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Upper Holocene sea level changes in the West Saronic Gulf, Greece

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ABSTRACT

Along the Peloponnesian coast of the Saronic Gulf and on the coast of Aegina and Poros islands, submerged coastal geomorphological features related directly with submerged ancient coastal constructions, indicate three distinct sea levels. Submerged tidal notches incised on the carbonate basement, beachrocks formed in the intertidal zone and archaeological indicators, such as the ancient harbour installations in Kenchreai and Epidaurus and on Aegina island, the extended coastal buildings and constructions in Agios Vlasis, Psifta and Palaiokastro-Methana, and Vagionia on Poros island, are used to determine the age and magnitude of submersion and the extent of the Upper Holocene marine transgression. By the correlation of geomorphological, historical and archaeological indications three distinct sea levels were identified, at -3.30 ± 0.15 m, -0.90 ± 0.15 m and -0.55 ± 0.05 m. Initial change in sea level occurred definitely after AD 400 ± 100. The intermediate change is dated between AD 1586 and 1839, and the most recent change after 1839. Sea transgression followed a long period of sea level stability, which lasted at least 2200 years, from the Middle Bronze Age to the Late Roman period.

1. Introduction

The West Saronic Gulf, between the east coast of the Peloponnese and the islands of Salamis, Aegina and Poros (Fig. 1a, b), is fragmented by active seismic zones that is considered to have caused footwall uplift and hanging wall subsidence during their successive activations throughout the Upper Holocene (Fig. 2). Sea level changes that occurred in specific coastal locations of these areas are mainly attributed to paroxysmal subsidence episodes connected with strong earthquakes (Scranton et al., 1978; Papanastassiou and Gaki-Papanastassiou, 1993; Noller et al., 1997; Nixon et al., 2009; Dao, 2011; Papanikolaou and Roberts, 2011).

As reported by Scranton et al. (1978), in the bay of Kenchreai on the north side of the Peloponnesian coast of the Saronic (Fig. 1a–c), the submersion of the Roman harbour possibly occurred during three distinct phases, which caused a total sinking of the constructions by 2.30 m. The first phase, which resulted in a submersion by 0.70 m, is correlated with the strong earthquake of AD 77. The second phase coincides in time with the earthquakes of AD 365 and 375, which caused further subsidence by 0.80 m. Finally, the third phase is related to the seismic events of the 6th century AD causing again a subsidence of approximately 0.80 m.

Rothaus et al. (2008) stated that in the coastal area of Kenchreai the excavations revealed level, intact, paved floors, damaged only by later intrusions and no traces of liquefaction, slumping, or lateral spreading were found, implying that the subsidence is almost totally fault-controlled. They consider that the fish tanks of the south breakwater are the only sure dated indication of sinking of the site and up today there is not any other archaeological evidence certainly indicating the number of the co-seismic events that struck Kenchreai. The E–W oriented Oneia fault zone that ends at the bay of Kenchreai (Fig. 2) is an active normal structure with a length varying from 7 km to 9 km and magnitude of earthquake potentials 5.5 R (Papanikolaou et al., 1996; Kranis et al., 2004). The ancient harbour lies in the immediate hanging wall of this fault zone, which according to Papanikolaou and Roberts (2011) may have caused a significant cumulative subsidence during successive activations. The strong earthquakes of AD 365–400, 551, 1756, 1858 and 1928 caused serious damage in the area and their macroseismic effects are associated with this fault zone (Papanastassiou and Gaki-Papanastassiou, 1993; Noller et al., 1997; Papazachos and Papazachou, 1997; Rothaus et al., 2008).

Twenty kilometres south, on the Peloponnesian coast of the Saronic Gulf, in the bay of Korphos (Fig. 1b), Nixon et al. (2009) examined and correlated tidal notches with foraminifera/thecamoebians fossil assemblages found in sediment cores drilled in the salt marsh nearby the village of Korphos and so they produced a sea level curve. They argue that much of 4 m rise in relative sea level

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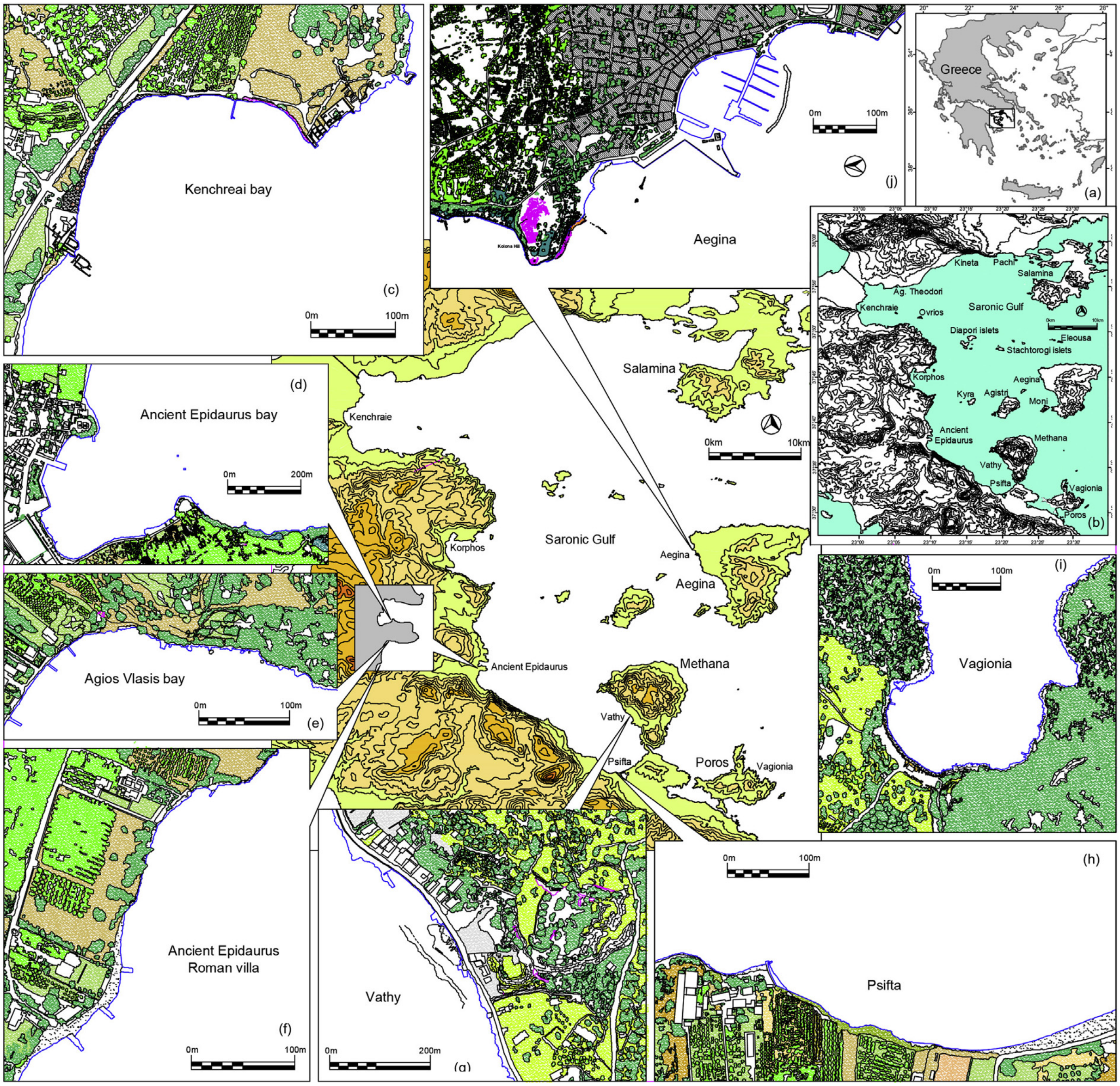

Fig. 1. (a), (b): Location maps of the Saronic Gulf, (c): Kenchreai bay, (d): Ancient Epidaurus bay, (e): Agios Vlasis bay, (f): coast of Epidaurus country villa, (g): Vathy coast of the Methana peninsula, (h): Psifta coast, (i): Vagionia bay on Poros island, (j): seafront of the ancient and modern city of Aegina (after Mourtzas and Kolaiti, 2013).

occurred at Korphos in the last 5500 years during five distinct tectonic phases of subsidence that formed the sea levels of −2.94 m around 5100 BP, −1.74 m ~4400 BP, −1.34 m ~2650 BP, −0.88 m ~1600 BP, and the approximate present level ~400 BP. According to the authors, earthquakes causing coseismic subsidence occur once every 1412 ± 1068 y at Korphos.

Dao (2011) found two submerged beachrock platforms on the coast of Kalamianos Mycenaean settlement, 2.5 km east of Korphos (Fig. 1b). ^{14}C dating of wood charcoal fragments from the younger beachrock phase at −3.50 m to −3.70 m yielded a calibrated age of approximately 1600–1400 BC, slightly earlier than the Late Helladic (1400–1200 BC) potsherds that have been incorporated into it. The older beachrock phase at −5.80 m to −5.90 m comprises well preserved sherds of Early Helladic (2700–2200 BC) jars. The noticeable different rate of sea level change between the two adjacent positions is attributed by Dao (2011) to neotectonic activations of the intermediate faults.

Negris (1904) estimated that the detached west breakwater of the ancient harbour of Aegina on the NW coast of Kolona Hill (Fig. 1b, j), has submerged by 3.70 m since its operation. Knoblauch (1969, 1972) considered that over the last 3800 years sea level has risen by 3.55 m–4.05 m in the ancient harbour of Aegina. He also stated that during the Classical period (482 BC) sea level was at −2.20 m to −2.50 m, whereas in Roman times (*ca.* AD 250) was at −1.60 m to −1.90 m. Mourtzas and Kolaiti (2013) based on geomorphological and archaeological indications defined three distinct relative sea levels at depths of 3.17 ± 0.05 m, 0.97 ± 0.05 m and 0.52 ± 0.05 m. They also attempted to date the sea level changes based on archaeological evidence and historical sources and concluded that the initial sea level change in Aegina occurred certainly after AD 170 and most likely after AD 250, the intermediate change between AD 1586 and 1839, and the most recent change between 1839 and 1999. They first argued for a long period of sea level stability that lasted from the Middle Bronze Age to the Late Roman period.