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# Sea level changes and past vegetation in the Punic period (5th–4th century BC): Archaeological, geomorphological and palaeobotanical indicators (South Sardinia – West Mediterranean Sea)

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A B S T R A C T

The ancient shorelines and main differences in the vegetational landscape of S Sardinia during the Punic period (5th–4th century BC) have been recognized by an interdisciplinary archaeological, paleobotanical and geomorphological approach. Sixteen trading amphoras and one olla of Punic manufacture brought to light during underwater exploration in Santa Gilla Lagoon (S Sardinia, W Mediterranean) provide data on relative sea level changes. The infilling mud of each retrieved amphora is representative of the ages lasting for about 200–300 years. The macro-archaebotanical contents document the use of seeds and fruits of *Vitis*, *Sorbus*, *Ficus*, *Olea* and *Prunus* during Punic trading and suggest the occurrence of agro-pastoral practices in the surrounding plains or the area behind the lagoon system.

The palynological analysis documents the presence of holm and cork oak forests, a widespread Mediterranean forest with *Juniper* and *Pinus*, and a developed stagnant coastal system, and reveals a climate-induced past vegetation change that is likely to have been emphasized by anthropogenic pressure and agriculture activity during the 4th century BC.

The GPS localization of the amphoras shows a distribution according to curved alignments that probably correspond to the shorelines (5th-4th century BC) at − 1.95 ± 10 m and −1.70 ± 10 m. Geomorphological data reveal a sea level rise of about 25 cm during a century, corresponding to 300 m of shoreline regression towards the alluvial plain. With these rapid processes of drowning of the coastal plain, the presence of Punic settlements along the lagoon borders documents the reorganization of commercial and economic activities. This shows the great adaptability of the ancient population to the sea level rise (SLR) and fast-flooding processes of the coastline in a lagoonal area vulnerable to subsidence phenomena.



## 1. Introduction

The Mediterranean has long been an important route for merchants and travellers, including in ancient times, allowing trade and cultural exchanges. Sardinia, due to its geographical position in the centre of the Mediterranean Sea, has always been an ideal base for sea trade. Conformation of trade with other civilizations in the past is evidenced from the Bronze Age by several artefacts that have been found in Nuragic sites, testifying to the scope of commercial relations between the Nuragic people and others in Europe and beyond (Bernardini, 2010; Porcu, 2013). Some highly distinctive physical media for maritime shipping have been associated with these exchanges from the outset. Among these, amphoras are known to have been used to carry wine, olive oil, spices and fish products, as well as several other liquid or semi-liquid goods (Laubenheimer, 2013; Bevan, 2014). Finding original content in the amphoras discovered in archaeological sites is extremely rare, but any that is found is very precious for deducing agricultural and food-related practices, which is achieved on the basis of the direct archaeological evidence of residues (usually olive stones or resin linings) found inside them (Arobba et al., 2014).

The recovery of several Punic artefacts that have been brought to light during underwater explorations in Santa Gilla Lagoon (Fig. 1; Cagliari, S Sardinia; W Mediterranean) allows us to provide

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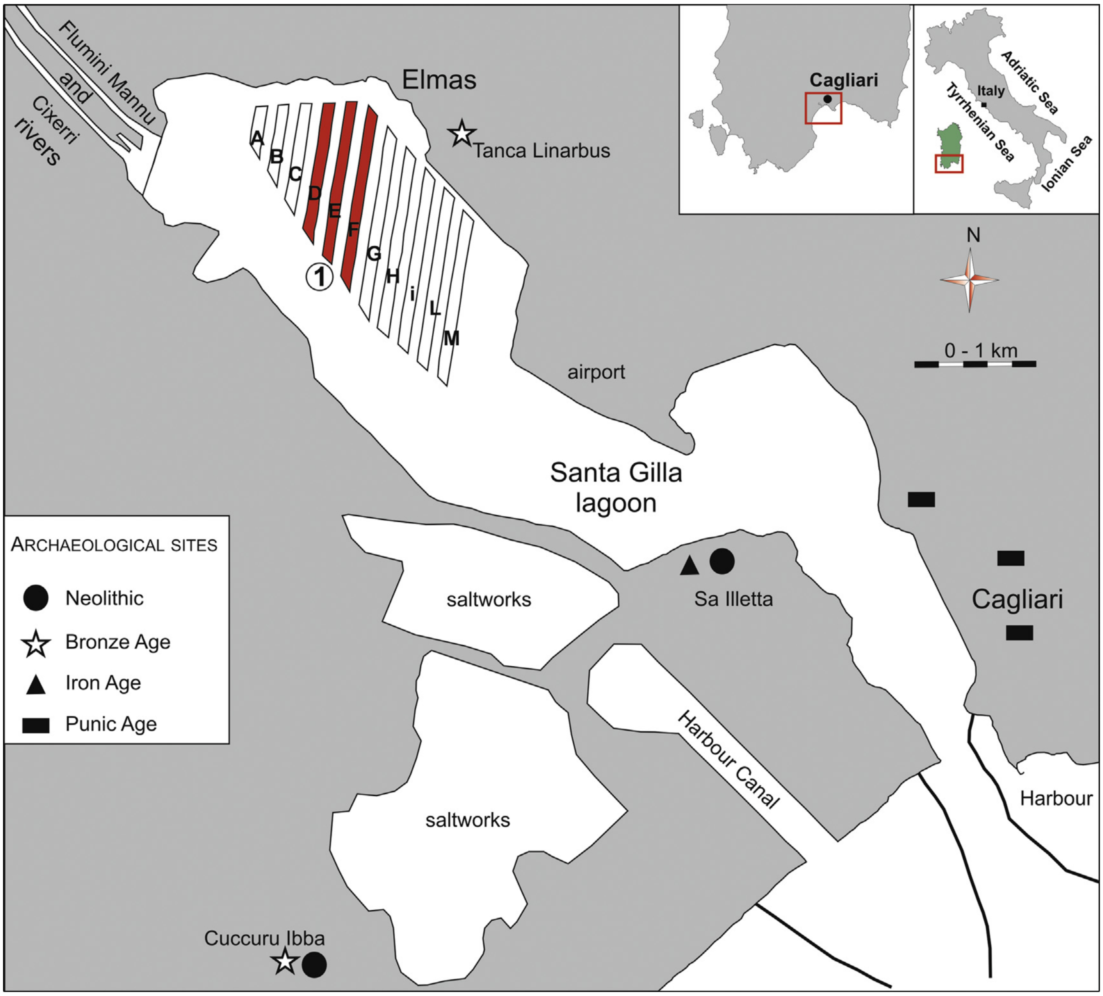


**Fig. 1.** Location map of the study area and the surrounding area of archaeological interest. (1) Underwater archaeological excavation sites. The dredging canals D,E and F are in red. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

archaeological and geomorphological data and to investigate the infilling sediment in order to study pollen, spores and archaeobotanical content such as seeds and fruits.

The amphoras identified are comparable to “sacco” (bag-shaped) and “siluro” (torpedo-shaped) types, which can be dated to between the 5th and 4th centuries BC (2450 ± 40 age cal. BP 1σ; Antonioli et al., 2007, 2009). The amphoras were found in the NE field of Santa Gilla Lagoon, about 1.60 m below the mean sea level, resting on a layer of shells under 1 m of mud that preserved the hard parts of their original content (Bernardini et al., 1993; Solinas, 1997; Solinas and Orrù, 2006). One amphora (E10) was clearly used to transport liquid, because only a cork was found inside it. This was the same size as the amphora's hole and the internal walls were covered by a thick layer of resin. A few amphoras contained food products like meat, while several others were found broken and their contents were lost.

Close to the archaeological site and at the mouth of the lagoon, we studied the filling sediment of the paleo river-valley attributed to the low stand (MIS2) during the Holocene sea level rise. The comparison between these chrono-stratigraphic data and the sea level curve of the glacial-hydro-isostatic model (Lambeck et al., 2011) made it possible to establish the paleo-shorelines of Santa Gilla Lagoon during the Punic period (Orrù et al., 2004; Antonioli et al., 2007).

The main aim of this paper is to use a multidisciplinary and integrated (archaeological, paleobotanical and geomorphological) approach to obtain information concerning: the traditional use of seeds and fruits during Punic times; the impulse behind the agricultural activity of the period; the ancient coastlines of Santa Gilla Lagoon and the sea level rise; the vegetation of S Sardinia; and the climatic trend over the 200–300 years of Punic colonization (509–238 BC).

## 2. Environmental setting and geomorphology

Santa Gilla Lagoon is located on the W side of Cagliari (Sardinia, Italy; Fig. 1; 39°12′59″ N – 09°02′39″ E). It is a NW–SE orientated depression, and roughly deltoid in shape. It connects in the S to the Mediterranean Sea through a narrow channel. On the N shore, the lagoon has two major freshwater inflows from the Flumini Mannu and Cixerri rivers (Fig. 1). The average water depth is 1 m, with a maximum of 2 m in the artificial channel connecting the lagoon with the sea.

The lagoon is set on the S end of the Campidano valley. It was formed by the fluvial erosion of Quaternary sediment and was successively filled by the sea during the Holocene as a consequence of combined climate fluctuations and subsidence actions (Pecorini, 1986). After the sea's Würm regression (stage 2, 15/18 ka), which produced strong erosion of the Tyrrhenian marine sediment (“Panchina Tirreniana” Auct.), the erosional valley was separated from the seawater by a coastal sandy bar that already existed in the

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