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Integrated methods for understanding and monitoring the loss of coastal archaeological sites: The case of Tochni-*Lakkia*, south-central Cyprus

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ABSTRACT

Previous research on the environment of island and coastal areas has demonstrated that erosion substantially affects coastal archaeological site preservation and can lead to the loss of important information regarding past trade and maritime activities. These same at risk coastal archaeological loci are central to much current archaeological focus on networks and connectivity. In practical and theoretical terms, this places significant stresses on local governments and archaeologists, who are trying to monitor rapidly deteriorating cultural heritage and rescue information vital to future research. Beyond ad hoc observations, rigorous methods to quantify such issues have rarely been developed in the archaeology of the Eastern Mediterranean, including the island of Cyprus. In this paper we demonstrate an integrative method, which employs historic aerial photographs and laser scanning to illustrate, quantify and monitor coastline change and its impact on cultural heritage since the industrialisation of the south-central coast of the island in the mid-20th century CE.

1. Introduction – archaeology and the problem of coastal erosion

The coast, as the natural interface between land and sea, provides unique opportunities to explore past socioeconomic processes and human-environment interactions, as well as significant challenges to archaeologists in terms of preservation and methods of investigation (Ford, 2014; Tartaron, 2013: 188–190 on "coastscape"). Coastal areas are places of high connectivity and intensified interaction, and the character of their archaeology often reflects this centrality. While these coastal zones shed light on a distinct set of activities in the past, our ability to interpret them can be severely hampered by the impact of coastal erosion – a problem that is affecting archaeological and historic contexts in the Mediterranean (e.g. Little and Yorke, 1975; Paskoff et al., 1985; Nieto and Raurich, 1998) and beyond (Black Sea: Stanchev et al., 2013; Red Sea: Bailey et al., 2007; North Sea and Atlantic Europe: Dawson, 2005; Bates et al., 2013; Daire et al., 2012; Caribbean: Fitzpatrick et al., 2006; Fitzpatrick, 2012; Persian Gulf: Khakzad et al., 2015b; Pacific: Carson and Athens, 2007; North America: Rick et al., 2009; Reeder-Myers, 2015).

The loss of coastal land to erosion presents a serious obstacle to our still emerging – let alone efficacious – understanding of the archaeology of these liminal areas, as it engenders the deterioration of coastal archaeological features at an unpredictable rate. This results in the exposure and subsequent disappearance of material culture often without systematic archaeological recording – a phenomenon that Erlandson (2008) summarised as the "erosion of human history". As a result, a wide range of past human activities associated with the coast remain unrecorded, their context poorly understood and our understanding of past human interaction at local, regional and interregional scales impaired. Coastal erosion is, thus, both a predicament of cultural heritage preservation and an epistemological problem.

In this framework, the Mediterranean Sea, a region defined by its coasts (Horden and Purcell, 2000), a protagonist in archaeological and historical scholarship on liminality (Monroe, 2011), networking (Knappett, 2011), and connectivity (Braudel, 1972; Broodbank, 2013), and a place with a long history of maritime archaeology (summary in Marriner and Morhange, 2007: 137–144) is particularly vulnerable and relevant (Fig. 1). Erosion linked to rapid coastal development has greatly affected Mediterranean archaeology over the past century. Yet, while widely recognised as a problem, efforts to systematically quantify coastal erosion at archaeological sites remain limited. In addition, although valuable information has been obtained by integrating

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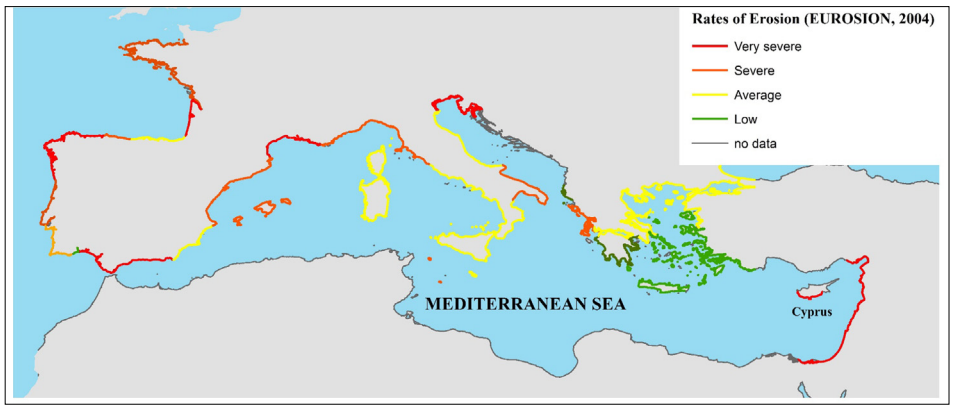

Fig. 1. Coastal erosion in Europe.
(Adopted from EUROSION, 2004, using ESRI base map.)

archaeological, historical, geological, sedimentological and geomorphological studies (papers in Pye and Allen, 2000; Morhange et al., 2000; Marriner et al., 2008a, 2008b; Anthony et al., 2014: 336; Tartaron, 2013: 162–171; Devillers et al., 2015), coastal erosion is a destructive process that does not allow the reconstruction of lost material.

The unpredictable and geodynamic nature of the coastline complicates the identification of material evidence that holds important information regarding past human interactions on the coast (Davis and Barnard, 2000; Erlandson, 2012; Rick and Fitzpatrick, 2012; Mourtzas, 2012; Mourtzas and Kolaiti, 2013: 411). In addition, it tends to defocus quantifying and interpreting the reality of progressively lost archaeological record. In several Mediterranean contexts, researchers linked coastal erosion with changes in the sediment supplies (e.g. Anthony et al., 2014: 340; Anthony, 1994), particularly from rivers that are the most important sources of sediment (Tartaron, 2013: 145). In this context, extensive reservoir construction, dredging and fluvial regulation, resulted in delta and coastal erosion (Anthony et al., 2014: 351, tbl.2), which was in turn "controlled" with coastal defences. These features in association with dredging and the construction of artificial beaches and marinas have impacted sediment movement through longshore drift and altered the coastal topography.

Alterations to the sediment supply of the coast have progressively affected the geomorphological stability of Mediterranean coasts, and geomorphologists have argued that coastal destabilisation over the past two centuries, and especially over the past 50 years, appears more aggressive. Many also argued that accelerated erosion – erosion exceeding 0.5 m/year – is largely a 20th century phenomenon (Anthony, 1994; Hooke, 2006; El Banna and Frihy, 2009; Anfuso et al., 2011; Anthony and Sabatier, 2012, 2013; Anthony et al., 2014: 336; 347–352; El Mrini et al., 2012; Halouani et al., 2013) and linked, amongst other factors, to the modernisation of earlier traditional land-use practices. This does not suggest that pre-modern coastal alteration was less dramatic (e.g. Ford, 2014: 775–776). It suggests, though, that modern alterations appear more consistently aggravated and extensive. As such, they provide an excellent opportunity, and archaeologically critical necessity, to study the relation between erosion and cultural heritage preservation, quantify erosion and enable action to restrain this recent, rapid degradation of vanishing archaeological resources.

Heritage management strategies to date have focused on environmental monitoring, and the implementation of integrated coastal zone management plans (Micaleff, 2003; Khakzad, 2014a, 2014b; Khakzad et al., 2015a, 2015b). To this end, researchers and heritage managers have employed large-scale monitoring of coastal recession and advancement to reconstruct erosion patterns and investigate their relationship with the relative preservation of archaeological materials in situ. Some of these approaches include: (1) production and comparison of coastline maps via in situ recording with total station (digital topographical survey) and interpolation through aerial photography and satellite image analysis (e.g. Vasseur and Hequette, 2000; Vrieling, 2006; Zhang et al., 2007; Ghanavati et al., 2008; Sesli et al., 2008; Kuleli, 2010: 388; Bell, 2012: 470–471; Brunning, 2012: 455; Fitzpatrick, 2012); (2) examination of the extent of material evidence suggestive of ancient shorelines via terrestrial and underwater survey (e.g. Sewell, 2013; Andreou and Sewell, 2015); (3) production of a visual record of newly exposed features with comparative section photography (e.g. Fitzpatrick, 2012; Andreou and Sewell, 2015); (4) statistical analyses with the use of Digital Shoreline Analysis Software (e.g. Kuleli, 2010); (5) production of quantifiable 3D models via aerial laser scanning (e.g. Risbøl et al., 2015; Doneus et al., 2015) and terrestrial laser scanning (TLS) (e.g. Rosser et al., 2005; Infante et al., 2012); (6) production of smaller-scale, less detailed, yet quantifiable 3D models of eroding features with aerial photogrammetry (e.g. Yilmaz et al., 2007; Magnani and Schroder, 2015); and (7) production of vulnerability models of exposed archaeological heritage (e.g. Dawson, 2005; Daire et al., 2012; Reeder-Myers, 2015).

In seeking a high-resolution but rapid and cost-effective approach to the topic, we selected to combine aerial photographs (APs) and terrestrial laser scanning (TLS). We use these as the primary tools to provide standardised observations in order to monitor and study coastal erosion and assess its impact on the cultural heritage along the south-central coast of Cyprus since its industrialisation in the mid-20th century. We use APs as a base map to digitise the diachronic coastline and quantify the amount of land lost since the 1960s. This will provide an indication of the rate in which archaeological features have been deteriorating in the modern era and highlight vulnerable areas that require more diligent recording. We then employ a TLS survey as a time-effective means of detailed recording of the archaeological components of coastal sections on an annual basis. With this integrated approach, we develop a valuable methodology, which can be applied on similar cases in rapidly vanishing archaeological contexts.

Before presenting an analysis of these methodologies and their application, it is necessary to contextualise coastal erosion in the archaeology of Cyprus.

2. The eroding history of the island of Cyprus

Archaeological and textual evidence as early as the Late Bronze Age (LBA; 1680/1650–1100 BCE) suggests that Cyprus was a key participant in the international economic spheres of the Eastern Mediterranean, particularly through export of its copper resources (Knapp, 2013: 416–427). Despite the abundance of material evidence of engagement with the sea, we know surprisingly little regarding the locations of anchorages and harbours on the island (Sauvage, 2012) and less on their role in local and regional-scale dynamics. This is hardly surprising,