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HOLOCENE SEA-LEVEL CHANGES IN EUBOEA

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ABSTRACT

Based on geomorphological, archaeological and marine biological data and AMS ^{14}C dating of exposed *Lithophaga* fossils, differential, 3,000 years old relative sea-level changes along the coasts of north and central Euboea have been documented: 100-km long, 0.7-1.0m uplift along the Aegean coast, 20-km long, 1.1 uplift in the North Aegean Gulf and up to 2m subsidence in other parts of the island. Such differential relative sea-level changes undoubtly reflect a tectonic control on the Late Holocene coastal geomorphology of the island, and this result can be extrapolated to the whole of the Eastern Mediterranean. As far as uplifts in Euboea are concerned, they are not related to normal faults in a simple way, but they may reflect accomodation of shear strain from the North Anatolian fault, or continuing uplift of metamorphic core complexes.

INTRODUCTION

The geomorphological and tectonic history of the Aegean during Holocene has been the matter of a long-lasting debate: Cayeux (1907) proposed that a relative sea-level stability exists, but Negris (1904) argued that his observations of submerged ancient coastal sites document a new eustatic sea-level cycle, for the amplitude of subsidence in a number of ancient coastal sites is a function of time; this relationship was not, however, observed in the data of Flemming (1978), otherwise confirming the Holocene marine transgression which was assigned to back-arc extensional tectonics, in accordance with the ideas of McKenzie (1978). Recently, the ideas of Negris (1904) were put forward again by Kambouroglou et al (1988), who argued that the subsidence in a number of sites of Euboea are proportional to time. However, Mariolakos and Stiros (1987), Stiros and Papageorgiou (1989; 1990; in press), Stiros et al (1992), Roberts (1988) and Mourtzas and Stavropoulos (1989) presented evidence of Late Holocene raised beaches

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in various Aegean coasts. These uplifts have been assigned by Keraudren (1970) to climatic effects ("Versilian shorelines"), and by Jackson and McKenzie (1983) to isostatic motions of footwall blocks of normal faults. The aim of this paper to discuss the Late Holocene coastal evolution of Euboea, the largest island in the Aegean back-arc basin; more explicitely, (i) to present evidence of relative land uplift and subsidence, (ii) to show that these coastal changes are tectonically controlled, and (iii) to investigate whether observed uplifts can be related in a simple way with the activity of normal faults.

PREVIOUS STUDIES OF HOLOCENE SEA-LEVEL CHANGE IN EUBOEA

The first who presented evidence of Late Holocene marine regression in Euboea was Georgiadis (1907) who studied the submerged ancient harbours of Eretria and Neos Pyrgos, while Blanc (1964) reported a Late Holocene, 2.5m high marine sedimentary platform near Limni (for location see Fig.1)

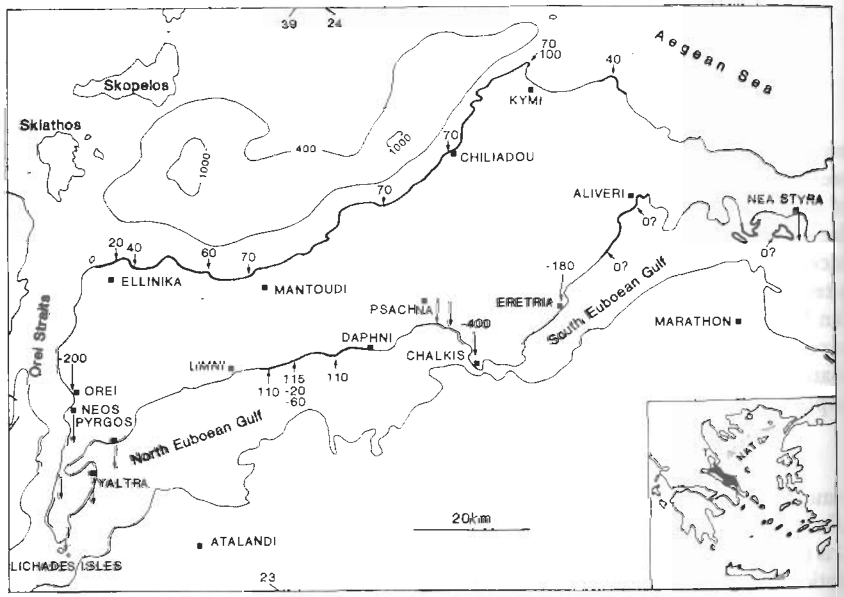

Fig. 1: Location map and summary of observations of Late Holocene relative sea-level changes in north and central Euboea. Heavy line indicates notched coastline (active and/or fossil continuous or discontinuous notches). Numbers with arrows indicate estimate of uplift in centimeters; short and long arrows stand for geomorphological and archaeological data, respectively. Bathymetric escarpment north of Euboea is indicated by the 400 and 1000m contours. Details in the text and Table 1. In the inset, T stands for Thessaly, while the North Aegean Trough (NAT) is shaded.

It is however interesting to note that the first report of Holocene tectonic motions in the island is due to archaeologists: observations of uplifted marine notches along the Aegean coast and quasi-submerged ancient sites in the Psachna plain led Sackett et al (1966) to the conclusion that Central Euboea is tilting to the southwest along its long axis. Recently, Stiros and Papageorgiou (1989) presented a summary of observations of relative sea-level change in Central Greece, while Stiros et al (1992) published AMS ^{14}C dating of *Lithophaga lithophaga* fossils collected from raised beaches along the NE and SW coast of north Euboea, and suggested that this uplift reflects a seismic motion.

On the contrary, Kambouroglou and others (1988) and Kambouroglou (1989) argued that the subsidence of archaeological sites in the area of Chalkis and Eretria reflects a eustatic sea-level rise, but Kambouroglou et al (1989) reported marine stata above present-day sea-level in the vicinity of the submerged archaeological site of Manika, at Chalkis.

METHODOLOGICAL APPROACH

Our data of Late Holocene, relative sea-level changes are based on geomorphological, marine biological and archaeological observations, or their combination. The criteria on which recognition and estimation of parametres of relative sea-level change are the following:

Geomorphological criteria

According to Pirazzoli (1986), during short (up to a few thousand years) periods of relative sea-level stability biological and chemical factors and the mechanical action of waves tend to produce an erosional notch in steep, calcareous cliffs (Fig. 2).

Fig. 2: Typical notch profile at Chiliadou.

When the tidal range is small, less than 10cm (as is the case with most of the Aegean), in relatively sheltered sites a notch centered at mean sea-level with its top at the height of 30-40cm will often be formed during a period of relative sea-level stability of a few thousand or even a few hundred years. A relative sea-level rise or drop will produce submerged or uplifted notches or sets of notches, which, in certain circumstances can be preserved and provide evidence of past sea-levels.

Archaeological criteria

Ancient coastal constructions are sensitive indicators of small-scale sea-level changes, (for example Negris, 1904; Flemming, 1978; Flemming and Pirazzoli, 1981; Pirazzoli, 1988), but can usually provide qualitative results or estimates of the minimum value of the sea-level change only; yet, in some cases, it is even possible to deduce the exact amplitude of progressive changes in the relative sea-level; for example, Murray (1982) reported cases of ancient harbour quays in Western Greece repaved to counteract relative sea-level rise. Stylistic dating of architectural remains or pottery fragments, occasionaly combined with historical information (for the last 2,800 years), usually provide a lower bound for the dating of observed marine regression or transgression in ancient sites, but occasionally more precise estimates (time bracketing) can also be deduced (Flemming, 1978; Flemming and Pirazzoli, 1981; Murray, 1982).

Marine biological criteria

Littoral marine organisms, and mainly those who build fixed skeletons or dig holes or burrows in coastal limestone of the infralittoral fringe (for example vermets and mussels, respectively) have a life-span of at least several years which allows them to integrate small-scale (notably seasonal) variations of sea-level. The upper level attained by some of these marine species (for example vermetid *Dendropoma petraeum*) is often well defined, appears as a horizontal line on the littoral rock and can be defined as a biological mean sea-level. This level is linked with a simple relationship to morphological indicators of present sea level, such as notches and benches; this relationship, however, may vary from place to place, and can be determined only after a study of the local biological zonation (see Fig. 3, Pirazzoli and others, 1982; 1989; Stiros et al, 1992) Usually, traces of biological sea-level (borers and monostromatic bioconstructors) are destroyed (bio-eroded) in case of submersion or of slow emersions, but are often able to perdure in case of episodic (usually co-seismic) emersions.

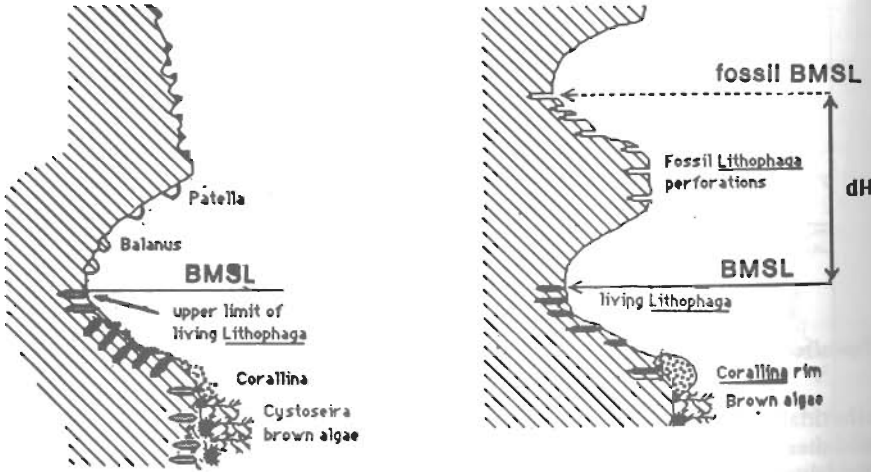

Fig. 3: Left: Local biological zoning, biological mean sea level (BMSL) and their relationship with notches in Euboea. Right: Relative sea-level drop (dH) as the difference in height of fossil and active BMSL.

In these last cases, if there has been no significant change in the littoral flora and fauna, either in specific composition or habitat, nor dramatic changes in the coastal morphology affecting biological zonation, the upper level of fossil organisms liable to be used as a sea-level indicator may be compared to that of the same organisms presently living on the modern shore level, and their altitudinal difference represents a fairly accurate measurement of the relative sea-level fall (Fig. 3). This type of measurement, provided that certain simple precautions are taken (Laborel, 1986), has the great advantage to be independant of the actual oceanographic sea-level which is often difficult to calculate with accuracy in places where tides gauges are rare or absent, for is affected by tides, winds and atmospheric pressure. The accuracy in the estimate of relative sea-level change obtained by biological observations depends on local conditions, but may be better than ±10cm. Biological observations are very useful for sea-level change studies for two other reasons. First, they may allow to separate a slow (usually eustatic) uplift from a brutal seismic jerk, since in the former case bioerosion will have the time to smother organic traces or destroy monostromatic skeletons. And second, fossil biological constructions such as algal or vermetid benches may be dissected and easily dated by radiometric methods, and thus give the age of a seismic movement or the age and duration of a sea-level standstill.

Combined criteria

Archaeological data can be combined with geomorphological data and provide complementary information on relative sea-level changes; for example, exposed ancient remains covered by marine conglomerates and vermets, or drilled by *Lithophaga*, *Clionids* etc give evidence of, and help in dating a relative sea-level fall as well (see Mariolakos and Stiros, 1987; Papageorgiou et al, in prep).

OBSERVATIONS OF RELATIVE SEA-LEVEL CHANGE IN EUBOEA

Our inter-disciplinary research in Euboea was based both on bibliographical and original data. These data are subject to certain limitations: (i) the distribution and the limited knowledge of ancient sites in most parts of the island, (ii) the distribution of carbonate rocks that permit formation and preservation of notches, and the temperature of waters along the coasts of Euboea; especially its northern coasts affected by cold, northern streams which make them unsuitable for the development of warm-water species like vermetids, which can rarely only been observed in the southern Euboean gulf (at Eretria, for example). Similarly, reef-building calcareous algae such as *Lithophyllum lichenoides*, common in Mediterranean waters are also absent. So, the only marine species which could be used as sea-level indicator was the rock-boring mussel *Lithophaga lithophaga* (Linneus), the upper limit of the zone in which it lives coincides with the vertex or retreat point of the notch (Fig. 3). The very small size of *Lithophaga* shell was another difficulty with radiometric dating and necessitated the introduction of accelerator mass spectrometry (AMS) ^{14}C dating techniques to the study of Holocene fauna (see Stiros et al, 1992).

Geomorphological observations

A nearly continuous, 100km long raised marine notch can be followed along the northern (Aegean) coast of the island (Figs. 1, 2). In most areas a single notch is present, but in at least two places two superimposed notches can be observed (Fig. 1). Based on marine biology criteria (see above) the amplitude of emergence is estimated to be 0.7m along the coast between Mantoudi and Kymi, and 0.2 to 0.4 at the north and south endpoints of the notch. In the promontory north of Kymi, the second notch testifies to a 1.0m emergence. These estimates are accurate to whithin 0.1 and 0.2m. An emerged notch testifying to a relative sea-level drop of around 1.1m has been observed along a distance of about 15 km along the southern coast of North Euboea, between Dafni and Galataki Monasteri, south of Limni, next to the area where Blanc (1964) reported a Holocene marine sedimentary platform. At the same area, two other notches, the upper one partially filled with *Corallina* have been observed below the present sea-level. These notches are likely to correspond to fossil shorelines at 0.2 and 0.6m below the present sea-level, respectively, but the significant tidal range in the North Euboean Gulf (up to 1m, Zoi-Morou, 1981) makes estimations less accurate (0.2-0.3m) than in the northern (Aegean) coast.

In both the southern and northern emerged coast of North Euboea, however, the occurrence of exposed and preserved *Lithophaga* shells is likely to testify to episodic uplifts. AMS ^{14}C dating of such shell fragments collected from the notches indicate that uplifts occurred between 1250 and 20 BC (Stiros et al, 1992). On the contrary, the age of the submerged notches near Limni are unknown. Some evidence of relative land uplift exists for the area of Yaltra, in the NW part of the island, where empty holes of *Lithophaga*, up to 50cm high have been reported by Roberts (1988). No notch, however, has been observed in this area, nor any evidence for the age of Lithophaga exists. A modern notch has been observed along the coast between Eretria and Aliveri, but only in Aliveri is well developped and testifies to a relative land stability for a period of at least some hundred years. Farther south, in the Styra area, an underdeveloped notch with its roof nearly 30cm above the water can be observed in outcrops of Mesozoic- Eocene limestones of the Gavrovo zone (Bornovas and Rondogianni, 1983); these notches are likely to indicate a relative sea-level stability or a small rise, but the amplitude of tide in the south Euboean Gulf makes observations less accurate.

Archaeological observations

Georgiadis (1904) was the first to study in details the submerged ancient harbours of Eretria and Neos Pyrgos. Signs of the latter have been obliterated by ekistical development of the area and construction of a new mole, above the ancient, submerged one. As far as Eretria is concerned, Kambouroglou (1989) estimated an 1.5-1.8m relative sea-level rise in the last 2,300 years, but he also reported some ancient constructions founded on a 3m thick layer of Holocene marine sediments. Sackett et al (1966) reported sumberged ancient remains in a number of sites, including Yaltra, next to some rocks bearing signs of perforations by *Lithophaga*, of unknown, however, age. These archaeological observations are summarized in Table 1, from which it can be concluded that ancient constructions providing information on submerged strandlines are between 6,000 and 500 years old, but the main bulk of data corresponds to ancient constructions about 2,500 years old.

Table 1
Summary of archaeological observations of relative land subsidence in north-central Euboea

Site	observation	age (ka)	subsidence (m)	references
Eretria (harbour)	mole, quays	2.3	1.5-1.8	(1),(5)
Chalkis (Manika)	buildings	4.8-4.3	>4.0	(3),(4)
Chalkis (Manika)	buildings	2.1-1.6	s	(4)
Chalkis (Ag. Stefanos)	buildings	2.5-2.3	s	(4)
Chalkis (Nea Artaki)	buildings	4.8-4.3	s	(4)
Chalkis (Nea Artaki)	buildings	1.7-0.6	s	(4)
Limni	basilica	1.7-1.5	s	(8)
Psachna (Varka)	inhabitation layer	>2.9	s	(3)
Aidipsos (Koumbi)	inhabitation layer	7.0-6.0	s?	(3)
Yaltra (Athinai Diades)	mole	2.3	s	(6),(7) Lichades
Isles	buildings	1.5-0.5?	s	(2),(3)
Cheronissos (N of Yaltra)	walls	?	s	(3),(8)
Neos Pyrgos	mole	2.5	1.5-2.0	(1),(8)
Orei	buildings	2.5	>2.0	(8)
Nea Styra	mole	?	s?	(3)

Ages based on stylistic archaeological dating. s: no estimate of subsidence amplitude is available. References: (1) Georgiadis (1907), (2) Gidarakos (1938), (3) Sackett and others (1966), (4) Kambouroglou and others (1988), (5) Kambouroglou (1989), (6) Lehmann-Hartleben (1923), (7) Anonymous (?), (8) this study.

Historical evidence of relative sea-level change

The opening of the Euripos Straits at Chalkis and the Straits between Euboea and Kea (the large island SE of Euboea, see Fig. 1, inset) have been assigned to earthquakes by ancient Greek and Latin writers (Guidoboni, 1989), probably exaggerating co-seismic subsidence of coastal areas. Some of these subsidence, for example that associated with the 426 BC earthquake (Guidoboni, 1989, Papazachos and Papazachou, 1989) were probably associated with landslides, but others, for example the 1758 event that was associated with subsidence of three islets in northern Euboea (see Papazachos and Papazachou, 1989), were of tectonic, probably, origin.

TECTONIC CONTROL ON THE EVOLUTION OF THE EUBOEAN COASTS

The available data indicate that in the last 2,000-3,000 years the coasts of north and central Euboea are characterized by an alternation of emerged and submerged beaches which testify to differential motions of up to 3m (2m subsidence and 1m uplift) along a distance of less than 20km. Such differential motions, clearly, can only be related to tectonic effects, a result consistent with the identification of co-seismic uplifts and subsidences, deduced from marine biology observations and historical data, respectively. This result is very important for the notch along the Aegean coast of north Euboea correlates with notches along the Thessalian coast, farther north (Stiros and Papageorgiou, in press) and gives evidence of a more than 200-km long, rather uniformly raised beach.

THE MECHANISM OF UPLIFT

While uplifts along the Aegen arc can be related with compressional tectonics, the uplifts in the back-arc basin are apparently related with normal faults (see for example Mercier et al, 1979). This appears as a paradox, for normal faultings leads to subsidence, and not uplift. Jackson and McKenzie (1983) in an effort to solve this problem suggested that the downward

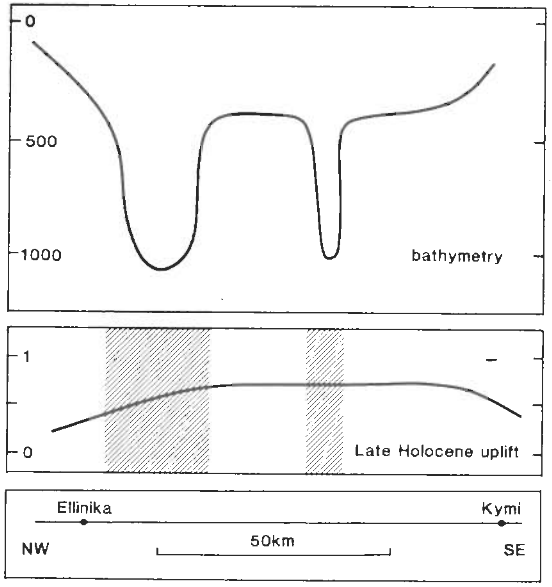

Fig. 4: Throw of the normal fault (deduced from the bathymetry) controlling the north Aegean coast of the island, and Late Holocene uplift along the same coast, projected along the long axis of the island. No correlation between the two graphs that could indicate that uplift is a simple function of normal fault throw exists.

Table 2

Raised beaches, ≤10m high in the Aegean and the Eastern Mediterranean

Location	height (m)	age (Ka BP)	Dating	References
Liban	2.0-2.2	3.0	C	(1)
Liban	0.8	1.5	C	(1)
Antiocheia (Hatay), S.E Turkey	2.0-3.0	2.5	C	(2)
Antiocheia (Hatay), S.E Turkey	0.7-0.8	1.5	C	(2)
Alanya, SE Turkey	0.5-1.3	1.5	C	(3)
Cyprus, southern coast	8-11	190	U	(4)
Cyprus, southern coast	3	120	U	(4)
Cyprus, northern coast	1	1.5	S	(5)
Crete	9-1	1.5	C	(6)
Antikythira	2.7	1.5	C	(6)
Rhodes	3.8	2.2	C	(7)
Euboea	1.0	3-2	A	(8)
Corinth (Lechaion)	1.0	1.5-2.0	S	(9)
Derveni (Mavra Litharia)	1.5	1.5	A	(9)
Derveni (Mavra Litharia)	1-6	*	P	(9, 10)
Skyros	3.5-4.0	**	P	(11)
Dardanelles	10	*	P	(11)

Dating : 14C (C), stylistic archaeological (S), Uranium series (U), AMS 14(C) (A), P Palaeontological, * Quaternary, previously described as Tyrrhenian, ** Milazzian

References : (1) Sanlaville (1977); (2) Pirazzoli et al (1991); (3) Kelletat and Kayan (1983); (4) Poole et al (1990); (5) Dreghorn (1981); (6) Laborel et al (1979); Pirazzoli et al (1982), Thommeret et al (1981); (7) Pirazzoli et al (1989); (8) Stiros et al (1992); (9) unpublished data (10) Georgiadou -Dikaioulia and Markopoulou-Diakantoni (1976); (11) Keraudren (1970)

movement of the hanging wall block in a major normal fault (including that controlling the Aegean coast of Euboea, appearing as a more than 1000m deep escarpment, see Fig. 1) is accompanied by an isostatic uplift of its footwall block, and that subsidence is 10 times higher than uplift. The graph, however, of the height of the Late Holocene uplift along the two coast of northern Euboea does not correlate with bathymetry (see Fig. 4).

As the latter is supposed to indicate the downward movement of the hanging wall block of the normal fault controlling the northeast coast of Euboea, uplift is not related in a simple way with normal faulting. Furthermore, the length of raised beaches, both in Euboea and Thessaly testify to larger-scale processes; accomodation of shear from the North Aegean Trough appears as a plausible explanation. Another possibility is the uplifts along the Aegean coast of Thessaly (Stiros and Papageorgiou, in press) and Euboea to be related to a continuing uplift of metamorphic rocks of Thessaly and southern Euboea metamorphic complexes (Shermer et al, 1989; Vergely and Mercier, 1990).

HOLOCENE RELATIVE SEA-LEVEL CHANGES IN A REGIONAL SCALE

In the past, Holocene raised beaches in the Aegean and the Aegean arc have been explained as relicts of a Versilian (5,500BP) sea-level highstand (Keraudren, 1970); similarly, raised beaches in the Levant have been attributed to eustatic sea-level peaks at about 3,000 and 1500 BP (Sanlaville, 1977). However, recent evidence suggests first, that most of these uplifts are episodic, probably co-seismic in origin (Thommeret et al, 1981; Pirazzoli et al, 1982; 1989; Stiros et al, 1992). Second, as can be deduced from Table 2 raised beaches in Greece and the Eastern Mediterranean are not correlated with known climatic peaks, are not coeval, nor their height is indicative of their age.

And third, some of them bear clear signs of tectonic deformation (mainly tilting, for example in Crete and SE Turkish coast, see Pirazzoli et al, 1982; 1991). For this reason, a tectonic control on the coastal evolution of the Aegean and the wider area during Late Holocene is likely.

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REFERENCES

ANONYMOUS (?). Athinai Diades. Helios Dictionary, Athens. 1, 620 (in Greek).

BLANC, J.-J. (1964). Campagne de la Calypso en Mediterranee Nord-Orientale (1960)-5. Recherches geologiques et sedimentologiques: Ann. Inst. Oceanogr. 41, 220-270.

BORNOVAS, J. and RONDOGIANNI, T. (1983). Geological map of Greece, 1:500,000 scale, IGME, Athens.

CAYEUX, L. (1907). Fixite du niveau de la Mediterranee a l'epoque historique (Delos, Crete). Ann. Geogr., 16, 97-116.

FLEMMING, N. (1978). Holocene eustatic changes and coastal tectonics in the Northeast Mediterranean: Implications for models of crustal consumption. Trans. R. Soc. Lond., A-289, 405-458.

FLEMMING, N. and PIRAZZOLI, P. (1981). Archeologie des cotes de la Crete. Histoire et Archeologie, Les Dossiers, 50, 56-81.

GEORGIADIS, A. (1907). Les ports de la Grece dans l'antiquite qui subsistent encore aujourd'hui. Published in Athens for the Exposition Maritime de Bordeaux, 1907.

GIDARAKOS, D. (1938). Geological and geomorphological investigation of the volcanic Lichades Isles and correlatation with Mt Iti and the opposite coast of Lokris. Proceedings of the Academy of Athens, 13, 99-107 (in Greek).

GUIDOBONI, E., (1989). Catalogo, area Mediterranea, in I terremoti prima del Mille in Italia e nell'area Mediterranea, SGA, Bologna.

JACKSON, J and McKENZIE, D. (1983). The geometrical evolution of normal fault systems. J. Struct. Geol., 5, 471-482.

KAMBOUROGLOU, E. (1989). Eretria. Paleogeographic and geomorpholog ical evolution durring Holocene. Relationship between ancient environment and ancient inhabitation. Phd. Thesis, University of Athens, Edition of the Municipality of Eretria.

KAMBOUROGLOU, E., MAROUKIAN, H. and SAMPSON, A. (1988). Coastal evolution and Archaeology north and south of Khalkis (Euboea) in the last 5,000 years, (Raban, A., ed.), Archaeology of coastal changes, BAR Int. Ser., 404, 71-79.

KAMBOUROGLOU, E., SAMPSON, A. and MAROUKIAN, H. (1989). The coastal topography and archaeology of Manika, an early Helladic town in east central Euboea, Greece, (Y. Maniatis, ed.), Archaeometry, Proceedings of the 25th Int. Symp., 461-467.

KELLETAT, D., and KAYAN, I. (1983). Alanya batisindaki kiyularda ilk ^{14}C tarihlendirmelerinin isiginda Gec Holosen tektonik harekketler: Turk. Jeol. Kurumu Bul., C, 26, 83-87.

KERAUDREN, B. (1970). Les formations quaternaires marines de la Grece. Phd Thesis, Faculte de sciences, Paris University.

LABOREL, J. (1986). Vermetid gastropods as sea-level indicators. (van de Plassche, O. ed.), "Sea-level research: A manual for the collection and evaluation of data", 281-310, Geobooks, Norwich.

LABOREL, J., PIRAZZOLI, P.A., THOMMERET, J., and THOMMERET, Y(1979). Holocene raised shorelines in western Crete (Greece). Proc. 1978 Symposium on coastal evolution in the Quaternary, Sao Paolo, Brasil, 475-501.

LEHMANN-HARTLEBEN, K. (1923). Die antiken Hafenanlagen des Mittelmeeres. Klio,Beiheft 14, new Folge, Heft I.

MARIOLAKOS, I., and STIROS, S. (1987). Quaternary deformation of the Isthmus and Gulf of Corinthos (Greece). Geology, 15, 225-228.

McKENZIE, D. (1978). Active tectonics of the Alpine- Himalayan belt: the Aegean Sea and surrounding regions. Geophys. J. royal astron. Soc., 55, 217-254.

MERCIER, J.-L., DELIBASSIS, N., GAUTHIER, A., JARRIGE, J.-J., LEMEILLE, F., PHILIP, H., SEBRIER, M., and SOREL, D. (1979). La neotectonique de l' arc Egeen. Rev. Geol. dyn. Geogr. Phys., 21(1), 67-92.

MOURTZAS, N. and STAVROPOULOS, X. (1989). Recent tectonic eveolution of coasts of Samos island (East Aegean). Bull. Geol. Soc. Greece, 23/1, 223-241.

MURRAY, W.H. (1982). The coastal sites of western Akarnania- A topographical-historical survey. Phd Thesis, Univ. of Pennsylvania.

NEGRIS, P. (1904). Vestiges antiques submerges. Athen. Mitt., 29, 341-363.

PAPAGEORGIOU, S., STIROS, S. and SIGALAS, C. (1990). New evidence of Late Holocene sea-level changes in the Aegean and Santorini: tectonic, eustatic and volcanological effects (D. Hardy, J. Keller, V. Galanopoulos, N. Flemming, T. Druitt eds.), Thera and the Aegean world III, The Thera Foundation, London, Vol. II, 416-421.

PAPAZACHOS, B. and PAPAZACHOU, K. (1989). Earthquakes in Greece, Zitis, Thessaloniki.

PIRAZZOLI, P. (1986). Marine notches. (van de Plassche, O. ed.) "Sea-level research: A manual for the collection and evaluation of data", 361-400, Geobooks, Norwich.

PIRAZZOLI, P. (1987). Sea-level changes in the Mediterranean. (Tooley, M. and Shennan, I., eds.), Sea-level changes, 152-181, Blackwell, Oxford.

PIRAZZOLI, P. (1988). Sea-level changes and crustal movements in the Hellenic arc (Greece). The contribution of archaeological and historical data, (Raban, A., ed.). Archaeology of coastal changes: BAR International series 404, 157-184.

PIRAZZOLI, P., THOMMERET, J., THOMMERET, Y., LABOREL, J. and MONTAGGIONI, L. (1982). Crustal block movements from Holocene shorelines: Crete and Antikythira. Tectonophysics, 86, 27-43.

PIRAZZOLI, P., MONTAGGIONI, L., SALIEGE, J., SEGONZAC, G., THOMMERET, Y. and VERGNAUD-GRAZZINI, C. (1989). Crustal block movements from Holocene shorelines, Rhodes Island (Greece). Tectonophysics, 170, 89-114.

PIRAZZOLI, P.A., LABOREL, J., SALIEGE, J., EROL, O., KAYAN, I. and PERSON, A. (1991). Holocene raised shorelines on the Hatai coasts (Turkey): Palaeocological and tectonic implications. Marine Geology, 96, 295-311.

POOLE, A., SCHIMMIELD, G., ROBERTSON, A. (1990). Late Quaternary uplift of the Troodos ophiolite, Cyprus: Uraniuum series dating of Pleistocene coral. Geology, 18, 894-897.

ROBERTS, S. (1988). Active normal faulting in Central Greece and Western Turkey. Phd Thesis, Cambridge Univ.

SACKETT, L., HANKEY, V., HOWELL, R., JACOBEN, T. and POPHAM, R. (1966). Prehistoric Euboea: Contribution towards a survey. The annual of the British Scholl at Athens, London, 61, 32-112.

SANLAVILLE, P. (1977). Etude geomorphologique de la region littorale du Liban. Publ. Univ. Liban, Sect. Etud. Geogr, Beyrouth, 859pp.

SHERMER, E., LUX, D. and BURCHFIEL, B. (1989). Age and tectonic significance o metamorphic events in the Mt Olympos region, Greece. Bull. Geol. Soc. Greece, 23/1, 13-28..

STIROS, S. and PAPAGEORGIOU, S. (1989). Upper Holocene sea-level changes and some implications for the tectonics of Central Greece. Bull. Geol. Soc. Greece, XXIII/1, 259-269 (in Greek).

STIROS, S. and PAPAGEORGIOU, S. Post-Mesolithic evolution of the Thessalian landscape. Proccedings, La Thessalie, Colloque International d'archeologie, Lyon 1990 (in press).

STIROS, S., ARNOLD, M., PIRAZZOLI, P., LABOREL, J., LABOREL, F. and PAPAGEORGIOU, S. (1992). Historical co-seismic uplift on Euboea Island, Greece. Earth and planet. sci. Lett., 108, 109-117.

THOMMERET, Y., THOMMERET, J., LABOREL, J., MONTAGGIONI, L. and PIRAZZOLI, P. (1981). Late Holocene shoreline changes and seismotectonic displacements in western Crete (Greece). Z. Geomorphol. Suppl. Bd., 40, 127-149.

VERGELY, P. and MERCIER, J. (1990). La fenetre metamorphique de l'Olympe (Macedoine, Grece): Compression et extension Cenozoiques. Bull. Soc. Geol. France, (8)6, 819-829.

ZOI-MOROU, A. (1981). Tidal data of Greek harbours. Oceanographic study 13, Hydrographic Survey, Athens.