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# The so called 'Herodotus Springs' at 'Keri Lake' in Zakynthos Island western Greece: A palaeoenvironmental and palaeoecological approach

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ABSTRACT

In the present study the palaeoenvironmental setting of the coastal mire/swamp zone called 'Keri Lake', on Zakynthos Island, west Greece is presented. The mire/swamp area is famous for the asphalt-pitch seepages named as 'Herodotus-springs'. In order to interpret the Holocene evolution of the area, samples from four 7 m long vibracores were analyzed for their total organic carbon, total nitrogen and sulfur contents, as well as for their micro- and macro-fauna. The chronological framework of this study was based on three $^{14}C$ ages, while the age depth model and the sedimentation rate were estimated applying OxCal software. The age depth model indicates that the cores cover the period from the middle Holocene to present, with a mean sedimentation rate of 1 mm/yr. Before 4000 BP large part of the area inundated by the sea while after 4000 yrs BP the ecosystem changed to a high marsh and gradually to a fen environment, where peat accumulated under telmatic to limnotelmatic conditions. The trends and the ratios of the geochemical markers TOC, TN and TS clearly reflect the palaeoenvironmental change from terrestrial to fen depositional environments. The results show that during the middle Holocene the Herodotus Lake was influenced by sudden sea water inundation events, possibly as a result of high waves or storm events, while since the late Holocene the setting is that of a brackish coastal fen, where peat accumulates, under the significant inflow of fresh water that originates from the karstic systems of the catchment area.



## 1. Introduction

Early Mediterranean civilizations, made broad use of the coastal areas of the eastern Mediterranean, as it is clear from the Greek, Roman and Phoenician settlements, which are described by Davis and Fitzgerald (2004). Coastal areas provided them with available food sources, as well as geomorphological setting for harbors, hence, for transporting goods. From the geological point of view coasts are dynamic sedimentary environments, with changing characteristics and nature from time to time due to sea level fluctuations, sediment budget, tectonics and human impact (Kjerfve, 1994; Bird, 2008). Additionally, coastal transitional environments constitute important archives for the study of Holocene palaeoenvironmental changes. Shoreline dislocation, sea level and palaeoclimatic changes during the Holocene in the eastern Mediterranean region have been described and reviewed by Fouache and Pavlopoulos (2005), Vött (2007), Brückner et al. (2010), Finné et al. (2011) and Pavlopoulos et al. (2012), based on sedimentological, archaeological, palaeontological and geochemical data. For the central and western Mediterranean region studies concerning climatic events, coastal evolution, human interference and dating methods are presented by Pascucci et al. (2014a), Pascucci et al. (2014b).

Sea level rise is one of the principal processes that affected the geomorphology and coastal depositional environments of the Mediterranean during the Holocene. As a result of the sea level rise the correspondingmarine transgression inundated lowlands and created coastal lagoons, marshes and embayments. Moreover, the eastern Mediterranean is part of the today active convergent

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boundary of Eurasian and African plates and is one of the most seismically active regions worldwide. As a consequence of the high seismo-tectonic activity, coastal areas have been influenced by tsunamis and marine inundation. In the Holocene several geo-archaeological findings point to tsunami events all around the eastern Mediterranean Sea and particularly in western Greece (Vött et al., 2009, 2011). Several studies have brought to light a number of examples where coastal areas and ancient cities were influenced in the historical and prehistorical times by sea level rise, tsunami events and marine transgression (Kontopoulos and Avramidis, 2003; Brückner, 2005; Evelpidou et al., 2010; Ghilardi et al., 2012, 2013; Pavlopoulos et al., 2013; Avramidis et al., 2014; Apostolopoulos et al., 2014; Weiberg et al., 2016).

For archaeologists, studying coastal landscapes has become important to understand development of ancient human societies and their environment (Rapp and Kraft, 1994; Aberg and Lewis, 2000). Previous studies (Papazisimou et al., 2000) revealed that the area of the Keri Lake is actually an active mire, with peat-accumulation taking place mostly in a fen environment behind a sand barrier; these studies were based on lithological descriptions, pH and electrical conductivity values and peat-ash yields (inorganic residue after combustion at 550 °C), as well as on palynological results, from hand-driven cores along the mire. A new field campaign took place in October 2013 and two more cores were obtained. The objective of the new coring campaign was to apply geochemical as well as micro- and macropalaeontological analyses.

In this study the new set of data is evaluated in conjunction with the data of Papazisimou et al. (2000) in order to provide a more comprehensive palaeonvironmental and palaeoecological evolution of the so called 'Herodotus Springs' of Keri Lake, while an attempt is made to reconstruct the landscape of the ecosystem and to compare it with the existing archaeological knowledge of the area.

## 2. Regional setting - study area

Zakynthos Island is one of the most seismically active regions in the Mediterranean Sea (Papazachos and Papazachou, 1997), as it is located very close to the convergent boundary between the African and Eurasian plates and Cephalonia fault (Fig. 1a), is undergoing very rapid and intense ground deformations (Lagios et al., 2007). Geologically, the island is distinguished into two geotectonic zones, the Ionian and Pre-Apulian, which are separated by the Ionian thrust (Fig. 1b). The sedimentation in Zakynthos Island is characterized by the deposition of evaporites during Triassic and calcareous deposits from Cretaceous to Miocene, as well as by clastic deposits of Plio-Quaternary age (Fig. 1b) (Duermeijer et al., 1999; Papanikolaou et al., 2011). Both compressional and extensional tectonism influenced the geomorphology and the sedimentation of the island (Zelilidis et al., 1998). Avramidis et al. (2013) and Panagiotaras et al. (2012) studying a 21 m core from the north part of Zakynthos Island, reconstructed the Holocene depositional environments and interpreted them in relation to the regional climatic forcing, suggesting that the abrupt events of marine conditions could reflect storms or tsunami events.

The study area is the ancient so called 'Herodotus Springs' of Keri Lake, located in the southern part of Zakynthos Island, expanding over an area of 3 km$^2$ and lying 1 m above the sea level (Fig. 1b). The Keri Lake is separated from the open sea by a low relief sand barrier, which is partially artificial so its communication with the open sea is limited (Fig. 2). The initial limnic environment evolved into a coastal fen overgrown mainly with reeds and other peat-forming plants, while the open water areas are restricted to small ponds (Papazisimou et al., 2000). The fen develops in a small Neogene tectonic depression defined by E-W trending normal faults (Papazisimou et al., 2000) (Fig. 2).

This ecosystem is unique in Greece due to the presence of

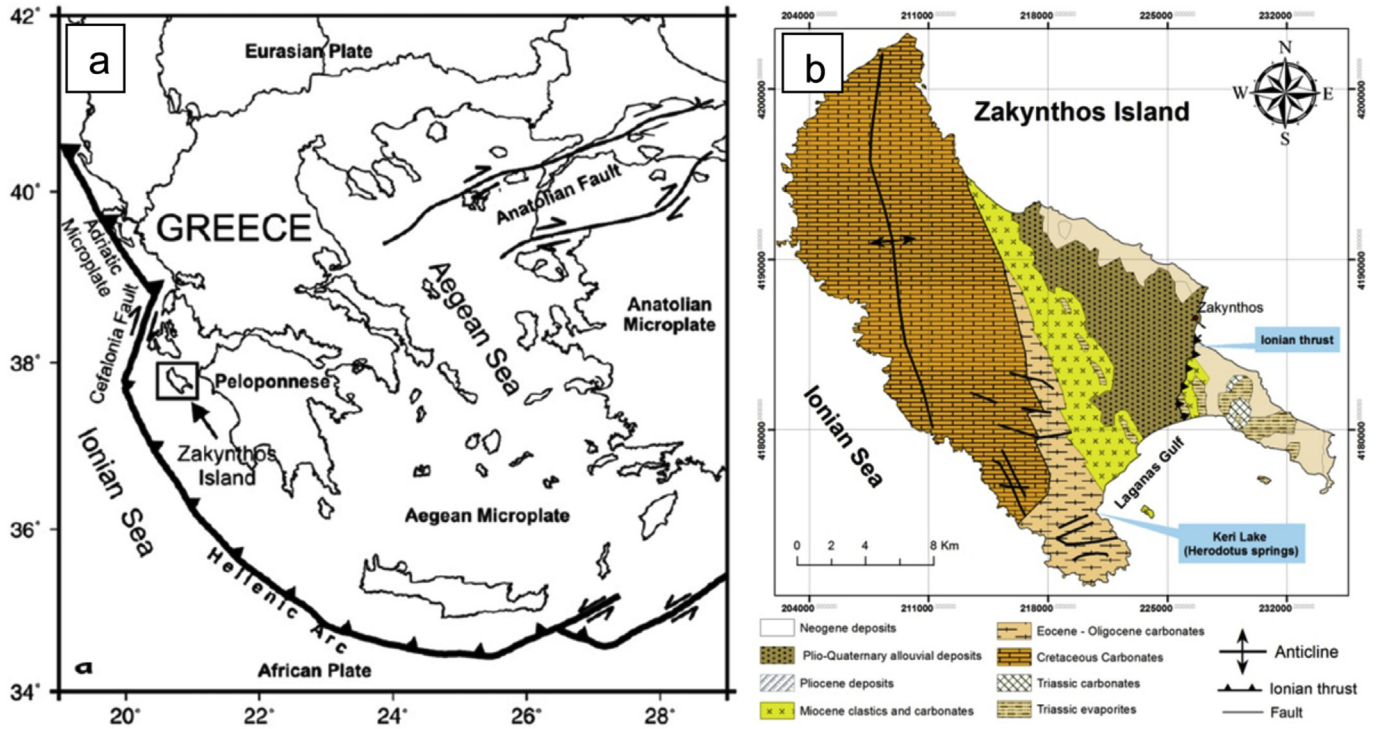


**Fig. 1.** (a) Map of Greece showing the Hellenic trench, the plate boundaries and the major fault systems and (b) geological map of Zakynthos island (I.G.M.E., 1980) with the location of Herodotus Lake of Keri.

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