Quaternary International 401 (2016) 4–16

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Impact of Holocene tsunamis detected in lagoonal environments on Corfu (Ionian Islands, Greece): Geomorphological, sedimentary and microfaunal evidence

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A R T I C L E I N F O

Article history:
Available online 8 August 2015

Keywords:
Palaeotsunami
Coastal geomorphology
Sedimentary analyses
Microfaunal analyses
Neotectonics
Corfu Island

A B S T R A C T

In this paper, we present for the first time geomorphological, sedimentary and microfaunal evidence of palaeotsunami impact on Corfu (Ionian Islands, Greece). The island of Corfu is located in an area of exceptional tectonic stress: towards the south, the African oceanic plate is being subducted underneath the Aegean plate, whereas towards the north, the Adriatic and European plates form a continental collision zone. Recent publications provide evidence of earthquake related co-seismic movements that potentially trigger extreme wave events as well as relative sea level fluctuations. In this context, we investigated two selected near-coast geological archives – the Chalikiopoulou Lagoon in the east and the Korission Lagoon in the southwest of Corfu Island. Our results clearly document that the eastern as well as the southwestern coasts of Corfu were repeatedly affected by palaeotsunami impact during the Holocene. With regard to the local topographical constellation and the recent geomorphodynamic potential of each study area, evidence of high-energy wave impact is based on the stratigraphical and microfaunal record of selected vibracoring sites as well as on numerical modelling results. It is concluded that the eastern coast of Corfu is preferably affected by high-energy wave impacts from a southern direction. Such impacts are most likely related to teletsunamis from the major seismical zone of the Hellenic Trench. In contrast, the southwestern coast of Corfu is endangered by impacts from both western and southern directions. Such impacts may comprise teletsunamis triggered in the Hellenic Trench or the Etna regions but may also be caused by local submarine landslides at the steeply sloping continental shelf directly west of Corfu. Our study builds a bridge between palaeotsunami-research conducted in the southern Ionian Sea and the Adriatic Sea and allows to better discriminate between the effects of teletsunamis and locally triggered events within one of the seismically most active regions in the eastern Mediterranean.
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1. Introduction

Palaeotsunami events trigger severe and abrupt changes of sedimentary and ecological environmental conditions associated with distinct geomorphological processes. These events and processes may be of temporary character and provoke an interim interruption of prevailing geomorphological conditions to be re-established after a specific period of time. Alternatively, extreme wave events may also cause thorough and enduring changes in the geo- and ecosystem and strongly influence the subsequent overall landscape evolution. However, such events are often documented in the form of distinct marker horizons within the sedimentary record and allow a multi-proxy based reconstruction of their spatial and temporal dimensions and their specific influence on landscape evolution as well as on man-made infrastructure (e.g. Hadler et al.,

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http://dx.doi.org/10.1016/j.quaint.2015.07.019
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2013; Vött et al., 2013). In this context, recent publications provide evidence of potential triggers for extreme wave events affecting the Ionian Island of Corfu during the Holocene. For example, Pirazzoli et al. (1994) document two co-seismic movements in central Corfu that date to the 8th–4th cent. BC and younger times, respectively. These events are associated with strong earthquakes which have to be considered as potentially tsunamigenic. Recently, Mastronuzzi et al. (2014) report on earthquake-related co-seismic events on Corfu in association with relative sea level fluctuations that occurred around 1000 BC, 300 BC and, more recently, around 430 or 1278 AD. These events clearly demonstrate the high neotectonic activity in the area of Corfu during historical times. Abrupt sea level changes associated to (pre-)historical earthquakes are also known for adjacent areas in northwestern Greece (Besonen et al., 2003; Vött et al., 2011a) and the coasts of the Adriatic Sea (Mathers et al., 1999; Antonioli et al., 2007, 2009; Fouache et al., 2010; Faivre et al., 2011; Evelpidou et al., 2012). Based on geophysical and sedimentological investigations of submarine slopes and depressions offshore western Corfu, Poulos et al. (1999) describe numerous seismically induced mass movements. Due to the narrow and steeply sloping continental shelf, such submarine mass movements have also to be regarded as potential triggers for palaeotsunami events. Although several entries in tsunami and earthquake catalogues prove multiple tsunami landfalls on Corfu (Partsch, 1887; Soloviev et al., 2000; Ambraseys and Synolakis, 2010; Hadler et al., 2012), these events have so far not been searched for in the geological record of the island. However, a multitude of geomorphological and sedimentological traces of tsunamigenic impact were published for the Ionian Islands of Cefalonia and Lefkada (Vött et al., 2009a, 2009b, 2011a, 2011b, 2014; May et al., 2012; Willershäuser et al., 2013), Zakynthos (Avramidis et al., 2013), the western and southern Peloponnese (Scheffers et al., 2008; Hadler et al., 2015; Vött et al., 2015) and western Crete (Dominey-Howes et al., 1998; Shaw et al., 2008).

As Corfu is located close to the narrow Otranto Strait between Italy and Greece (maximum width of 75 km), tsunami waves that enter the Adriatic Sea from the south are expected to be strongly amplified near Corfu due to funnelling effects. Furthermore, the shallow water depths of this epicontinental sea are expected to cause strong shoaling of waves proceeding towards the north. However, as the Adriatic Sea is a dead end structure, tsunami wave trains entering from the south will inevitably cause an inundation along Adriatic coasts. Geo-scientific evidence of tsunami events that affected the Adriatic Sea during the younger Holocene is published by Gianfreda et al. (2001), Mastronuzzi and Sansò (2004), Maramai et al. (2007), Paulatto et al. (2007), Pignatelli and Mastronuzzi (2009) and Pasarić et al. (2012) for the Italian coasts. Evidence of multiple tsunami landfall is also described for coastal areas in southern Italy, located directly opposite to Corfu (Scicchitano et al., 2007, 2010; Stewart and Morhange, 2009; De Martini et al., 2010). However, traces of palaeotsunami impact along eastern Adriatic coasts have not yet been reported.

In this contribution, we present geomorphological, sedimentary and microfaunal evidence of palaeotsunami impact on Corfu derived from two different geo-archives, the Chalikiopoulou Lagoon located to the southwest of Corfu city and the Korission Lagoon lying in the southwest of Corfu Island. This is the first study in search of palaeotsunami traces in the northwesternmost part of Greece. The investigations are part of an interdisciplinary geo-archaeological project dealing with the influence of man–environment interaction on the palaeogeographical evolution of the Kanoni Peninsula, where the ancient city of Corfu is located. The project is led by the 8th Ephorate of Prehistoric and Classical Antiquities in collaboration with the University of Mainz and the Centre Camille Jullian, Aix-Marseille Université.

2. Regional setting

Being the northernmost Ionian Island, Corfu (Greek: Kerkyra) is located close to the transition from the Ionian Sea to the Adriatic Sea (Fig. 1). The island is situated in an exceptional tectonic stress field between the subduction zone of the Hellenic Trench in the south and continent–continent collision of the Apulian and Eurasian plates in the north (Poulos et al., 1999; Sachpazi et al., 2000; van Hinsbergen et al., 2006, Fig. 1). The collision zone is separated from the west Hellenic subduction zone to the south by a large dextral strike-slip fault zone, the Cephalonia Transform Fault (CTF, Fig. 1, cf. Kokkalas et al., 2006). As northern branch of the Hellenic Arc, especially the Kerkyra–Cefalonia-depression and also adjacent NNW–SSE-striking faults have to be considered as potential sources of strong seismic events (Poulos et al., 1999). On Corfu itself, recent seismic activity bound to compressional tectonic processes is demonstrated by a cluster of shallow epicentres and folded marine sediments along the Corfu thrust (Broadley et al., 2006; Kokkalas et al., 2006).

Regarding the overall wind and wave climate, Corfu is located in the transition from the westerlies to the subtropical zone and therefore influenced by westerly winds and storms during the winter months (Soukissian et al., 2007). As a consequence, the wind-exposed western coast of Corfu is commonly affected by strong storms (study site Korission Lagoon, Fig. 1), while the arcuate shape of the island protects the quiescent and almost lake-like (Partsch, 1887) Gulf of Corfu, located in the east of the island (study site Chalikiopoulou Lagoon, Fig. 1).

2.1. *Chalikiopoulou Lagoon*

Chalikiopoulou Lagoon (Fig. 2), located southwest of Corfu City, has a north–south extent of 2.2 km and a west–east extent of 1.4 km. The average water depth is less than 1 m, so that even in the central part of the lagoon, fishermen reach their nets and fish traps by foot. It is assumed that the Hyllaikos harbour of Ancient Corfu was located in the Chalikiopoulou Lagoon (Baika, 2014). The surrounding hills in the west and south as well as the Kanoni Peninsula east of the lagoon consist of Miocene marls while the coastal lowlands, located at sea level or a few meters above, are dominated by Holocene alluvial deposits (IGME, 1970). In the western and southern part of the lagoon, two fluvial systems have formed small alluvial fan deltas. Vibracoring and geophysical studies were realised at the northern fringe of the Chalikiopoulou Lagoon, some 20 m distant from the recent shoreline (Fig. 2).

2.2. *Korission Lagoon*

Located in the southwestern part of Corfu, Korission Lagoon (Figs. 1 and 3) is directly exposed to the open Ionian Sea. The lagoon shows shallow water depths below 1.5 m (Alexopoulos et al., 2007). A beach barrier system, up to 200 m wide, separates the lagoonal system from the Ionian Sea. This sand accretion barrier formed within the course of the Holocene sea level rise and is believed to have been already established at a position several meters below its present sea level (Alexopoulos et al., 2007). According to IGME (1970), thick aeolian sediments in the southeastern part of the lagoon document strong Holocene aeolian activity covering Pleistocene calcareous sandstones of marine origin (Fig. 3, see also Sordinas, 1969; Darlas et al., 2006). This sandstone unit, together with overlying consolidated Pleistocene dune material, forms the bedrock along the eastern and northern shores of the water body. The northern and northwestern near-shore areas are dominated by alluvial deposits. Today, there are no fluvial systems which drain the hinterland into the Ionian Sea or the lagoon.

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