The submerged cultural landscape: examples from the Bay of Naples

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Abstract. A substantial amount of prehistoric and historic cultural landscapes is now submerged. Sea levels have fluctuated throughout geological time, periodically encroaching or retreating across coastal plains. These now-submerged zones were important for prehistoric and historic humans, allowing access to marine and terrestrial resources and to transportation and migration routes.The principal process contributing to sea-level changes is the exchange of water between the continental ice sheets and the oceans (glacio-eustatic sea-level changes). Eustatic sea-level changes occur on an oceanic to worldwide scale. They also result from a change in the size of the ocean basin following tectonic seafloor spreading (tectono-eustasy) or sedimentation (sedimento-eustasy). In addition, sea level changes can be driven by local changes of the land with respect to the sea surface due to tectonic deformations, sediment compaction, and human activity. Inundated terrestrial archaeological sites, however, can result from a number of other natural processes, as well as sea-level changes, including earthquakes (such as Port Royal in Jamaica), volcanic processes (such as the ports of Misenum and Baiae, and Portus Julius and Nisida in the Bay of Naples) and flooding event (such as Herakleion and Eastern Canopus in Egypt).

Keywords. Submerged cultural landscape, Bay of Naples, marine geophysics, sea level change, Baiae, Puteoli, Portus Julyus.

1. Introduction

Since the Last Ice Age (18.000-19.000 years BP) extensive regions of the present seafloor were sub-aerially exposed. As the climate has warmed following the end of this last cold period, sea level has been rising about 120 m. In particular, starting from 18.000 years BP, most of the European territory was drowned by sea transforming the geographical and environmental context of human development. Sea level rise rapidly displaced coastal populations landwards until ca. 6.000 years BP, when a broad sea level stability (Holocene climatic optimum) meant that human societies started to settle around present coastlines. Since this time, submersion of major coastal sites is mainly linked to local processes and relative sea-level changes.

The Mediterranean basin has experienced major sea level changes during glacial cycles, evidence for which occurs in both the geological and archaeological records [1].

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Prehistoric artefacts and human remains are documented in the great sea caves at Palinuro [2], with a bone breccia cemented on the walls, and near Marseille where the submerged palaeolithic cave of Cosquer (27.000–18.500 years BP) with rock art paintings has its mouth at a depth of - 37 m [3]. Similar findings are located at a depth of - 21 m off the southwest tip of Gibraltar [4]. However, the most complete prehistoric site with artefacts undisturbed in stratigraphic context is at Atlit in the eastern Mediterranean on the coast of Israel [5]. This is a Neolithic village submerged at - 10 m and dated at about 9.000 to 8.500 years BP with many preserved organic materials, including woven basket-work, charcoal, burials, and a fresh-water well, and evidence demonstrating fishing crop cultivation and animal husbandry.

Most of the underwater archaeological sites now submerged in the Mediterranean area date back to Greek and Roman times. Archaeological remains such as harbour infrastructures, fishponds, villae maritimae, nymphaei, private or public buildings or town quarters, are currently underwater because of relative sea level variations or other natural processes. Many of them are located along the coasts of Italy, Greece and Egypt. Statuary and megalithic blocks attributed to Pharos' celebrated lighthouse at Alexandria in Egypt lay at 5 m below present sea level following coastal instability phenomena [6]. The Greek city of Helike and its harbour, built on a fluvial delta, were destroyed by an earthquake and submerged in 373 B.C [7]. The ancient city and harbour remains of Megisti on Castellorizo island, Greece, have been drowned −2.5 to −3 m below present sea level due to a gradual 1.5 to 2.0 mm/yr subsidence of the Lycian coast since antiquity [8].

In this paper, examples that illustrate the sea floor physiographic and cultural characteristics in the Bay of Naples are discussed. It is emphasized that cultural and natural resources are not mutually exclusive categories and that a correct approach to the submerged cultural landscapes has to account for the relationships among living and non-living resources, and their environment.

2. Materials and methods

Among new technologies that enable representation of the submarine landscapes, marine geophysical surveys provide fast and cost-effective tools now widely applied to the reconnaissance and management of underwater cultural and natural resources. Geophysical surveys are non-destructive methods of investigation that allow preserving the artefacts and landscape sites as well as the context in which they are found. This is of special relevance since maritime archaeological heritage is a non-renewable resource which is lost forever if destroyed. They can therefore be used for the non-destructive detection, imaging, research, inspection and monitoring of submerged sites [9].

Marine geophysical techniques are based on acoustic methods [10, 11]. Usually, a full-scale geophysical survey applied to submerged landscapes should be conducted using a combination of four techniques [7, 12]: side scan sonar and swath bathymetry or multibeam echo sounder to map the bottom surface, magnetometer to detect iron targets, and diving (in shallow water) or video/ROV inspections (in deep water) for ground-truthing. Side scan sonar and multibeam use narrow beams of acoustic energy to locate, map and investigate archaeologically sensitive site and submerged landscapes as well as to detect and study wrecks and associate materials. Multibeam systems are used to simultaneously collect several depth measurements and are usually composed of a computer unit, transmit and receive transducer for sending and receiving sound in the water, a positioning system, a gyro-compass and a motion sensor. The collected data consist in a scattered “numb” of depth measurements that need to be spatially re-organized in a regular matrix called DEM (Digital Elevation Model). Such data can be used to create precise bathymetric maps (digital relief of the bottom). A side scan sonar system is an acoustic device which aims to produce a two-dimensional image of the seabed with near photographic quality. The system consists of a tow fish, which is towed behind a research vessel, a deck unit and a workstation. Its main use is for the detection of shipwrecks, but it can equally be deployed for the characterization of submerged landscapes where a relic land surface is believed to exist.

Such devices facilitates collecting a large amount of spatial information in a limited period of time and allow to accurately determine the positions of maritime heritage sites providing useful tools for underwater cultural landscapes characterization and management. The integration of data generated by these techniques, with accurate positioning data generated by global or local positioning systems (such as GPS), allow the application of these tools to map large or smaller areas at great resolution and facilitates the use of the results to monitor gradual changes of underwater cultural sites through repeated surveys of the same area. Results are stored in digital format and can be easily integrated with other data through the use of geographic information systems (GIS). In this way, multibeam and side scan sonar data combined with visual inspections and sampling may provide a continuous overview of the seabed morphology and composition and of associated cultural features.

3. The Campi Flegrei coastal area

At the Campi Flegrei volcanic complex in the Bay of Napoli, southern Italy, the ancient ports of Misenum and Baiae, and Portus Julius and Nisida (the ancient Pozzuoli, Baia, Bacoli, Miseno and Nisida) are presently drowned up to 15 m below mean sea level. This is one of the most extensive submerged archaeological area in Italy. Besides harbour infrastructures, it includes urban sites, residential buildings, thermal baths, and fisheries. Because of vertical ground deformations most of these sites are currently submerged and still in part undiscovered.

The entire area is part of a large caldera [13], an active volcanic area characterized by frequent earthquakes, hydrothermal manifestations and phenomena of slow uplift and subsidence known as bradyseism. Volcanic activity is documented back to ca. 60.000 yeas BP, with the last eruptive event occurred in 1538, when a new volcanic structure (the Mont Nuovo) was formed. A 200 m seaward shift of the coastline was recorded at that time.

The ground movements of this area since Roman times are well known thanks to the borings produced by marine molluscs on the columns of Serapeo, the ruins of a roman market in the city of Pozzuoli [14,15] (Fig. 1). In the third century a.C., Serapeo and its neighbours started to be submerged by the sea. The subsidence continued until the tenth century, reaching about 7 m below sea level. Then the pattern changed and an uplift started, culminating in 1538 with the Mount Nuovo eruption. At that time, two days before the eruption, uplift had culminated in a + 7 m ground movement (relative to present sea level), as documented by Delli Falconi’s A.D. 1539 gravure [16]. After 1538 the site subsided again until 1968, since than the Campi Flegrei have been characterized by rapid and significant uplifts and subsequent slow and slight subsidence. The two major events of 1969–1972 and 1982–1984 resulted in a total uplift of ca. 3.5 m. After that, only minor (a few centimeters) and short-lasting uplift episodes have been recorded in 1989, 1994, and 2000.

3.1. The submerged cultural landscape

The Campi Flegrei submerged sites from the ancient Puteoli harbour to Baiae have been mapped thanks to several years of underwater archaeological surveys [17, 18]. Baiae was a natural embayment probably used as a harbour by the 'Cumani' settlement. In Roman age, it was mainly a residential centre, consisting of villas, thermal baths and inns. The inner part of the bay of Baia was occupied by a lake (Baianus Lacus), which was connected to the sea by an artificial channel. Several structures surrounded the Baianus Lacus, whose remains are now submerged at depths ranging from 4 to 10 m. They are the Claudius' Nympheo (1st Century BC), a thermal complex of two buildings near the Nympheo and a great villa attributed to the Pisoni family (Pisoni's Villa). This latter consisted of several rooms with a global rectangular plan structure with most of the internal sector occupied by gardens and surrounded from apses and columns. Sedimentary evidence shows that the town of Baiae was active until at least the end of the fourth century after Christ, when a decline started following the insurgence of the bradyseism and the resultant inundation of entire areas of the town [19].

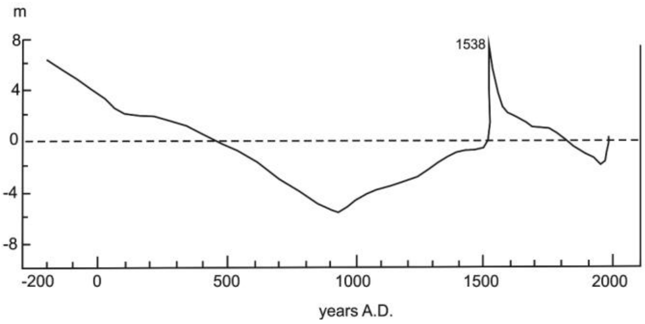

Figure 1. Ground vertical deformation trends of Serapeo proposed by Parascandola [10].

In September 2013 the submerged cultural landscape off Campi Flegrei was investigated using a Reson Seabat 8101 multibeam [20, 21]. This echosounder is characterized by a 240 kHz acoustic source frequency, 101 beams and 1508 of pulse width, and is particularly suitable for high-resolution mapping in shallow water (up to 100 m depth). Field procedures included the definition of sound velocity profiles in the water column (SVP) collected on a daily basis, and the compensation of vessel attitude and orientation by motion sensor. Processing of data was performed through a dedicated software and procedures that included a despiking of the soundings surface through logical and statistical filters for noise removal, and manual removal of spikes due to fake soundings. Processed data were then interpolated with weighted average and merged to produce a very high resolution digital terrain model (DTM) with a bin size of 1 m.

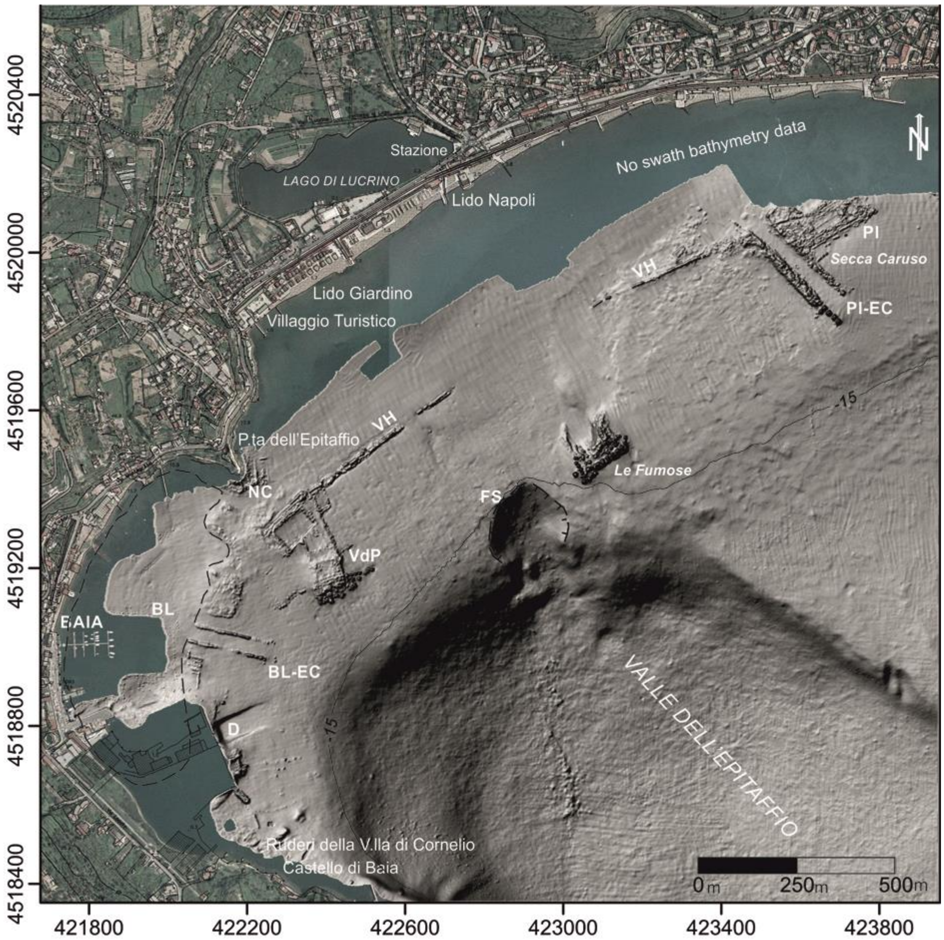

Figure 2. Shaded relief map of the Pozzuoli bay submerged cultural landscape merged with aerial photograph and topography of the on-land areas. PI: Portus Iulius, PI-EC: Portus Iulius entry channel, VH: Via Herculanea, FS: failure scar, VdP: Villa dei Pisoni, NC: Claudius' Nymphaeum, BL: Baianus Lacus, BL-EC: Baianus Lacus channel entry, D: dredging. The contour level of -15 m is also shown. Modified from Violante, 2017 [21].

The resulting multibeam bathymetric map (Fig. 2) provides a detailed image of the seafloor morphology off Pozzuoli Bay and of related cultural landscape. This kind of representation helps to foster a collective perception of the cultural landscape with regards to morphology and topography of the seabed. It shows how the submerged artefacts and harbour infrastructures shape the modern underwater landscape of today as a consequence of volcanic and sedimentary processes that occurred in the last 2000 years. During this time, the Pozzuoli Bay underwent rapid and dramatic change that completely reshaped the coastal area, after significant sea level changes and a volcanic eruption in the 1538 (Mount Nuovo eruption).

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