we accept that they are of Pleistocenic age of marine phase.

e) Kalo Nero region

Near Kalo Nero Bay at the place Ligidi, 2,5 km before the Monastery of Aghios Ioannis Capsas and to the south of the locality Pezoula, sandstone and sandstone-conglomerate beds are found enclosing plentiful fossils, among which there are some guiding ones for the Tyrrhenian age (fig. 15).

The formations of sandstones and sandstone-conglomerates overlie unconformably mainly on Pliocenic marls, as also on Mesozoic limestone formations. The thickness of the Tyrrhenian beds fluctuates between 1 - 10 m approximately. The height of the formed terrace reaches 2 - 25 m (fig. 16) Above 25 m the sandstone-conglomerates are covered by debris and thus a lateral transition to the abruptly rising mountains is formed. At the point of contact of the Neogene beds with the Tyrrhenian ones or of Mesozoic beds with the Tyrrhenian ones freshwater flows out. This water has a high content of several salts, so the region is called Good Water (Kalo Nero).

Inside the lower system of marly-sandstone horizons of Neogene the following fossils have been found:

Anomia (Anomia) ephippium LINNÉ
Chlamys scabrella LAMARCK
Chlamys varia LINNÉ
Ostrea (Ostrea) lamellosa BROCC.
Spondylus crassicosta LK.
Amussium cristatum (BRONN)
Pecten jacobaeus LK.

As proved by the above species these horizons at Ligidi locality are of a Pliocenic age.

Over the above mentioned beds the following strata lie unconformably. From the bottom upwards we observed:

a) Tenacious and loose sandstone-conglomerates including an important number of fossils in their upper part. They are transgression conglomerates.

b) Fossiliferous sandstone beds of yellow-white colour which are sediments of a deeper marine phase.

c) Sandstone-conglomerates with cobbles of white and black limestones and diabases, as well as cherts of red-white colour. This bed might be considered as a regression conglomerate.

Fig. 15. Coast of Ligidi in Kalo-Nero Bay: Marly sandstone horizons of Neogene and the overlying discordantly Tyrrhenian sandstones and sandstone-conglomerates.

Fig. 16. A view of the Tyrrhenian terrace along the coast of Kalo-Nero Bay.

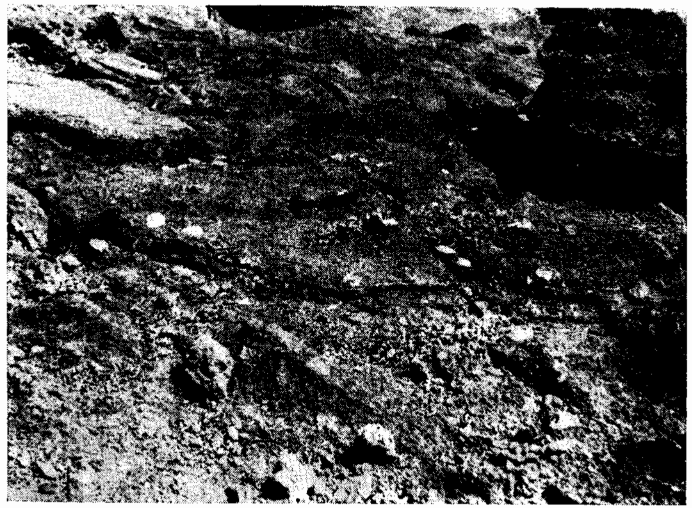

Fig. 17. Fossiliferous sandstone at Ligidi locality.

In the above mentioned beds of sandstone and sandstone-conglomerates, especially in the sandstones, the presence of numerous fossils has been confirmed, among which is the characteristic gastropod of the Tyrrhenian beds, *Conus testudinarius* MARTINI. The region as mentioned above is rich in fossils, enormous Spondylus and Glycymeris being especially abundant. The first ones surpass the second ones, thus we may say that we are dealing with benches of *Spondylus gaederopus* (fig. 17).

The fossils determined are the following:

Lamellibranchiates

Arca (Arca) noae LINNÉ
Glycymeris (Glycymeris) glycymeris (LINNÉ)
Glycymeris (Glycymeris) bimaculata POLI
Pecten (Pecten) jacobaeus (LINNÉ)
Spondylus gaederopus LINNÉ
Acanthocardia (Acanthocardia) aculeata LINNÉ
Barbatia (Barbatia) barbata (LINNÉ)
Ostrea (Ostrea) lamellosa BROCC.
Loripes (Loripes) lacteus (LINNÉ)
Lima (Lima) lima (LINNÉ)
Chama (Chama) gryphoides LINNÉ
Chlamys (Flexopecten) flexuosa (POLI)
Dosinia lupinus LINNÉ
Chlamys (Flexopecten) glabra (LINNÉ)
Cardium (Cerastoderma) edule communis DOD.
Venus (Venus) verrucossa LINNÉ
Aequipecten opercularis LINNÉ
Cardita (Cardita) antiquata (LINNÉ)
Cardium paucicostatum SOW.
Chlamys varia LINNÉ
Meretrix (Callista) chione (LINNÉ)

Gastropods

Conus testudinarius MARTINI
Conus (Puncticulis) mediterraneus HWASS
Natica (Natica) millepunctata LAMARCK

Thericium (Thericium) lividulum antiquum MALATESTA
Thericium (Thericium) vulgatum (BRUGUIÈRE)
Truncalariopsis trunculus (LINNÉ)
Patella (Patella) caerulea LINNÉ
Astraea (Bolma) rugosa (LINNÉ)
Vermetus intortus LAMARCK
Fissurella italica DEFRANCE
Diodora (Diodora) italica (DEFRANCE)
Buccinulum (Euthria) corneum (LINNÉ)
Astraea (Bolma) rugosa (LINNÉ) (Operculum)
Mitra cornicula LINNÉ
Turritella (Turritella) tricarinata BROCCHI

Ciripedia

Balanus sp.

Corals

Cladocora cespitosa GUALT.

Algae

Lithothamnium sp.

f) Region of Aghios Ioannis Kapsas

At the coast a terrace is formed at a height ranging between 8-20 m consisting of sandstone-conglomerates and sandstone with fossils (fig. 18, 19). This terrace comes in contact through a lateral transition with debris on the steep limestone mountains. In these Cretaceous limestones the gorge of Kapsas is formed in the direction NNE-SSW, through which the rainwaters of the regions Epano and Kato Perivolakia are conveyed. The height of its slopes reaches 350 m, while the width ranges between 5 m and 15 m approximately.

At the western part of the exit of the gorge the above mentioned Tyrrhenian terrace is met. In the lower parts consisting of sandstone-conglomerates, as well as in the overlying reddish sandstone, petrified *Spondylus gaederopous, Glycymeris glycymeris* and *Chama gryphoides* have been found.

Over the already mentioned Tyrrhenian sandstone-conglomerates terrestrial colluvial deposits and slope fan debris are met.

At the eastern part of the coast, after Kapsas gorge, remains of a sandstone-conglomerate are observed at a height of 12-18 m on the steep coast consisting of Cretaceous limestones. These are the remains of the Tyrrhenian transgression.

g) Atherinolakkos location

After Cape Goudouras to the East at the coastal zone of the Ormos of Atherinolakkos, Pleistocenic marine strata of sandstone-conglomerates

Fig. 18. A view of the terrace of sandstone-conglomerate near the exit of the gorge of Ag. Ioannis Kapsas.

and sandstones of a reddish colour are found. These lie unconformably on Neogene marls and include exclusively fossils of the genus Glycymeris.

h) Ambelos Bay

Ambelos bay is located at the southeastern edge of the District of Sitia. In this bay, as it has also been reported by PAPADAKIS (1937), under sea level lie the ruins of the ancient city of Ambelos or Stylae. At the western end of the bay rises the hill Paranoma (height 41 m) and at the eastern end the hill Trachilas (height 56 m). Evidence of the fact that the hill of Trachilas continues into the sea, is provided by the small islands i) Anavatis (height 47 m) ii) Kephali (h. 24 m) and

iii) Kavalli (h. 59 m). On the last one, remains of Neogene marls are preserved (see fig. 20).

Around the middle of the coast of the bay is the mouth of the torrent which flows along the Ambelos gorge (fig. 21) The slopes of the gorge rise steeply to a height of about 350 m and show a width of

Fig. 19. Tyrrhenian fossiliferous sandstone-conglomerates and red-brown sandstones near Ag. Ioannis Kapsas.

15 - 30 m at the exit of the gorge. The gorge is in a NNW - SSE direction and in it the waters of Lamnoni region are drained.

The whole coastal zone is covered by a terrace of reddish sandstone 2-15 m in height, which includes numerous fossils. At this region another terrace is also met at a height of 40 - 70 m consisting of coarse-grained sandstone-conglomerates. At certain places this terrace is formed not by the existence of the sandstone-conglomerate but by the formation of a plane surface on the hills of Mesozoic and Neogene limestones. At the lower terrace, where we found numerous fossils, the lower horizon consists of sandstone-conglomerates, on which lies a horizon of reddish sandstones. In their horizons fossils have been found which are numerous in regard to the number of individuals but not in regard to the number of species. Characteristic are the benches with individuals of the genus

Fig. 20. A view of Ambelos Bay: (Π) Paramona hill, (T) Trachilas hill, (N) Kefali islet, (K) Kavalli islet, (A) Anavatis islet.

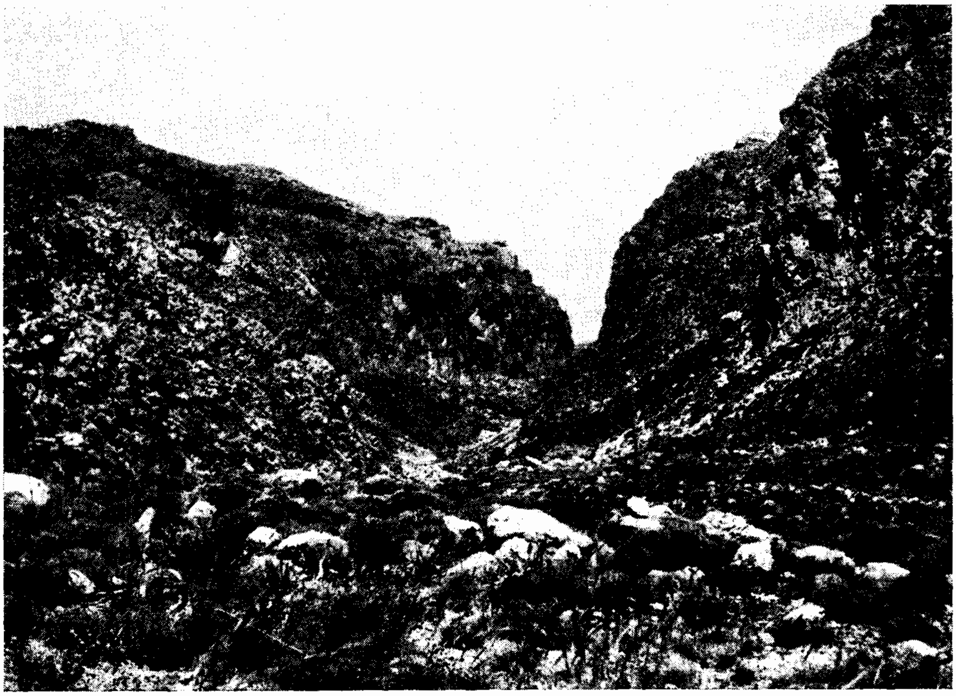

Fig. 21. The exit of the gorge of Ambelos.

Glycymeris. The fossils of the species *Glycymeris glycymeris* L. and *Glycymeris bimaculata* POLI are so abundant, that we may say that this is the richest fossiliferous deposit in benches with Glycymeris of all ever found on the Island of Crete (fig. 22).

These Tyrrhenian horizons of sandstone-conglomerates and sandstones lie unconformably either on pre-neogene limestones or on grey-green

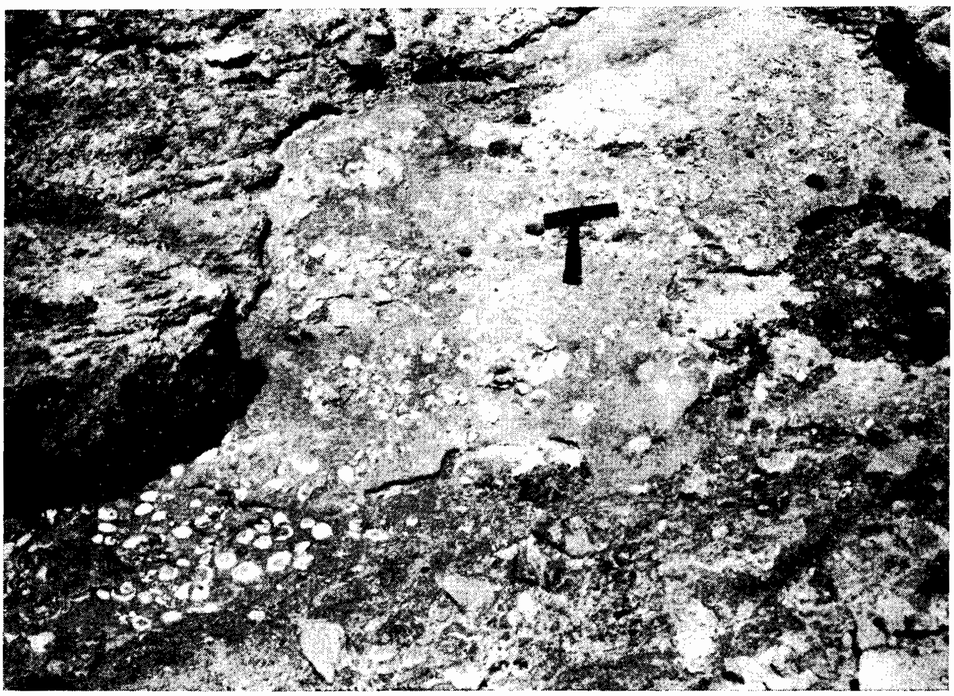

Fig. 22. Fossiliferous sandstones at Ambelos locality.

marls, in which characteristic fossils of the Pliocene have been found. The fossils found in the Pliocenic marls at the coast near Trachilas are:

Chlamys varia LINNÉ
Amussium cristatum (BRONN)
Pecten jacobaeus LAMARCK
Ostrea (Ostrea) lamelossa BROCCHI

i) Xirokambos Region

Eastwards off Ambelos Bay the village of Xirokambos is located, 21 km by road from the village Ziros. The village of Xirokambos is rapidly developing due to its beautiful sandy beach and its mild climate.

Fig. 23. A view of Xirokambos Beach. Alatsolimni lagoon is discerned.

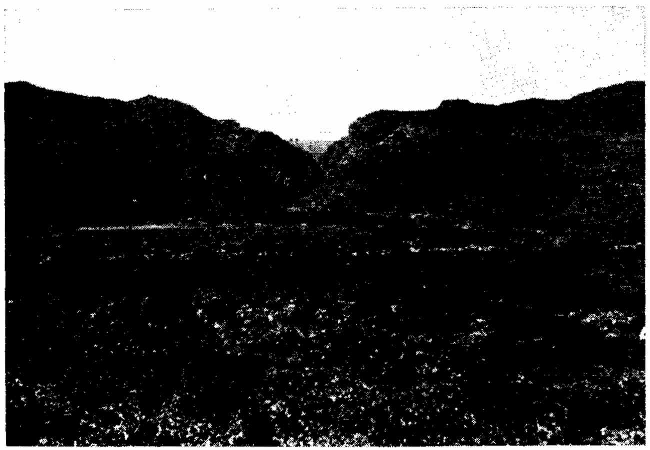

Fig. 24. A view of the exit of the gorge of Xirokambos.

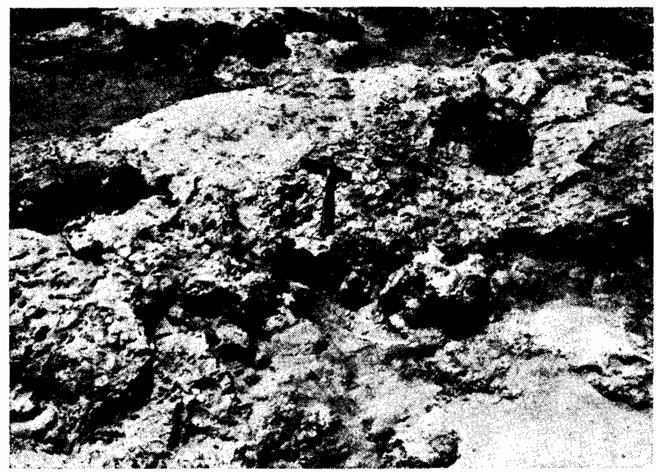

Fig. 25. Fossiliferous red-brown sandstones near Xirokambos.

At the base of the steep limestone mountains of the Tripolis zone a terrace of a height ranging between 3 - 30 m is formed consisting of sandstone-conglomerates and sandstones which lie unconformably on Eocenic limestones with Nummulites and on Neogene marls and marly limestones. In the sandstone-conglomerates of the lower horizon the following fossils have been found (fig. 25):

Lamellibrachiates

Spondylus gaederopus LINNÉ
Chlamys (Chlamys) multistriata (POLI)
Glycymeris (Glycymeris) glycymeris (LINNÉ)
Chlamys (Flexopecten) glabra (LINNÉ)
Lucina (Lucinoma) borealis (LINNÉ)

Gastropods

Astraea (Bolma) rugosa (LINNÉ)
Patella (Patella) caerulea LINNÉ
Patella (Patellastra) lusitanica GMELIN.
Thericium (Thericium) vulgatum (BRUGUIÈRE)
Truncularíopsis trunculus (LINNÉ)
Columbella rustica LINNÉ
Conus (Puncticulis) mediterraneus HWASS
Buccinulum (Euthria) corneum (LINNÉ)
Cerithium (Thericium) mediterraneum DESH.

In some places the Tyrrhenian strata are covered by alluvian deposits, while at the coast they are covered by white sandy zones and dunes. At the eastern end of the coast the small lagoon Alatsolimni is located (fig. 23), the southern part of which is surrounded by dunes and sand and the northern part by Tyrrhenian sandstone-conglomerates.

At the western part of Xirokambos a small gorge, the gorge of Xirokambos, is formed in the limestones (fig. 24). The height of its slopes reaches 240 m. Its direction is parallel to the direction of the previously mentioned Ambelos gorge, but its length is much smaller.

THIRD PART

Results of the morphometric study of Cobbles

As is shown in the previous chapter the shallow coastal zone along the southeastern coast of the District of Sitia is covered mostly by sandstone-conglomerates and sandstones of Tyrrhenian age. The existence of marine fauna in many localities indicates a priori the marine origin of the Tyrrhenian formations.

In earlier years the view had been expressed (CREUTZBURG 1961) that during the warm Tyrrhenian transgression when the sea-level was 25 - 30 m higher, the Pleistocenic conglomerates had been formed in the sea from embankments, as at Makrys Gialos, where the existence of Penctunculus in the sandstone-conglomerates up to a height of 25 m had also been reported.

Thus the purpose of this chapter is to prove with more positive arguments the marine formation of the cobbles, through the use of morphoscopy and morphometry of the cobbles from the sandstone-conglomerates of the SE coast of Sitia and moreover to contribute to the knowledge of the palaeogeography of SE Sitia during the Tyrrhenian period. The study of the cobbles was carried out at five locations on 100 cobbles from each location. The values of the measured sizes are given in the tables 2, 3, 4. For the calculation of the grade of i) the Flatness A, ii) the Dysymmetry D, iii) the Roundness R, as well as of the ratios E/L and E/l GAILLEUX'S method was used (for details: MARINOS *et al.* 1970). For the calculation of the Flatness the relation $A = \frac{L+l}{2E} \times 100$ is used, for the Dysymmetry the relation $D = \frac{AB}{L} \times 1000$, for the Roundness $R = \frac{2r}{L} \times 1000$, where r is the shortest radius of curvature, L the length of the cobble, i.e. its greatest dimension, l the greatest width laterally to the length, E the thickness of the cobble laterally

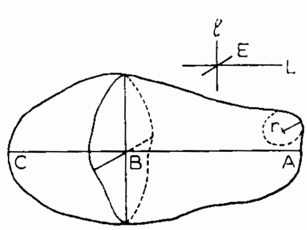

Fig. 26. Schematic representation of the morphometric elements of a cobble.

to the length and width and AB is measured on L from its intersection with the greatest width (fig. 26). The size of the cobbles measured ranged between 5 and 20 cm L. This size was chosen, because most of the cobbles ranged between these limits and were found in the sandstone-conglomerates of all five regions investigated.

For each location the mean values of the different sizes were calculated and the respective histograms of the flatness and the roundness were constructed (fig. 27, 28). Table 2 illustrates the results (mean values) of the measurements carried out at the five locations of the SE coast of Sitia.

TABLE 2.

Locations	Flatness $\overline{A}$	Dysymmetry $\overline{D}$	Roundness $\overline{R}$	Ratio $(\overline{E/L})$	Ratio $(\overline{E/l})$
1) Mavros Kolymbos	236	592	386	0,441	0,585
2) Koutsouras	270	557	340	0,362	0,489
3) Makrys Gialos	279	600	366	0,349	0,501
4) Kapsas	317	616	418	0,295	0,434
5) Xirokambos	302	597	377	0,324	0,479

i) For the Flatness, the literature (MÜLLER 1967) lists for the cobbles of river torrential formation A = 160 - 220 and for the cobbles of marine formation A = 230 - 280. The results of our calculations are as follows (see also table 3, fig. 27).

a) Mavros Kolymbos. At this location the values of the flatness of the cobbles show a minimum 134 and a maximum 428, the mean value being $\overline{A}$=236. The size of flatness at this location is found to be slightly higher than the limit, above which we assume marine formation of the cobbles (fig. 27).

b) Koutsouras. For the cobbles of this location the values of flatness range between 127 and 587 and the mean value is $\overline{A}$ = 270, which means that they are evidently of marine formation (fig. 27).

c) Makrys Gialos. The minimum and the maximum value are 134 and 625 respectively, $\overline{A}$ = 279, consequently the cobbles are definitely within the range of the cobbles of marine origin (fig. 27).

d) Kapsas. At this location the values of the flatness range between 159 and 681, the mean value $\overline{A}$ is 317, i. e. they are of marine formation (fig. 27).

e) Xirocambos. At this location the values of A range between 134 and 639. The mean value $\overline{A}$ is 302 which means that they are of marine origin (fig. 27).

ii) The index D of the Dysymmetry of a cobble is defined as the ratio AB/L. According to the tables of CAILLEUX and TRICART (1966) the values, between which this size ranges, are related to the petrologic composition of the cobbles. The mean values for the index D at

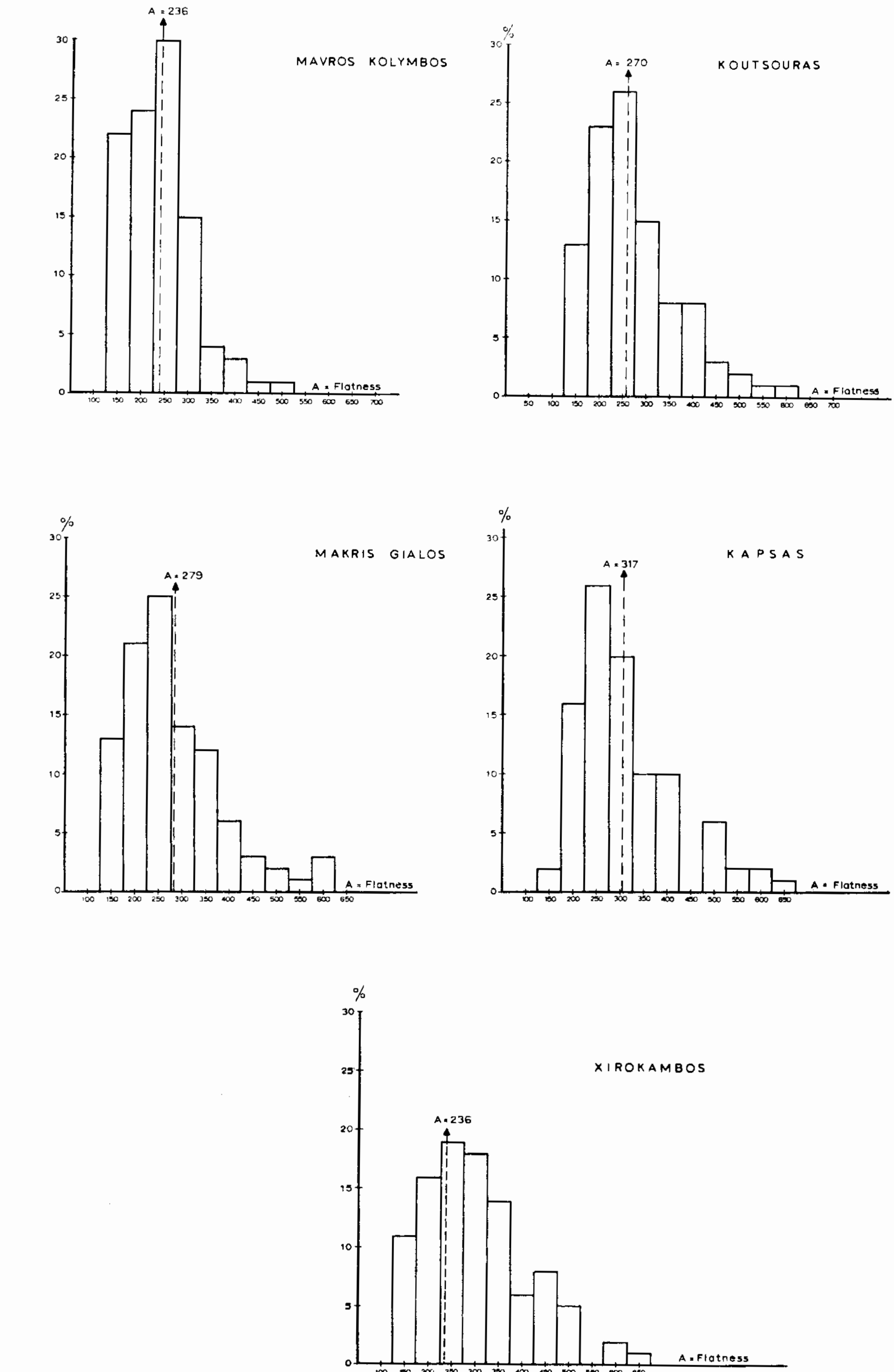

Fig. 27. Histograms representing the frequency-distribution of classes of Flatness A at the studied localities.

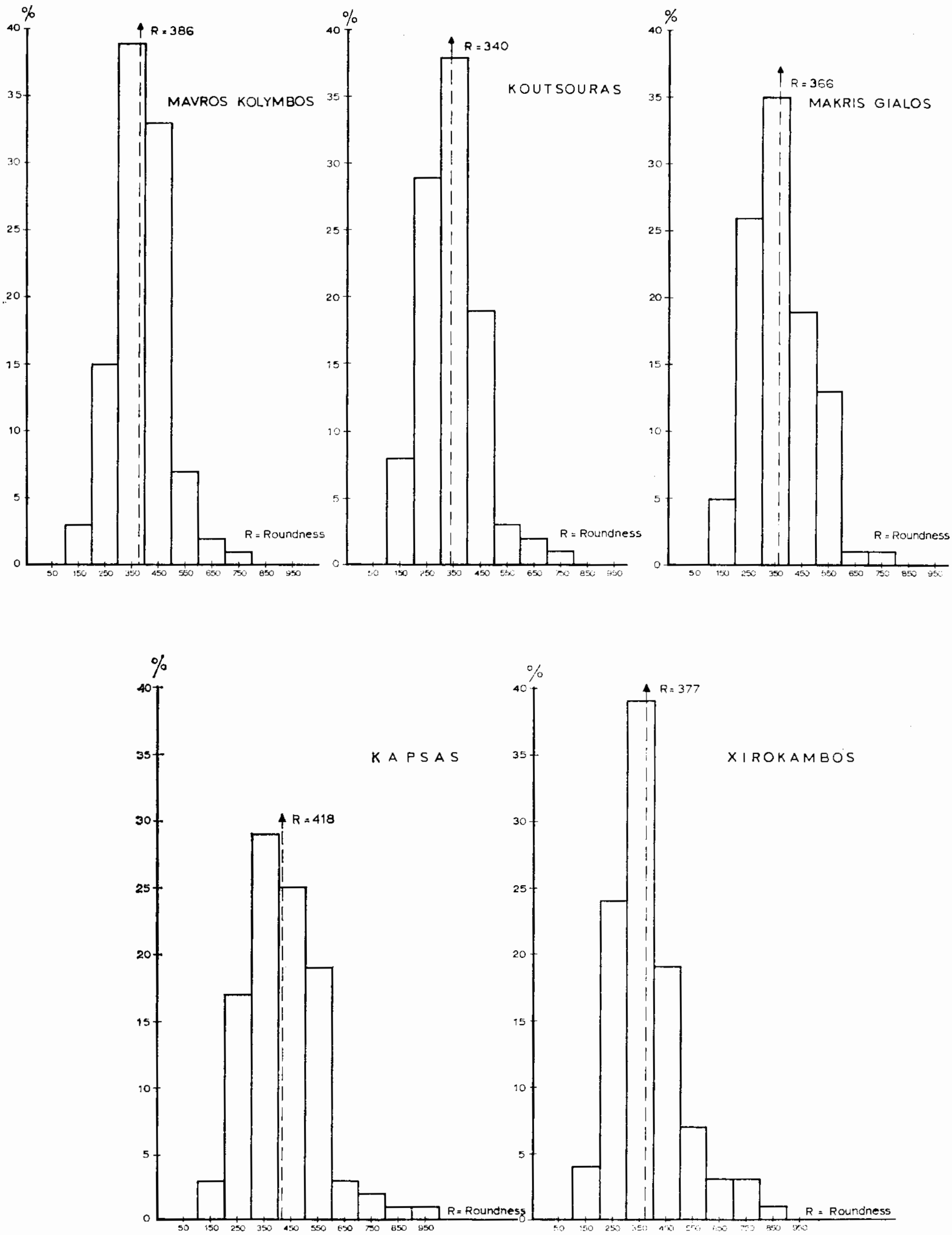

Fig. 28. Histograms representing the frequency-distribution of classes of Roundness R at the studied localities.

the locations investigated range between 557 and 616 (see table 2). Thus if we take into consideration the petrologic composition of the cobbles measured at each location, their formation may be attributed to marine action.

iii) For the R o u n d n e s s R of marine cobbles CAILLEUX assumes (MÜLLER 1967) values ranging between 170 and 610. All the mean values found prove the marine formation of the cobbles at the investigated locations (table 4). Thus

a) at Mavros Kolymbos $\bar{R} = 386$, the minimum and maximum values being 182 and 709,

b) at Koutsouras the mean value $\bar{R} = 340$ with an interval ranging between 180 and 707,

c) at Makrys Gialos the values of R range between 110 - 753, the mean value $\bar{R}$ is 366,

d) at Kapsas $\bar{R} = 418$ with minimum and maximum values 180 and 940 respectively,

e) at Xirokambos finally, the mean value $\bar{R} = 377$, the minimum and maximum values are 160 and 883.

For the fluctuations of frequency concerning the roundness R see the constructed histograms for each location (fig. 28).

iv) For the cobbles of the district of Sitia the r a t i o s E/L (thickness to length) and E/l (thickness to width) were also calculated. The mean values of these sizes for the locations examined were found to fluctuate for the ratio E/L between 0,295 and 0,441 and for the ratio E/l between 0,434 and 0,585 (see table 2).

The values found prove, according to the general model of BUTZER (MARINOS *et al.* 1970), that during the shape elaboration of the cobbles the main role was played by sliding.

v) The conglomerates under examination show petrologic variety of the cobbles for the different locations. Thus the petrographic composition of the cobbles is approximately the following (fig. 29):

a) at the location Mavros Kolymbos 31 % are from limestones, 28 % dolomites, 22 % from sandstones and the rest of the cobbles, come from cherts, limestones-conglomerates, schists and other material.

b) at Koutsouras 37 out of 100 cobbles belong to diabases, 17 % to black and grey limestones, 16 % to calcitic sandstones, 12 % to schists, 11 % to dolomites, 4 % to limestone-conglomerates and the rest are cobbles from cherts, calcite etc.

c) In the conglomerates of Makrys Gialos 27 % of the cobbles are

TABLE 3.

Frequency distribution of Flatness A.

	Class Limits	126 - 175	176 - 225	226 - 275	276 - 325	326 - 375	376 - 425	426 - 475	476 - 525	526 - 575	576 - 625	626 - 675
	Midpoints	150	200	250	300	350	400	450	500	550	600	650
Frequency %	Mavros Kolymbos	22	24	30	15	4	3	1	1	—	—	—
	Koutsouras	13	23	26	15	8	8	3	2	1	1	—
	Makrys Gialos	13	21	25	14	12	6	3	2	1	3	—
	Kapsas	2	16	26	20	10	10	5	6	2	2	1
	Xirokambos	11	16	19	18	14	6	8	5	—	2	1

TABLE 4.

Frequency distribution of Roundness R.

	Class Limits	101 - 200	201 - 300	301 - 400	401 - 500	501 - 600	601 - 700	701 - 800	801 - 900	901 - 1000
	Midpoints	150	250	350	450	550	650	750	850	950
Frequency %	Mavros Kolymbos	3	15	39	33	7	2	1	—	—
	Koutsouras	8	29	38	19	3	2	1	—	—
	Makrys Gialos	5	26	35	19	13	1	1	—	—
	Kapsas	3	17	29	25	19	3	2	1	1
	Xirokambos	4	24	39	19	7	3	3	1	—

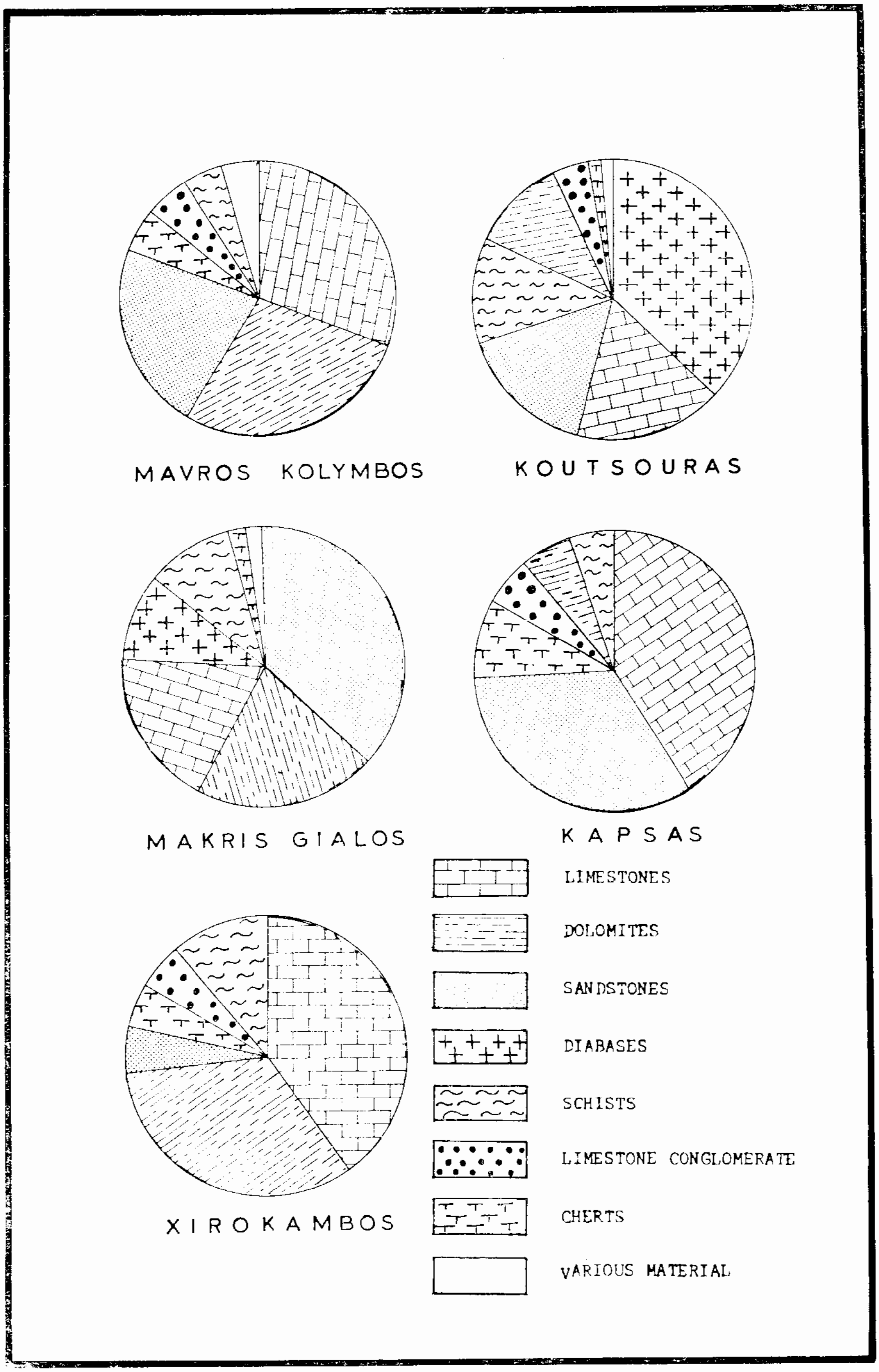

Fig. 29. Petrographic composition of cobble-assemblages (in percentages) at the investigated localities.

calcitic fine-grained sandstones, 18 % dolomites, 14 % grey and black limestones, 10 % diabases, 5 % schists, granodiorites, cherts etc.

d) at Aghios Ioannis Kapsas, 41 % of the cobbles are black, grey and white limestones, 33 % calcitic fine-grained sandstones, 9 % cherts red-brown and red-white in colour, 9 % limestone breccia-conglomerates and the rest of the cobbles are dolomites and schists.

e) At the location Xirokambos most of the cobbles are from limestones 40 %, 19 % are dolomites, 14 % calcitic sandstones and the rest of the cobbles are limestone breccias, schists, cherts, calcites, etc.

DISCUSSION

From the above descriptions of each of the areas investigated it can be concluded, that we have to deal with strata of the Tyrrhenian cycle of sedimentation sensus stricto and this because, as was mentioned at the beginning, the views concerning the Tyrrhenian period are still, in spite of numerous discussions, an open subject.

Owing to the existing dissimilarity in the thickness of the fossil-rich Tyrrhenian sediments in neighbouring localities of the examined area, we have constructed a series of schematic sections, in order to describe the paleogeographic evolution of the region during the Tyrrhenian age, which proved to be as follows:

i) After the deposition of the Neogene formations ascendent epirogenetic movements took place, developed into tectonic ones, resulting in the rupture and the formation of mainly normal faults. Thus later a base-relief was formed (Fig. 30 A).

ii) The descendent epirogenetic movements or the eustatic elevations of the sea which then followed — in our opinion probably mostly eustatic elevations of the sea — resulted in the gradual transgression of the lower parts of the already formed land (Fig. 30 B). Moreover the existing strata were scraped off and thus terraces of destructive form were built[1].

iii) The beginning of the Tyrrhenian cycle of sedimentation occurred with the transgression conglomerates, which occupied the lower parts of the old land. The marine origin of the conglomerates was also certified by the morphoscopy and the measurement of the cobbles (fig. 30 C).

1. Due to this fact, fossils of earlier deposits were withdrawn and then mixed with the Tyrrhenian strata, as for example, at the locality Fournou Koryfi, to the east of the village Myrtos, where (Symeonidis 1965) fauna of the Pliocene has been included in the Pleistocenic sandstone-conglomerate.

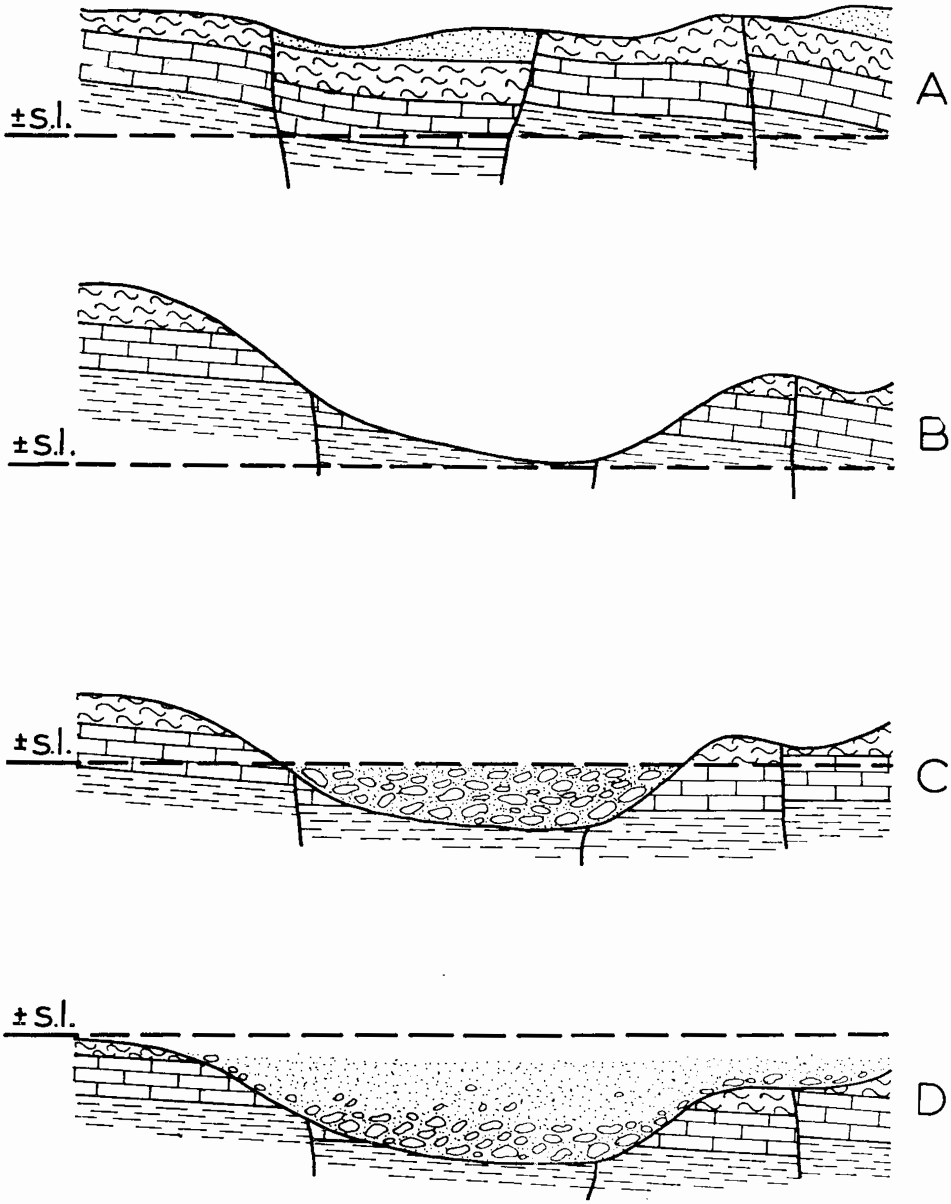

Fig. 30. Schematic sections summarising the paleogeographic evolution during the Tyrrhenian.

iv) While the Tyrrhenian transgression expanded and the sea-level gradually rose into parts of the coast, the deposition of conglomerates also continued as the coastal zone expanded progressively into the interior of the island. But as the transgression continued, the original coastal parts gradually obtained greater depth, with the result that sediments

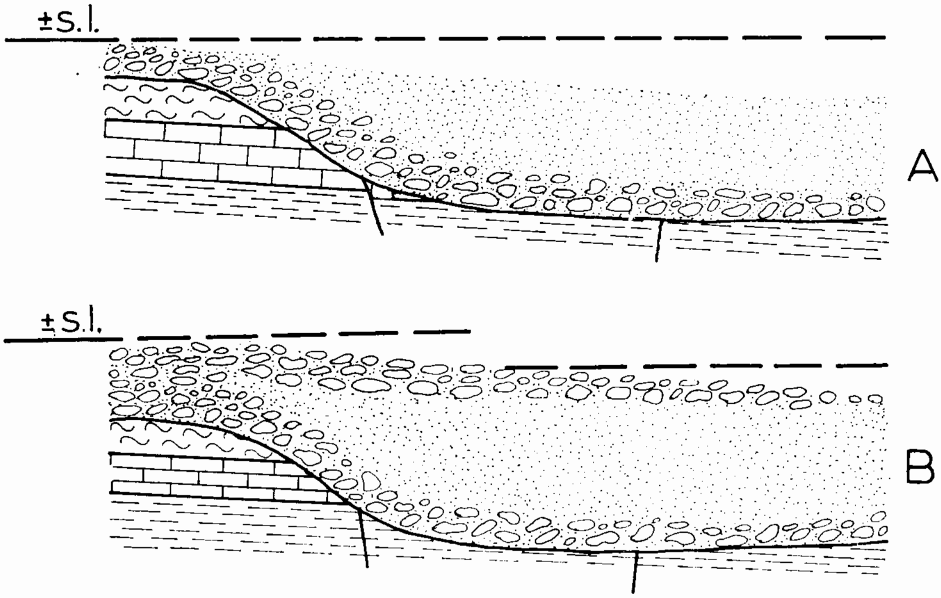

Fig. 30a. Schematic sections (oriented normally to those of fig. 30) summarizing the paleogeographic evolution during the Tyrrhenian).

lying over the basic conglomerate are more fine-grained, as for example, the sandstone bed, which has been observed in almost all the localities of the region investigated (fig. 30 D).

v) Thus the deposition of two different types of sediments took place: on the one hand of the sands and sandstones in the deeper places with gastropods, corals and lamellibranchiates, and on the other hand, on the side of the land, of the coarse-grained sandstone conglomerates with the thickshelled Spondylus and Glycymeris (fig. 30a section A).

vi) After the end of the sea transgression its regression started, the fulfilment of which must have occurred not continuously but in parts, as is concluded from the observed old strandlines, which will be discussed later.

vii) The deposition of the regression conglomerate covered the sand sediments of the deeper seas. But in certain places it covered the transgression conglomerates directly without the existence of intermediate sandstone bed (fig. 30a section B).

After the deposition of these last sandstone conglomerates a stagnation in the rhythm of the regression must have taken place or a new intratyrrhenian transgression must have occurred which resulted in some places in the formation of the characteristic furrow-like lines on the already deposited formation, like, for example, at Aghii Saranta, Makrys Gialos (fig. 10) or in other places in the deposition of sediments, which have not been certified in our region.

In the previous pages we have tried to explain the deposition of Tyrrhenian sediments in SE Crete based on the shape of the Tyrrhenian deposits and the present morphology of the coasts. It would be of interest to state some of our observations on the tectonic action before and after Tyrrhenian. As it has already been mentioned, after the deposition of the Pliocenic strata, tectonic movements took place, which resulted in the fracturing and faulting of the Neogene beds. The breaking up of the coasts of Crete was quite advanced so that the uplifts of the sea-level itself can explain the expansion of the transgressions.

After the deposition of the Tyrrhenian deposits some more recent faults were formed, considered as having been provoked by quite intense movements (DERMITZAKIS 1969). It is possible that many valleys and coasts represent reanimated old tectonic lines, the further evolution of which stopped during the Neogene and was repeated after the ascension of Crete during the Quaternary. So considering the posttyrrhenian movements, observed on the Tyrrhenian beds of Crete, it is obvious that the altimeter theory cannot be valid. Several authors already mention Tyrrhenian beds in Crete, at heights either higher or lower than the limits placed by the altimeter theory.

ACKNOWLEDGEMENTS

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SUMMARY

In this paper the Pleistocenic marine deposits of the coastal zone of the southeastern coast of Sitia district are described. These beds

enclose an important number of fossils. We can characterize them as of Tyrrhenian age, based on the guiding gastropod *Conus testudinarius* MART., the thickshelled, oversized lamellibranchiates of the species *Spondylus gaederopus* L. and the benches of genus Glycymeris. We also have verified through local comparative observations, that the lithological character, the enclosed fauna and the stratigraphical position of the Tyrrhenian deposits of SE Sitia resembles the corresponding beds of other areas of Crete.

The formations of Tyrrhenian age consist mainly of sandstones and sandstone-conglomerates, which lie unconformably on Neogene and Preneogene beds. Tyrrhenian beds with fossils have been verified at the locations Mavros Kolymbos, Koutsouras, Makrys Gialos, coast of Diaskari, Langada, Kalo Nero, Agh. Ioannis Kapsas, Atherinolakkos, Ambelos Bay, coast of Xirokambos.

A morphometric analysis of the enclosed in Tyrrhenian sandstone-conglomerates cobbles has been realised. The mean values found after calculations are: Flatness $\bar{A} = 236 - 317$, Dysymmetry $\bar{D} = 557 - 616$, Roundness $\bar{R} = 340 - 418$. These values confirm the marine origin of the cobbles at the examined places.

At last, sections are given and opinions are expressed about the paleogeographic evolution of the Tyrrhenian deposits of SE Crete.

ΠΕΡΙΛΗΨΙΣ

Εἰς τὴν παροῦσαν ἐργασίαν μελετῶνται καὶ περιγράφονται τὸ πρῶτον οἱ Πλειστοκαινικοὶ θαλάσσιοι σχηματισμοὶ τῆς παρακτίου ζώνης ἐπὶ τῆς νοτιοανατολικῆς παραλίας τῆς ἐπαρχίας Σητείας. Οἱ σχηματισμοὶ οὗτοι περικλείουν σημαντικὸν ἀριθμὸν ἀπολιθωμάτων. Χαρακτηρίζονται δὲ ὡς Τυρρηνίου ἡλικίας βάσει τοῦ καθοδηγητικοῦ γαστεροπόδου *Conus testudinarius* MART., τῶν παχυοστράκων ὑπερμεγέθων ἐλασματοβραγχίων τοῦ εἴδους *Spondylus gaederopus* LINNÉ καὶ τῶν τραπεζῶν τοῦ γένους *Glycymeris*.

Ὡσαύτως διεπιστώθη ἐξ ἐπιτοπίων συγκριτικῶν παρατηρήσεων, ὅτι ὁ λιθολογικὸς χαρακτήρ, ἡ ἐγκλειομένη παλαιοπανὶς καὶ ἡ στρωματογραφικὴ διάταξις τῶν Τυρρηνίων ἀποθέσεων τῆς ΝΑ Σητείας ὁμοιάζει πρὸς τὰ ἀντίστοιχα στρώματα ἑτέρων περιοχῶν τῆς Κρήτης, ἐντὸς τῶν ὁποίων ἀνευρέθησαν περισσότερα χαρακτηριστικὰ ἀπολιθώματα.

Οἱ Τυρρηνίου ἡλικίας σχηματισμοὶ συνίστανται κυρίως ἐκ ψαμμιτῶν καὶ ψαμμιτοκροκαλοπαγῶν ἐπικειμένων ἀσυμφώνως ἐπὶ Νεογενῶν καὶ Προνεογενῶν στρωμάτων. Τυρρήνια στρώματα μὲ ἀπολιθώματα ἐπιστοποιήθησαν εἰς τὰς περιοχὰς τῶν θέσεων Μαῦρος Κόλυμπος, Κουτσουρᾶς, Μακρὺς Γιαλός, Παραλία Διασκάρι, Λαγκάδα, Καλὸ Νερό, Ἅγ. Ἰωάννης Καψᾶς, Ἀθερινόλακκος, Ὅρμος Ἀμπέλου, Παραλία Ξηροκάμπου.

Ἐπίσης ἐπραγματοποιήθη μορφομετρικὴ ἀνάλυσις τῶν κροκαλῶν, τῶν περικλειομένων εἰς τὰ Τυρρήνια ψαμμιτοκροκαλοπαγῆ. Βάσει δὲ ὑπολογισμῶν αἱ εὑρεθεῖσαι μέσαι τιμαὶ τῆς Ἐπιπλατύνσεως $\bar{A} = 236 \cdot 317$, τῆς Δυσυμμετρίας $\bar{D} = 557 \cdot 616$, τῆς Στρογγυλότητος $\bar{R} = 340 \cdot 418$, ἐπιβεβαίωσαν τὴν θαλασσίαν διαμόρφωσιν τῶν κροκαλῶν εἰς τὰς μελετηθείσας θέσεις.

Τέλος παρατίθενται σχηματικαὶ τομαὶ καὶ ἐκφράζονται ἀπόψεις περὶ τῆς παλαιογεωγραφικῆς ἐξελίξεως τῶν Τυρρηνίων ἀποθέσεων τῆς ΝΑ Κρήτης.

REFERENCES

ANAPLIOTIS, K. & GEORGIADOU - DIKEOULIA, E. 1967.— Die tyrrhenischen Ablagerungen von Südwest Kreta. *Ann. Géol. d. Pays Hell.*, **18**, p. 271 - 279, Athènes.

BLANC, A. C. 1936.— La stratigraphie de la plaine côtière de la basse-Versilia et la transgression flandrienne en Mediterranée. *Revue Géogr. Phys. et Géol. Dyn.*, **IX**, 2, p. 129 - 162.

BOEKSCHOTEN, G. J. 1963.— Some geological observations on the coasts of Crete. *Geologie en Mijnbouw*, **42**, p. 241 - 247.

BONIFAY, E. 1964.— Pliocène et Pleistocène méditerranéens : Vue d'ensemble et essai de corrélations avec la chronologie glaciaire. *Ann. de Paléont. Vertébrés, t. L, fasc.* **2**, p. 195 - 226.

BONIFAY, E. & MARS, P. 1959.— Le Tyrrhénien dans le cadre de la chronologie quaternaire méditerranéenne. *Bull. Soc. Géol. de Fr.* (7), t. I, p. 62 - 78.

CAILLEUX, A. & TRICART, J. 1966.— Initiation à l'étude des sables et des galets, Paris.

CASTANY, G. & OTTMANN, F. 1954.— Le Quaternaire marin de la Mediterranée occidentale. *Rev. Geogr. Phys. et Géol. Dyn.*, **2**, I, p. 46 - 55.

CREUTZBURG, N. 1961.— Über junge Verschüttungserscheinungen auf der Insel Kreta und ihre Beziehungen zum Klima des Pleistozäns. *Ann. Géol. d. Pays Hell.*, **12**, p. 1 - 11, Athènes.

DERMITZAKIS, M. 1969.— Geological researches of the Neogene deposits of the Hierapetra province in Crete. *Ann. Géol. d. Pays Hell.*, **21**, p. 342 - 484, Athènes.

DERMITZAKIS, M. 1972.— Pleistocenic deposits and old strandlines in the peninsula of Gramboussa, in relation to the recent tectonic movements of Crete Island. *Ann. Géol. d. Pays Hell.*, **24**, p. 205 - 240, Athènes (cum. lit.).

GIGNOUX, M. 1913.— Les formations marines pliocènes et quaternaires de l'Italie du Sud et de la Sicile. *Ann. Univ.* Lyon, XXXVI.

GRADSTEIN, M. F. 1973.— The Neogene and Quaternary deposits in the Sitia district of eastern Crete. *Ann. Géol. d. Pays Hell.*, **24**, p. 527 - 572, Athènes.

ISSEL, A. 1914.— Lembi fossiliferi quaternary e recenti nella Sardegna meridionale. *R. C. Acad. Lincei*, (5), 23, p. 759 - 770.

KERAUDREN, B. 1970 - 1971.— Les formations Quaternaires marines de la Grèce. *Extr. du Bulletin du Musée d'Anthropologic Prehistorique de Monaco, Fasc.* 16, 17.

KÖSTER, E. 1964.— Granulometrische und morphometrische Messmethoden an Mineralkörnern, Steinen und sonstigen Stoffen, p. 336, Stuttgart.

KUSS, S. 1970.— Abfolge und Alter der pleistozänen Säugetierfaunen der Insel Kreta. *Ber. Natur. Ges. Freiburg i. Br.*, **60**, S. 35 - 83, Freiburg.

LÜTTIG, G. 1963.— Italienisches und griechisches Pliopleistozän. *Zeits. der Deuts. Geolog. Gesellschaft*, 114, Teil 1, S. 7-31, Hannover.

MARINOS, G. - SAKELLARIOU - MANE, H. - SOTIRIADIS, L. - SAPOUNZIS, E. 1970.— Sur la Paléogeographie de l'Égéide du nord dans la région de Cassandra (Chalkidie-Macédoine - Grèce). *Ann. Géol. d. Pays Hell.*, **22**, p. 1 - 27, Athènes.

MARS, P. 1963.— Les faunes et la stratigraphie du Quaternaire méditerranéen. *Recueil des travaux de la station marine d'Endoume*, Bull. 28, Fasc. 46, p. 61-97.

MITZOPOULOS, M. 1933.— Le Quaternaire marin (Tyrrhénien) dans la presqn'île de Pérachora. *Pract. Akad. Athinon*, **8**, p. 286 - 292.

MÜLLER, G. 1967.— Methods in Sedimentary petrology, p. 283, Stuttgart.

PAPAPETROU - ZAMANIS, A. 1971.— Dépot du Tyrrhenien dans la côte septentrionale de l'île de Crète. *Ann. Géol. d. Pays Hell.*, **23**, p. 301 - 307, Athènes.

PSARIANOS, P. 1961.— Die tyrrhenischen Ablagerungen der Insel Kreta. *Ann. Géol. d. Pays, Hell.*, **12**, S. 11 - 17, Athènes.

SCHRÖDER, B. 1970.— Über mittel- und jung - pleistozäne Meeres - Hochstände der Landenge von Korinth. *N. Jb. Geol. Paläont. Mh. Ig.*, H. 1, S. 27 - 33, Stuttgart.

SEGUENZA, G. 1880.— Le formazioni terziare nella provincia di Reggio Calabria. *Atti R. Accad.* Lincei (3), vol. **6**.

SELLI, R. 1962.— Le Quaternaire marin du versant adriatique-ionien de la peninsule italienne. *Quaternaria*, **VI**, 1962, p. 391 - 413.

SOTIRIADIS, L. 1970.— Morphometrische Analyse von Geröllen entlang dem Flusse Arkudolakkos auf der halbinsel Chalkidike, Griechenland. *Ann. Géol. d. Pays Hell.*, **22**, p. 263 - 268, Athènes.

SYMEONIDIS, N. 1965.— Das Neogen von Ostkreta. *Ann. Géol. d. Pays Hell.*, **16**, p. 249 - 314, Athènes.

SYMEONIDIS, N. 1967.— Die marine Pleistozäne Ablagerungen des SÖ Teils der Insel Kreta und der gegenüber liegenden Eiländern Chrysi (Gaiduronisi), Strongylo, Koufonisi. *Ann. Géol. d. Pays Hell.*, **18**, p. 407 - 420, Athènes.

SYMEONIDIS, N. & DERMITZAKIS, M. 1973.— Beitrag zur Kenntnis der Geologie der Inseln Angistri und Metopi (SW von Aegina). *Ann. Géol. d. Pays Hell.*, **25**, S. 250 - 280, Athènes.

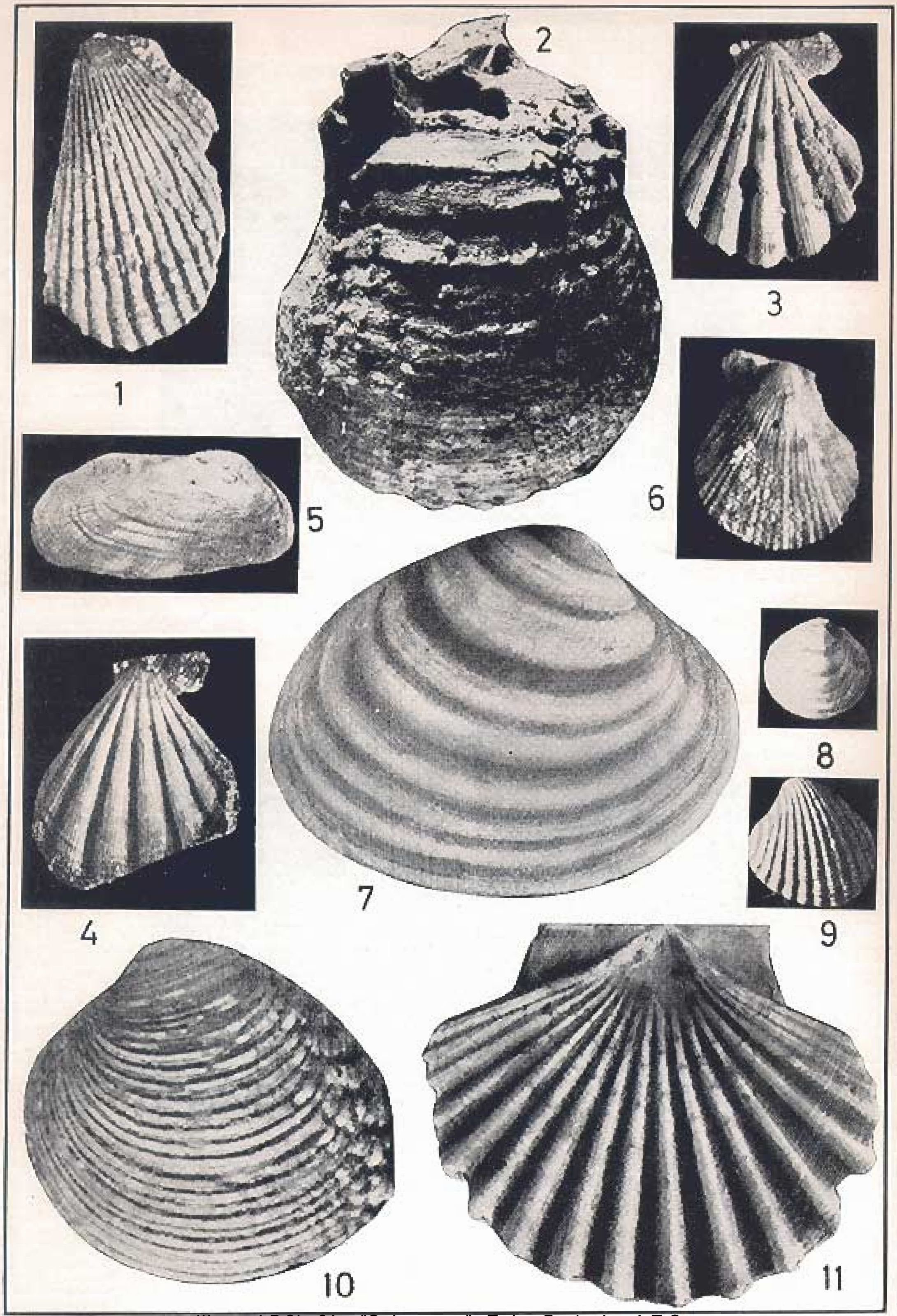
PLATE I.

1. *Lima (Lima) lima* (LINNÉ)
2. *Spondylus gaederopus* LINNÉ × 1/4
3, 4. *Chlamys pes-felis* LINNÉ
5. *Barbatia (Barbatia) barbata* (LINNÉ)
6. *Chlamys multistriata* POLI
7. *Meretrix (Callista) chione* (LINNÉ)

8. *Loripes (Loripes) lacteus* (LINNÉ)
9. *Cardita (Cardita) antiquata* (LINNÉ)
10. *Venus (Venus) verrucosa* LINNÉ
11. *Pecten (Pecten) jacobaeus* (LINNÉ)

PLATE II.

1, 2. *Conus testudinarius* MARTINI
3, 4, 5. *Conus (Punctinculis) mediterraneus* HWASS
6. *Murex (Trunculariopsis) trunculus* (LINNÉ)
7. *Buccinulum (Euthria) corneum* (LINNÉ)
8. *Monodonta (Osilinus) turbinata* (BORN.)
9, 10. *Natica (Natica) millepunctata* LAMARCK
11, 12, 13, 14. *Natica (Natica) millepunctata* LAMARCK
15. *Astraea (Bolma) rugosa* (LINNÉ)
16, 16a, 17, 17b. *Columbella rustica* LINNÉ
18. *Spondylus gaederopus* LINNÉ × 1/5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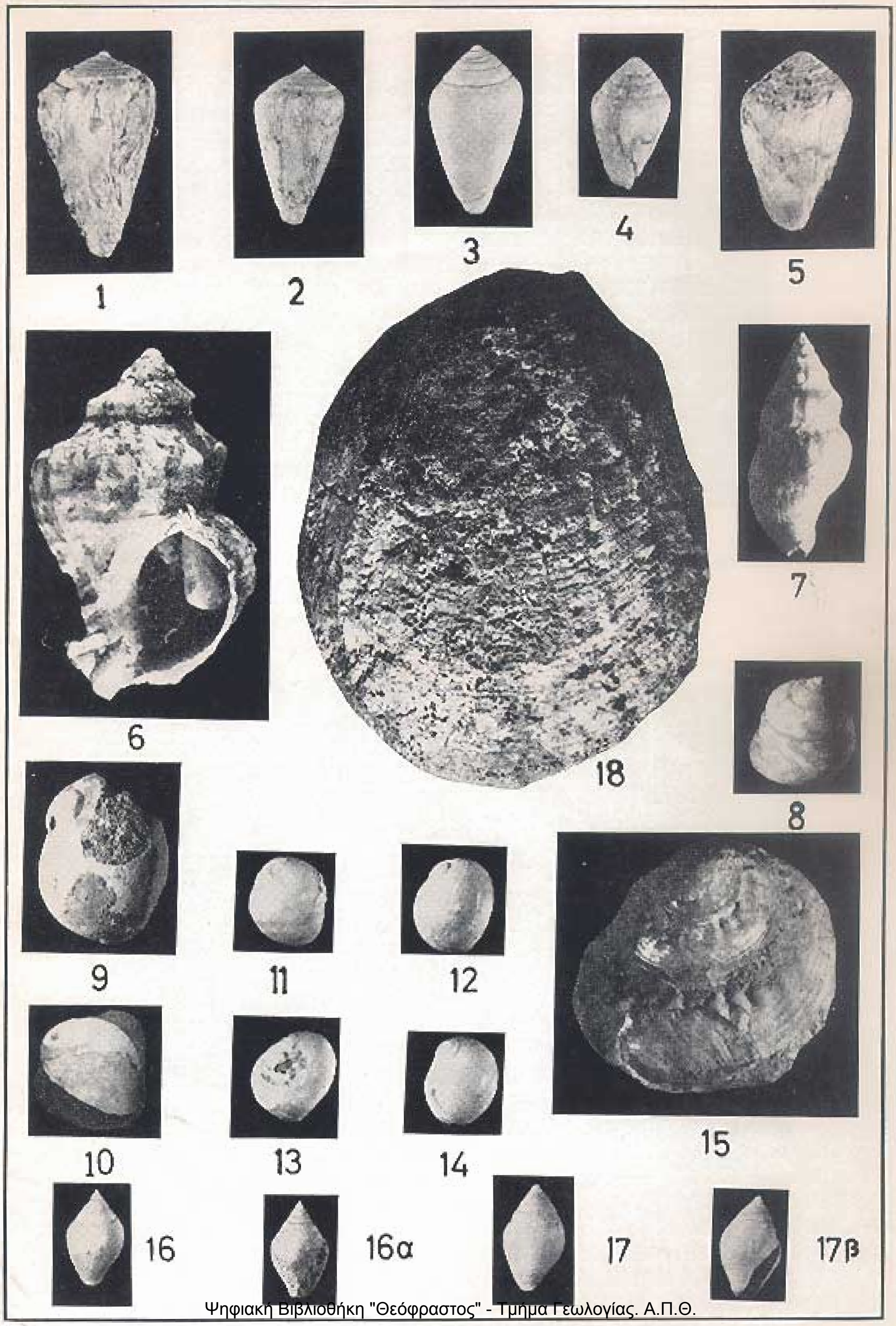
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