

MARIOLAKOS, I., SCHNEIDER, H., FOUNTOULIS, I., VOULOUMANOS, N. (1993). - Paleogeography, sedimentation and Neotectonic implications at the Kambos depression and Kitries Bay area. (Messinia, Peloponnesus, Greece). – *Πρακτικά βου Συν. Ελλ. Γεωλ. Ετ., τ. XXVIII/1*, σ. 397-413, Αθήνα.

**PALEOGEOGRAPHY, SEDIMENTATION AND NEOTECTONIC
IMPLICATIONS
AT THE KAMBOS DEPRESSION AND KITRIES BAY AREA
(MESSINIA, PELOPONNESU, GREECE)**

By

I. MARIOLAKOS¹, SCHNEIDER, H.², FOUNTOULIS, I.¹, VOULOUMANOS, N.¹

ABSTRACT

The Kambos depression and Kitries Bay area are located some 10km to the south of Kalamata city and filled up with continental and marine sediments (conglomerates, sandstones and marls) correspondingly. The presence of the *Hyalinea balthica* (SCHROETER) in the base of the marine succession indicates that their age is at least Early Pleistocene. Based on sedimentological, micropaleontological and neotectonic criteria, the paleoenvironmental history and neotectonic evolution of the area have been deciphered and mean rates for subsidence and uplift have been calculated. Moreover, it has been shown that the area has worked as a tectonic dipole, whose axis strikes approximately E-W and rotates towards NNW.

INTRODUCTION

Kambos depression and Kitries Bay area are located in the Messinia province (SW Peloponnesus), Greece), some 10km to the southeast from Kalamata city (**Fig. 1, 2**). The relief of the area is rather smooth, featuring hills and valleys that constitute the transitional forms towards the purely mountaneous region of Taygetos Mt. to the east. On the eastern part of the Kitries Bay, the relief continues its smooth form under the Messinian Gulf water, down to the shelf break, where an abrupt, tectonically induced change in the slope gradient takes place. This markedly differs from the underwater topography of the western part of the Messinian Gulf, in which a gentle topography continues underwater down to 1100 m (PAPANIKOLAOU et al., 1988).

The relatively gentle slopes of the Mantinia-Doli area and the steeper terrain of the southern part of the study area (south of Doli) in another eye-catching difference. This is due to tectonic control over the whole region, as we will see below.

(1): University of Athens, School of Geology, Dynamic Tectonic Applied Geology Section. Panepistimiopolis Zografou, GR - 157 84, Athens, Greece

(2): Univeritaet des Saarlandes, Fachrichtung Angewandte Geochemie, D-6600, Saarbruecken, Deutschland

The purpose of this work is to decipher the geological evolution of the area, mainly during the Late Neotectonic period. For this, a detailed geological mapping of the study area has been carried out and samples of the post-alpine marine sediments have been collected. Micropaleontological analysis of the samples, as well as sedimentological study of the whole area, provided information on the paleodepth during the deposition, as well as on the paleodynamics of sedimentation and the hydraulic regime inside the sedimentary environment. These data led to the understanding of the paleogeographic configuration of the area and, moreover, the neotectonic processes that led to the present-day form and structure.

The **rates** of events were calculated using geochronometry (in our case, age assignments yielded by foraminifera), which provided some datings on several stratigraphic levels. Having formed the paleogeographic configuration at selected time-slices and using the rates of the neotectonic period has been unraveled.

A paleontological study in the Kitries Bay area has been carried out by ALEXOULI-LIVADITI (1971), whereas the adjacent areas to the north have been studied by CHRISTODOULOU (1960), ZELILIDIS et al., (1988), MARCOPOULOU-DIACANTONI et al., 1989, and FRYDAS (1990).

GEOLOGY OF THE SOUTHERN MESSINIA PROVINCE

Alpine Geotectonic Units

At the Messinia area, the following four alpine geotectonic units (PSONIS, 1986), from lower, are present (**Fig.1**):

- i. The **Mani unit** (mainly marbles, L. Senonian – L. Eocene).
- ii. The **Arna unit** (mainly phyllites and quartzites).
- iii. The **Tripolis unit** (shallow-water carbonates, Triassic – L. Eocene and flysch, L. Eocene – E. Miocene).
- iv. The **Pindos unit** (pelagic limestones, radiolarites, the so-called "first flysch", thin-bedded limestones, L. Cretaceous and flysch, Danian – Eocene).

From the structural point of view, the four abovementioned geotectonic units form a succession of three nappes. Mani unit (slightly metamorphosed) is considered to be the relatively autochthonous one. Arna unit overthrusts Mani unit, Tripolis unit (the second nappe) overthrusts Arna unit and Pindos unit (the third nappe) overthrusts Tripolis unit (**Fig. 1**).

Post – alpine formations

Pliocene – Early Pleistocene marine sediments

They consist of marls, sandstones and polymictic conglomerates. Their lithology depends on the paleogeographic evolution of the different sites. They occur mainly in grabens and they are encountered up to approx. 460 m altitude, at the margins of the horsts. Their present-day altitude is controlled by the local kinematic conditions since the Early Pleistocene (MARCOPOULOU et al., 1989).

Continental Pleistocene deposits

They consist mainly of red-colored, polymictic but always siliceous, sands and conglomerates, the pebbles of which come exclusively from metamorphic rocks and/or radiolarites. They overlie unconformably the older formations and are deposited on a well formed paleorelief, which is different from the recent one in its details (MARIOLAKOS et al., 1987b).

Holocene deposits

These are unconsolidated or partly consolidated materials, mainly coarse, that are deposited as alluvial fans, river deposits, talus scree etc. (MARIOLAKOS et al., 1987b).

NEOTECTONIC STRUCTURE OF THE MESSINIA PROVINCE

The neotectonic structure of the Messinia province is characterised by the presence of large grabens and horsts bounded by wide fault zones. These large structures, from East to West, are the following (MARIOLAKOS & FOUNTOULIS, 1991): Taygetos Mt. mega-horst, Kalamata - Kyparissia mega-graben, Gargaliani - Filiatra mega-horst and Kyparissia Mts., which represent a complex morphotectonic structure (*Fig. 3a*).

At the margins, or inside, these 1st order neotectonic mega-structures, a great number of 2nd and 3rd order smaller horsts and grabens are present, which trend either parallel or roughly perpendicular to these 1st order mega-structures.

Neotectonic macrostructures at the southeastern margin of Kato Messinia Basin

At the southeastern margin of Kato Messinia graben, a great number of smaller-order structures are present, striking in different directions (*Fig. 3b*). Among them, the following are noteworthy (MARIOLAKOS et al., 1987b):

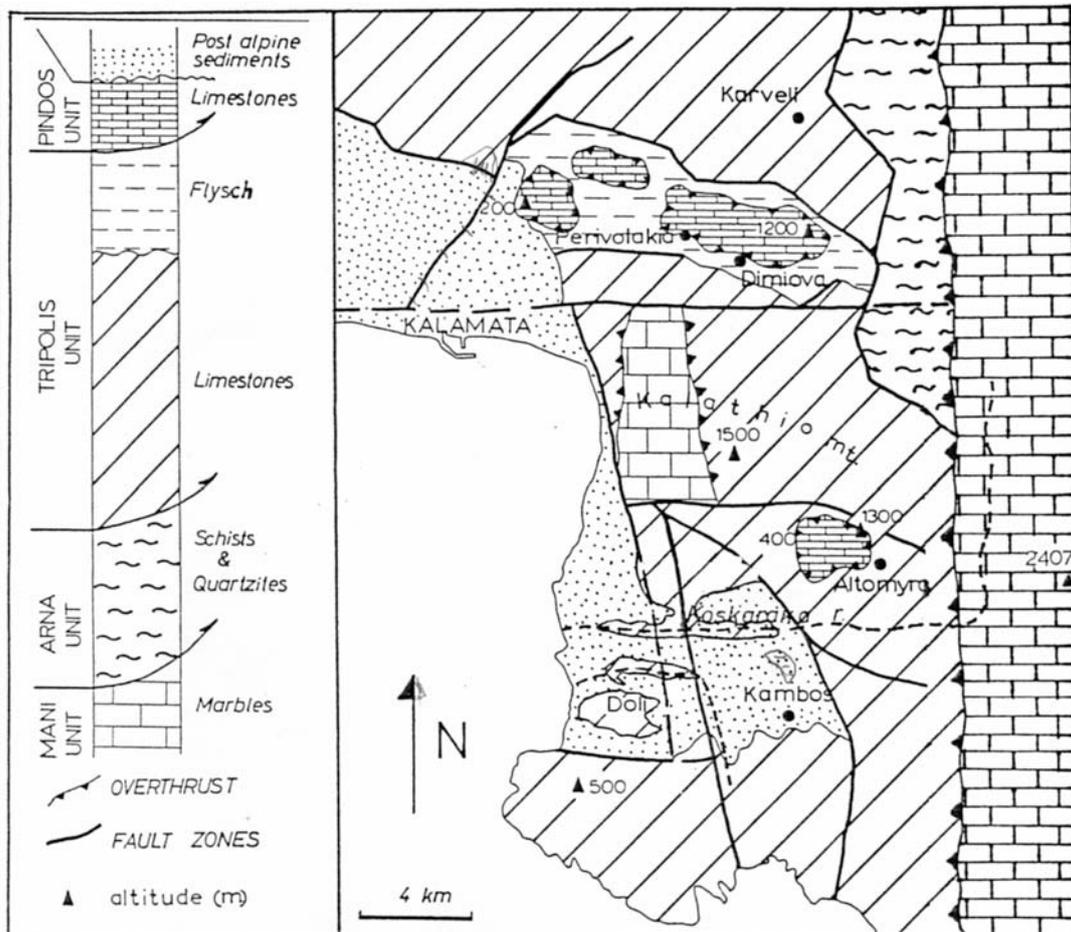


Fig. 1: Sketch maps of the:

- (a) Neotectonic mega-structures of southern Peloponnesus
 (b) Smaller order neotectonic macrostructures of the Kato Messinia sub-graben

1. The **Dimiova - Perivolakia graben**, striking E - W and rotating towards WSW around a N - S striking axis.
2. The impressive **Kalathion Mt.** horst, which strikes E- W and rotates towards E.
3. The **Altomyra semi-graben**, at the southern slopes of Kalathion Mt., which is transitional neotectonic macrostructure between the Kalathion horst and the Kambos graben.
4. The N-S striking **Kambos graben**.
5. The **Vardia - Koka horst**, striking N-S, built up from the Vardia - Koka - Doli - hills and
6. The **Kitries - Mantinia sub-graben**.

LITHOSTRATIGRAPHY AND BIOSTRATIGRAPHY

General

The area was mapped (scale 1/25.000) and field data were collected mainly from two sites (**Fig. 2**): (a) Mantinia section, located at the northern

part of the study area, (b) Doli section, approx. 2,5 km to the south of Mantinia section. In addition, some spot samples near the coastline of Kitries Bay, mainly from the road outcrops, were taken in order to form a more integrated view on the lower part of the post-alpine stratigraphic column of the study area.

Mantinia and Doli sections are comprised of post-alpine clastic sediments (conglomerates, sandstones and marls) and their overall estimated thickness is 250m and 360m correspondingly (**Fig. 4**). They were sampled at more or less regular intervals. This was neither easy, nor always possible. Both sections are far from ideal due to unexposed or inaccessible segments, erosion, gorges and inhabited areas. The thickness of the sections, therefore, has been estimated using indirect methods.

Mantinia section

The base of the section is located at the coastline near Akrogiali village, whereas the top is near Mantinia village, at 360 m above sea level.

The Mantinia section may be divided into two major sectors (Fig. 4a):

1. The lower one, consisting of alternations of sandstones, marls and oligomictic conglomerates (parts I-V), which are attributed to a marine depositional environment.
2. The upper one, consisting exclusively of conglomerates (part VI), for which there is no substantial evidence to support a marine depositional environment.

Dip direction of the beds belonging to the lower sector varies between NNW and NNE (340° to 010°) and the dip between 8° - 13° . The base (part I) of the section consists of thick-bedded (>30 cm) sandstones.

At the second (II) part the material becomes progressively finer, Intercalations of sandstones and marls dominate here and the bed thickness is smaller. Locally, syn-sedimentary structures are present. The third (III) part of the section consists of coarser material. Partly compacted sandstones dominate here, together with some marly intercalations.

The faunistic composition in this part (III) implies a larger depositional paleo-depth than in part II (substantially larger planktonic / benthic foraminifera ratio).

The fourth (IV) part consists of alternations of sandstones and conglomerates; the conglomerates are relatively compact and cemented with sandstone material. Their pebbles (usually 2-5cm in size, rarely larger) come exclusively from the partly metamorphosed rocks of the Mani geotectonic unit that builds the Taygetos Mt. core, which neighbors the study area at its eastern border, The altitude in which these conglomerates outcrop first is 110m.

The fifth (V) part consists of massive oligomictic conglomerates; their composition is identical to the one of the conglomeratic beds of the fourth part.

The sixth (VI) part consists of massive polymictic conglomerates. Their pebbles come from both the marbles of the Mani Unit and the carbonates of the Tripolis Unit.

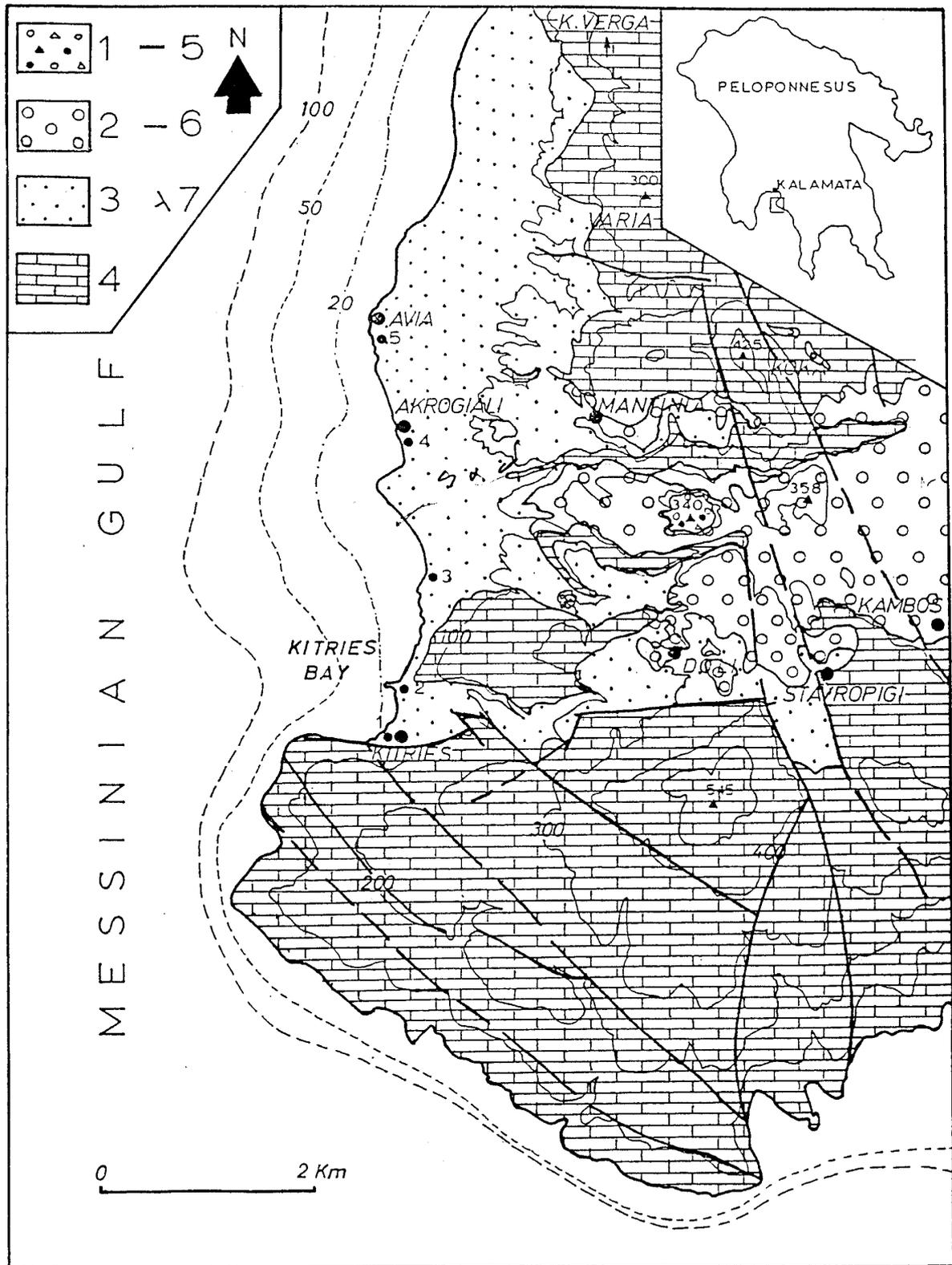


Fig. 2: Geological map of the study area. 1: polymictic conglomerates; 2: oligomictic conglomerates; 3: marls, marly sand stones and sandstones; 4: carbonates and flysch of the Tripolis geotectonic unit; 5: fault; 6: geological boundary; 7: dip and strike of the beds. See text for further details.

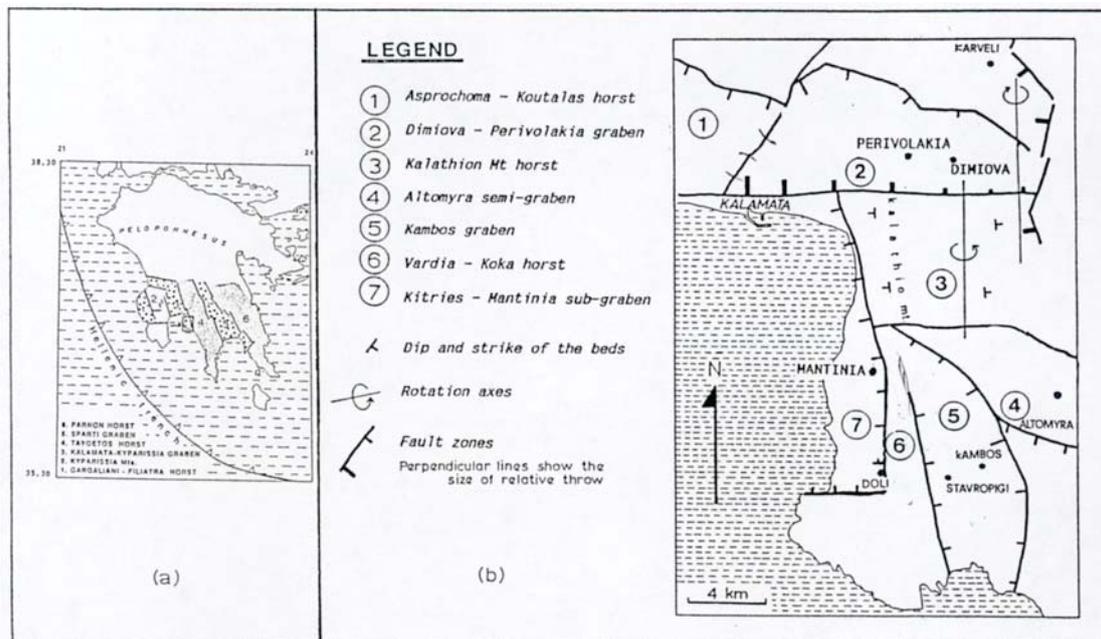


Fig. 3: Sketch maps of the:

(a) Neotectonic mega-structures of southern Peloponnesus

(b) Smaller order neotectonic macrostructures of the Kato Messinia sub-graben

Doli section

Located some 2,5km to the south of Mantinia section (fig. 2), Doli section is a 360m thick succession of sandstones, marls and conglomerates, unconformably deposited on a well-formed paleorelief on the Tri-polis Unit carbonates (fig. 4b). Beds dip 10°-15° to the NW (310° -320°), Syn-sedimentary structures are evidence for a rather unstable, high energy level depositional environment.

The Doli section may be divided into two main parts: the lower (I) and the upper (II) one, both of which are attributed to a marine depositional environment.

The first (I) part consists of alternations of sandstones and marls. Going upwards, the percentage of the sandstone beds raises from 50% to approx. 80% and, consequently, the marl percentage drops to 20%. Bed thickness raises too, from 10 to 50cm approximately. This may be tentatively interpreted as a gradual increase of the energy level of the sedimentary environment, probably because of the uplift that the adjacent areas underwent and the subsequent proximity of the sediment source area.

Diversity of benthonic foraminiferal species indicates that, from the bottom of this sector to the top, the paleodepth of the depositional environment decreases. On the very top of the part, only *Ammonia beccarii* (reported to be a "shallow sand dweller", DROOGER et al. , 1979) is present. The paleodepth at the base is not much, as also suggested by the total absence of planktonic

foraminifera and the presence of some members of the epiphytic group of benthonic foraminifera, (*Asterigerina planorbis*, *Gibicides lobatulus*, *Hanzawaia boueana*, *Rosalina globularis*), but, is substantially larger than the one at the top. This is further confirmed by the increase of the sandstone bed percentage and thickness towards the top.

The second (II) part consists of alternations of sandstones and oligomictic conglomerates. The pebbles come exclusively from the partly metamorphosed marbles of the Mani Unit (i.e. are identical to the ones of part IV of the Mantir1ia section) but their size is substantially larger (5-10cm).

To the south of the Aghios Nikitas church, a remnant of a polymictic conglomeratic horizon, which represents the topmost part of the Doli stratigraphic column, featuring cyclic deposition of positively-graded conglomerates (**Fig. 5**) has been found. Five cycles within 80cm of stratigraphic thickness have been counted. The pebbles of these conglomerates come from: (i) the marbles of the Mani Unit, (ii) the Trir>olis Unit carbonates and (iii) the lower members of the abovementioned sector (I), that occupy altimetrically higher regions at the southern part of the basin, This is further confirmed from the grain size: The alpine origin pebbles measure 0.5- 3 cm of larger diameter, whereas the Pleistocene-eroded cobbles (which, furthermore, are more vulnerable to erosion) measure 20- 50cm and are more angular than their alpine counterparts, This is attributed to shorter transportation distances for the Pleistocene-eroded cobbles, ir1 contrary to the alpine pebbles, The pebbles of these cyclic conglomerates are discoidal and imbricated (**Fig. 5**) so as if they dip to the sea. These conglomerates are most likely to represent regression cycles, as we will see below.

Spot samples

Several spot samples (fig. 2, o 1,2,3,4,5) were taken off the road outcrop, near the coastline of Kitries Bay. These marls actually constitute the very base of the stratigraphic column of the basin (since no remarkable fault, crossing the sediment- successions, was observed), although this is not immediately apparent, due to inhabited areas and cultivated land pieces between sections.

(SCHROETER) was found in abundance in most of the samples (Table 1).

Age assignments

As one may see in Table 1, *Hyalinea balthica* (SCHROETER) is present throughout the Mantinia section, as well as in the spot samples. This species is reported to -flourish in cold climatic conditions and to mark the base of the Pleistocene (BIZON & MULLER, 1977, SPAAK, 1983). Therefore, all the sediments from the coastline of the Kitries Bay and upwards to the Doli village are of Pleistocene age, as no large syn-sedimentary fault, crossing the post-alpine sediments, has been observed, except for one with a small (10 cm) throw, in the middle of the Doli section.

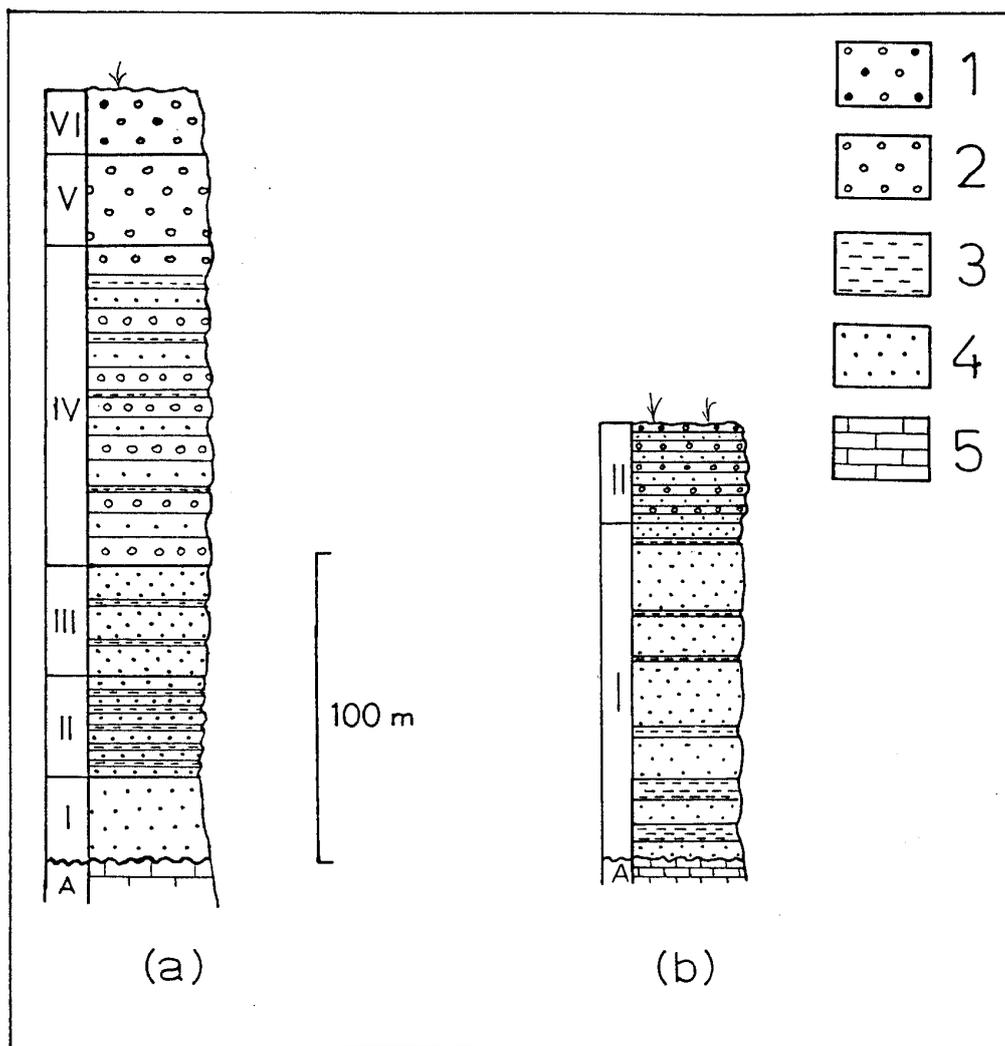


Fig. 4: Lithostratigraphic columns of the Pleistocene sediments of the Kitries Bay area. (a) Mantinia area; (b) Doli area. 1: polymictic conglomerates; 2: oligomictic conglomerates; 3: marls; 4: sandstones; 5: alpine basement. Numbers I-VI indicate section parts, according to the text.

The Pleistocene age is further confirmed by the relative abundance (30-50%) of sinistrally - coiled Neogloboquadrinids **together with** the presence of *Globorotalia inflata* (D'ORBIGNY) (presence of *Gl. inflata* together with more than 10% of sinistrally - coiled Neogloboquadrinids marks the Pleistocene, SPAAK, 1983). Moreover, the evolutionary stages of the benthic foraminiferal fauna contained in the samples indicate at least an Early Pleistocene age as well (P. Verhallen, pers. comm.). The abovementioned age does not conform to ALEXOULI - LIVADITI (1971) who, based on macrofossils, stated that the Kitries Bay area sediments are of Pliocene age.

Local "unconformity" at Kitries village

At the southern part of Kitries Bay, a structure resembling an unconformity is present within the Pleistocene sediments. Intensive surveying in the area verified the statement of ALEXOULI - LIVADITI (1971) that this unconformable deposition is of very local nature, It is most likely that the marginal fault zone at

the south most end of the basin (fig, 2) had been reactivated during the Early Pleistocene, and, therefore, the latest sediments were deposited unconformably over the underlying ones.



Fig. 5: Positively-graded, polymictic conglomerates. South of the Aghios Nikitas church, that marks the termination of the marine sedimentation.

DISCUSSION

Paleogeography of the sedimentary environment

In the Marltinia section samples, the diversity of the foraminiferal fauna is substantially larger than the one at Doli section samples (see Table 1). Many benthic species are present and, moreover, the frequencies of the shallow-dwellers are lower than the corresponding ones at the Doli section. This fact, together with the presence of planktonic species (that are totally absent at the Doli section) is attributed to a deeper- depositional environment for the Mantinia site. Sedimentological facts further confirm the paleo-depth difference between Mantinia and Doli depositional sites: sediments become progressively finer towards Mantinia site and the Mantinia column is thicker.

On the contrary, in the Doli section samples, only very shallow dwelling specimen are present (*Ammonia beccarii*, *Elphidium spp.*). These species are reported to thrive in shallow waters and to be vegetation-bound (ZWAAN, 1982). Furthermore, some of the tests are broken, yet not smooth enough to provide evidence for transport; it is the high energy level, due to -the small depth, of the sedimentary environment, that has broken them *in situ*.

From all the abovegoing, the conclusion is that the paleodepth of the sedimentary environment was larger at the northwestern part of the area (Mantinia site) whereas, at the Doli and Kitries sites, the paleoenvironment was shallower.

All these differences within the whole basin are temporally attributed to Early Pleistocene, as *Hyalinea balthica* marks.

Neotectonic - Kinematic interpretation

The morphogenetic processes on the alpine basement started immediately after the end of the thrusting movements (M. Miocene), hence the whole region started gradually to emerge.

The study area should have stayed emerged until the Late Pliocene, since there is no evidence on marine sediments of that age in the area, At the end of the Pliocene, the area has started to submerge, This may have happened earlier, if we accept that the neighboring graben of Kato Messinia (Ano Amfia - Thouria area) starts to submerge earlier too (MARCOPOULOU-DIACANTONI et al., 1989). The absence of marine sediments of Late Pliocene age however, does indicate that the Mantinia - Doli - Stavropigi area started to submerge at least at the very end of the Pliocene.

We may interpret the neotectonic evolution of the three neotectonic macrostructures (Kitries - Mantinia sub-graben, Vardia-Koka horst, Kambos graben) as follows (**Fig. 6**):

At the very end of the Pliocene the region started gradually to submerge.

At the beginning of the Early Pleistocene, deposition of shallow -water sediments took place on a well formed paleorelief on the carbonates and flysch of the Tripolis geotectonic unit at Kitries - Mantinia sub-graben. At the same time, the Vardia-Koka horst worked as a barrier for the clastic material (mainly pebbles) that came from the Taygetos Mt. horst (which was uplifted and eroded) and started to fill (**Fig. 6A**) the Kambos graben.

The absence of large synsedimentary faults and unconformities (with the exception of the one at Kitries, which is of very local nature) indicates that the subsidence to the west of the Vardia-Koka horst should have been uniform and continuous. The presence of several small order synsedimentary structures could be linked to seismic activity during the subsidence phase.

The whole area continued gradually to submerge. As a result, the transgression of the sea from the west to the east continued until all the study area was sunk below sea level, up to the Doli and Stavropigi villages (fig. 68). This is further confirmed by the presence of marine macrofossils close to the Stavropigi village, as also stated by ALEXOULI-LIVADITI (1971). Tectonic activity and/or climatic conditions provided a great amount of coarse clastic material, which passed over the Vardia-Koka horst and was deposited as alternations of sandstones and oligomictic conglomerates in a shallow - water marine environment, at the Kitries - Mantinia sub-graben. At the same time, in the Kambos graben, oligomictic conglomerates continued to accumulate, partly covering the pre-existing continental deposits.

It should be stressed that, the rate of the subsidence (and of the subsequent transgression of the sea) should have been higher than the potentially calculated one, based on sedimentological and stratigraphic criteria. This is due to the climatic shift at the beginning of the Pleistocene, which resulted to the climatic-eustatic sea-level drop.

SECTION PARTS & SPOT SAMPLES		MANTINIA SECTION		DOLI SECT.	SPOT SAMPLES	
		25- 60m	60- 95m	0- 110m	KITR IES	CAPE AVIA
SPECIES						
	<i>Ammonia beccarii</i> (LINNE)		o	o	o	
	<i>Amphicoryna scalaris</i> (BATCH)		o			o
	<i>Anomalina</i> sp.					o
	<i>Asterigerina planorbis</i> D'ORB.		o	o	o	o
B	<i>Bolivina spathulata</i> (WILL.)		o			o
	<i>Bulimina aculeata</i> D'ORB.		o	o		
	<i>Cancris auriculus</i> (FICHT. & MOLL)			o		
E	<i>Cassidulina neocarinata</i> THALM.		o	o		o
	<i>Cibicides lobatulus</i> (WALK. & JACOB)	o	o	o	o	
	<i>Cibicides ungerianus</i> (D'ORB.)		o		o	
N	<i>Elphidium crispum</i> (LINNE)			o	o	
	<i>Elphidium macellum</i> (FICHT. & MOLL)			o		
	<i>Globobulimina pyrula</i> (D'ORB.)			o	o	
T	<i>Gyroldina</i> sp.		o			
	<i>Hanzawaia boueana</i> (D'ORB.)	o	o	o		
	<i>Hyalinea balthica</i> (SCHR.)	o	o			o
H	<i>Lagena</i> sp.		o			
	<i>Melonis pompilioides</i> (FICHT. & MOLL)	o	o	o		
	<i>Nonionella turgida</i> (WILL.)			o	o	
I	<i>Planulina ariminensis</i> D'ORB.		o			
	<i>Pullenia bulloides</i> (D'ORB.)		o	o		
	<i>Pyrgo depressa</i> (D'ORB.)		o			
C	<i>Reusella spinulosa</i> (REUSS)	o	o			
	<i>Sphaeroidina bulloides</i> D'ORB.	o	o			o
	<i>Stainforthia</i> sp.		o			
	<i>Textularia saggitula</i> DEFR.	o	o			
	<i>Uvigerina peregrina</i> (CUSH.)	o	o		o	o
	<i>Globigerina apertura</i> CUSH.					o
P	<i>Globigerina bulloides</i> (D'ORB.)	o	o			o
L	<i>Globigerina falconensis</i> BLOW					o
A	<i>Globigerinita glutinata</i> (EGGER)					o
N	<i>Globorotalia crassaformis</i> (G. & WIS.)					o
K	<i>Globorotalia inflata</i> (D'ORB.)	o	o			o
T	<i>Globorotalia scitula</i> (BRADY)	o				o
O	<i>Globigerinoides obliquus</i> BOLLI		o			o
N	<i>Globigerinoides ruber</i> (D'ORB.)	o	o			o
I	<i>Globigerinoides trilobus</i> (REUSS)		o			
C	<i>Neogloboquadrina acostaensis</i> (BLOW)	o	o			o
	<i>Orbulina universa</i> D'ORB.	o	o		o	

TABLE 1: Qualitative distribution of benthic and planktonic foraminifera in the study area. Samples taken from a single part are lumped together. Only fossiliferous parts are displayed.

The sedimentation took place in smaller depths in the Doli site whereas, at the Mantinia site, the depositional paleodepth was larger. This is confirmed from sedimentological and micropaleontological evidence, as we have seen above.

At approximately the end of the Early Pleistocene, the kinematic regime shifted to an uplifting one. This resulted to the regression of the sea and the local revelation and subsequent erosion of the older, fossilized, pre-Pleistocene relief that had been formed on the carbonates and flysch of the Tripolis Unit.

The clastic material from both the abovementioned paleorelief and the marbles of the Taygetos Mt., was deposited as polymictic conglomerates in either a marine (cyclic regression conglomerates south of the Aghios Nikitas church, as stated above), or a continental environment.

These polymictic conglomerates mark the termination of the marine sedimentation over the whole area.

The uplift phase was neither abrupt, nor uniform over the whole area. The cyclic conglomerates at the top of the Doli section column are further evidence for this: They express smaller-order uplifting events which, consequently, resulted in pulses of clastic supply that was deposited in the basin. It is most likely that the rate of uplift was larger at the Doli - Stavropigi area and smaller at the Mantinia area and further to the north.

This is concluded because of:

1. At the Doli area, the first characteristic oligomictic conglomerate bench outcrops at 250 m above sea level whereas, at Mantinia, the same bench outcrops at 110 m. (See **Fig. 2**).
2. The Pleistocene marine sediments dip to the north - northwest.
3. The contact of the marine Pleistocene sediments to the alpine paleorelief is not lying on the same altitude everywhere, but the altitude of the contact decreases towards the north (**Fig. 2**).
4. The grain size of the marine sediments indicates sediment supply from the east-, (Taygetos Mt.) to the west (basin) and not from the south to the north, as one would expect if the dip of the sediments was of primary character.

Due to this kinematic regime, the Kambos graben drainage network consists of two main torrents, both lying at the northern part. These are the Koskarakas torrent (striking E-W) and a smaller one, approx. 1km to the south of Koskarakas (**Fig. 1**). The latter initially flows from the Stavropigi village to the north, At the Platoma site, its flow shifts to the west parallel to the Koskarakas torrent. Nevertheless, the E-W strike of both torrents is related to E-W striking faults, which permitted the drainage of the area eastern of the Vardia-Koka horst, to the sea. The creation of the gorges (**Figs. 1,2**), as well as the intensive linear erosion they display, is the result of:

1. The drainage of the neighboring area, far to the east of the Kambos graben,
2. The intensive uplift of the area and
3. The presence of the Vardia-Koka horst, built up of carbonates of the Tripolis geotectonic unit.

The aforementioned data enable us to calculate the mean rate of subsidence during the sedimentation and of uplift during the emerging period. For- these calculations, some additional remarks should be taken into consideration:

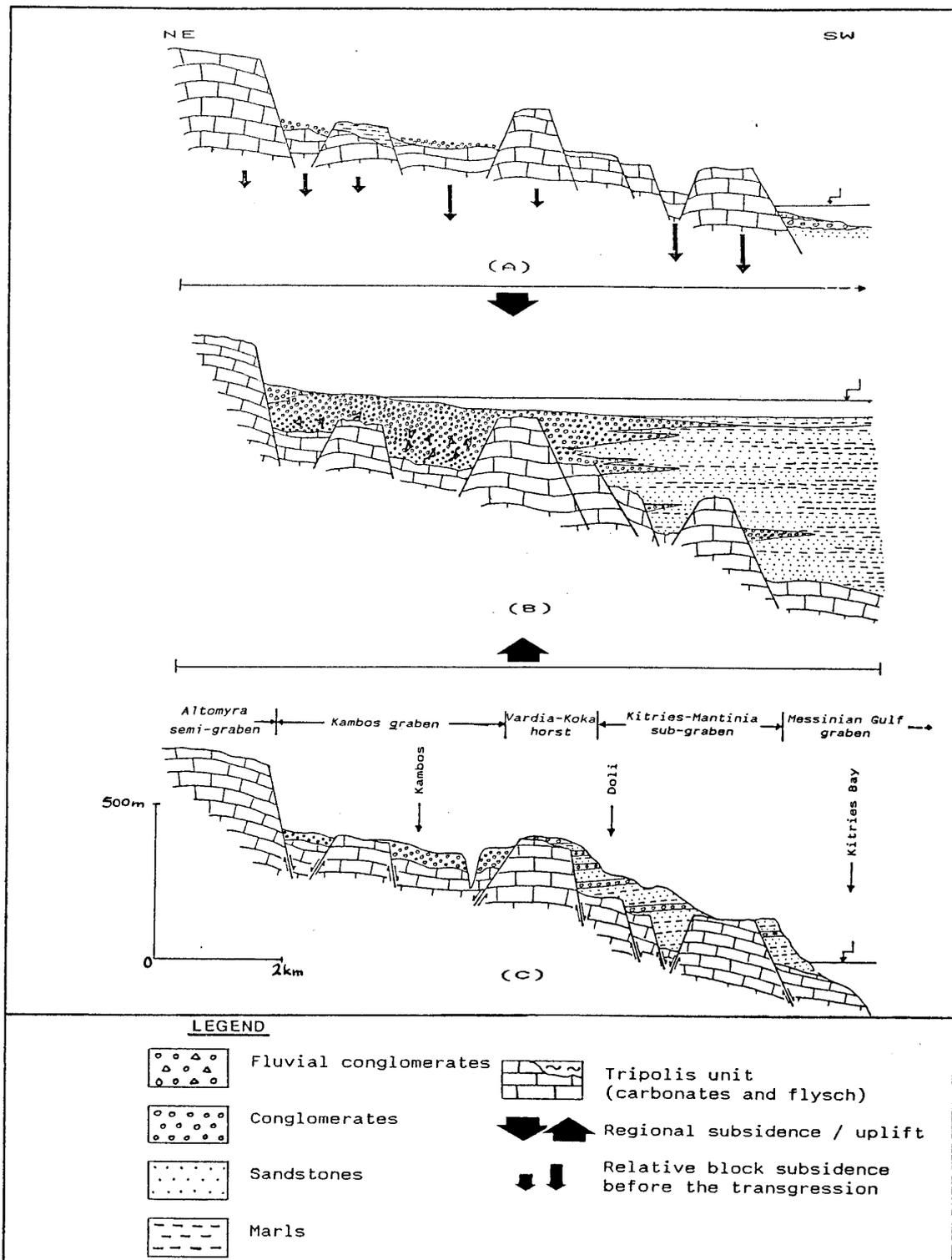


Fig. 6: Schematic depiction of the three main stages of the neotectonic evolution of the study area. (A) At the beginning of the deposition of the oldest pleistocene sediments. (B) Filling up with pleistocene marine deposits when the uplift started. (C) The present geological and morphotectonic status.

1. The visible thickness of the marine Pleistocene sediments in the Doli section is 360m, whereas in the Mantinia section is 230m.

2. Pliocene deposits are not present in the sections studied, since *Hyalinea balthica* which marks the base of the Pleistocene (BIZON & MULLER, 1977, SPAAK, 1983) is already present at the base of the stratigraphic column). The overall thickness of the Pleistocene deposits, therefore, is not exactly known, but is at least the observed one at the Doli section.
3. In other regions of the Messinia province (e.g, at the eastern margin of the Kato Messinia graben, Ano Amfia area) erosion of marine Pleistocene sediments of approx. 100 m has been estimated (MARCOPOULOU-DIACANTONI et al., 1989). To calculate the mean rate of subsidence, therefore, one should take into account that the total thickness should be much larger. Correspondingly, to calculate the mean uplift rate, we accept that the topmost members of the marine Pleistocene sediments have been (ur)lifted up to 360m at the Doli and 300m at the Mantinia areas, not taking the aforementioned 100m erosion into account.
4. The controversy on the age of the Pliocene Pleistocene boundary is well known. Several authors suggest that this should be placed at 2,4 Ma, whereas others are in favour of the 1.6 Ma age, or somewhere in between. It is considered herein that the age of the Pliocene - Pleistocene boundary is 1.6 Ma.
5. The global climatic changes at the Pliocene-Pleistocene boundary are well known, Instead of regression of the sea due to an ice age, however, a widespread transgression of the sea at the beginning of the Pleistocene is well documented throughout the Messinia region (MARCOPOULOU-DIACANTONI et al., 1991) due to regional neotectonics, since the region is located some 55km from the Hellenic Arc. Therefore, the sea-level changes (during both the subsidence and the uplift phases) were mainly tectonically, instead of eustatically, induced. In the following calculations, eustatically-induced sea-level changes were not taken into consideration.

Taking into account all of the above, the **mean subsidence rate (Vs)** at the whole area may be calculated:

$$V_s = \frac{360.000 \text{ mm}}{800.000 \text{ years}} = 0.45 \text{ mm/year}$$

The **mean uplift rate (Vu)** is:

$$V_{uD} = \frac{360.000 \text{ mm}}{800.000 \text{ years}} = 0.45 \text{ mm/year} \quad (\text{Doli area})$$

$$V_{uM} = \frac{300.000 \text{ mm}}{800.000 \text{ years}} = 0.37 \text{ mm/year} \quad (\text{Mantinia area})$$

From the kinematic point of view, therefore, it is certified that, at the Doli area, the mean subsidence rate is the same than the mean uplift rate whereas, at the Mantinia area, the uplift rate is 1.2 times lower than the subsidence rate.

CONCLUSIONS

The study area is a complex multifractured neotectonic macrostructure, typical of the transitional neotectonic zones located between two mega-structures. In our case, these two mega-structures are the Taygetos Mt. Horst to the east and the Messinian Gulf graben to the west. It is, in fact, a mosaic of variably sized blocks, which however, are rather small.

The almost total absence of large (and many) faults crossing the marine pleistocene deposits is evidence for the following:

1. The fragmentation of the study area, as well as the position of the blocks relative to each other, had taken place before the deposition of the marine Pleistocene sediments. The fragmentation of the study area, as well as the position of the blocks relative to each other, had taken place before the deposition of the marine Pleistocene sediments.
2. During both the subsidence and the uplift phase, the aforementioned small blocks lost their tectonic independence. As a result, the "mosaic" of blocks behaved as a single macroblock (neotectonic unit).

The study area, therefore, is a typical example of an area (located within marginal neotectonic zones) that behaves as a graben for a long period but, during a later phase, is connected to one, or more, neighbouring blocks and hence shows a totally new kinematic behaviour. Such cases are very frequent in the wider Messinia area: as an example, the present-day Asprochoma - Koutalas horst (MARIOLAKOS et al., 1987b), in earlier stages of its neotectonic evolution, consisted of at least two blocks: the Asprochoma graben and the Koutalas horst, which were separated by the relatively large Leika fault zone. These two blocks behaved as a single unit during the uplift phase.

It is evident that the study area has worked as a dipole whose axis of rotation strikes approx. E - W. The dipole has worked during the subsidence phase, as well as during the uplift phase, without changing its direction of rotation, i.e. the local, rotational, stress field remained the same during the whole Pleistocene. It was the regional kinematic (as a consequence of the dynamic) regime that shifted from subsidence to uplift at the Middle Pleistocene, since all the Early Pleistocene marine sediments have been uplifted several hundreds of meters over the wider Messinia province (MARCOPOULOU-DIACANTONI et al., 1989, 1991).

REFERENCES

- ALEXOULI-LIVADITI, A. (1971): Contribution a la connaissance du Neogene de la region de Kalamata. *Bull. Geol. Soc. Greece*, vol. **8/2**, pp. 102-116, Athenes. (In Greek).
- BIZON, G. & MULLER, C. (1977): La limite Pliocene - Pleistocene dans l' ile de Zante - la coupe de la Citadelle. *C.R. somm. Soc. Geol. Fr.*, vol. **4**, pp. 212-216.

- CHRISTODOULOU, G. (1960): The pliocene foraminifera of Kalamata. *Bull. Geol. Soc. Greece*, vol. **IV/1**, p.p. 85-97, Athens. (In Greek).
- DROOGER, C.W., MEULENKAMP, J.E., LANGEREIS, C.G., WONDERS, A.A.H., VAN DER ZWAAN, G.J., DROOGER, M.M., PAJU, D.S.N., DOEVEN, P.H., ZACHARIASSE, W.J., SCHMIDT, R.R., ZIJDERVELD, J.D.A. (1979): Problems of detailed biostratigraphic and magnetostratigraphic correlations in the Potamidha and Apostoli sections of the Cretan Miocene. *Utrecht Micropal. Bull.*, vol. **21**, 222 p., Utrecht.
- FRYDAS, D. (1990): Plankton - Stratigraphie des Pliozans und unteren Plestozans der SW - Peloponnes, Griechenland. *Newsl. Stratigr.*, vol. **23/2**, pp. 91-108, Berlin - Stuttgart.
- MARCOPOULOU-DIACANTONI, A., MIRKOU, M.-R., MARIOLAKOS, I., LOGOS, E., LOZIOS, S., FOUNTOULIS, I. (1989): Stratigraphic observations at the post-alpine sediments at the area of Thouria-Ano Amphia (Messinia) and their neotectonic interpretation. *Bull. Geol. Soc. Greece*, vol. **XXIII/3**, pp. 275 - 295, Athens. (In Greek).
- MARCOPOULOU-DIACANTONI, A., MIRKOU, M.-R., MARIOLAKOS, I., FOUNTOULIS, I. (1991): Stratigraphic and paleogeographic observations on the post-alpine sediments of the Filiatra area (SW Peloponnesus, Greece) and their neotectonic interpretation. *Bull. Geol. Soc. Greece*, vol. **XXV/2**, pp. 593-608, Thessaloniki. (In Greek).
- MARIOLAKOS, I. (1976): Thoughts and viewpoints on certain problems of the geology and tectonics of Peloponnesus (Greece). *Ann. Geol. Pays Hellen.*, vol. **27**, pp. 215 - 313, Athens. (In Greek).
- MARIOLAKOS, I., & FOUNTOULIS, I. (1991): Neotectonic macrofolds at the Filiatra area (Southwestern Peloponnesus, Greece). *Bull. Geol. Soc. Greece*, vol. **XXV/3**, pp. 19-38, Thessaloniki. (In Greek).
- MARIOLAKOS, I., SABOT, V., LOZIOS, S., LOGOS, E., MERTZANIS, A., FOUNTOULIS, I. (1987a): Morphotectonic observations in the Dimiova-Perivolakia graben. *Proc. 1st Congr. of Geogr. Soc. Greece*, vol. **B**, pp. 101-118, Athens. (In Greek).
- MARIOLAKOS, I., SABOT, V., ALEXOPOULOS, A., DANAMOS, G., LEKKAS, E., LOGOS, E., LOZIOS, S., MERTZANIS, A., FOUNTOULIS, I. (1987b): Microzonic study of Kalamata city (Geomorphology, Geology, Neotectonics). - *EPPO Report*, 110 p., Athens. (In Greek).
- PAPANIKOLAOU, D., CHRONIS, G., PAVLAKIS, P., LYKOUSIS, V., with contrib. of ROUSSAKIS, G. and SYSKAKIS, D. (1988): Neotectonic map of the Messinian Gulf. *Nat. Cent. Marine Res.*, Athens.
- PSONIS, C. (1986): Geological map of Greece, scale 1:50.000, KALAMATA sheet. *IGME Publ.*, Athens.
- SPAACK, P. (1983): Accuracy in correlation and ecological aspects of the planktonic foraminiferal zonation of the Mediterranean Pliocene. *Utrecht Micropal. Bull.*, vol. **28**, 160 p., Utrecht.
- ZELILIDIS, A., KONTOPOULOS, N., DOUTSOS, TH. (1988): Geotraverse in the Neogene - Quaternary deposits of SW Peloponnesus. *Bull. Geol. Soc. Greece*, vol. **XX/2**, pp. 85-97, Athens. (In Greek).
- ZWAAN, G. J. van der (1982): Paleoecology of late Miocene Mediterranean foraminifera. *Utrecht Micropal. Bull.*, vol. **25**, 202 p., Utrecht.