Invisible landscapes: a journey beneath the sea in the Bay of Naples, Italy

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ABSTRACT
This paper is complementary to the video presented by the author at Blue Planet Economy (BPE) European Maritime Forum 2021. The video deals with three-dimensional reconstruction of the submarine landscapes in the Bay of Naples based on high-resolution multibeam bathymetry. This technology is indeed very effective for the identification and study of submerged features and allows for a comprehensive access to the underwater environment to diving and non-diving public. The presented bathymetric data were acquired during various oceanographic cruises aboard CNR Research Vessels, in the frame of several research projects, and mainly as part of the CARG project - Geological cartography of marine areas. Creating such accurate seabed reconstructions provide a primary record of the current state of the submerged landscapes and allows for the establishment of various measures for their future preservation and monitoring.

KEYWORDS: submerged landscapes, submerged cultural heritage, multibeam bathymetry.

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1 INTRODUCTION

Underwater landscapes are not human living environments and we do not see them directly and continuously. The notions of panorama, or even quite simply perspective, viewpoint, belvedere and background are not applicable in the undersea environment. In addition, underwater landscapes resting at depths greater than 100m are largely invisible to the majority of the public. Nevertheless, underwater landscapes do exist and, to a large extent, we know how to represent them.

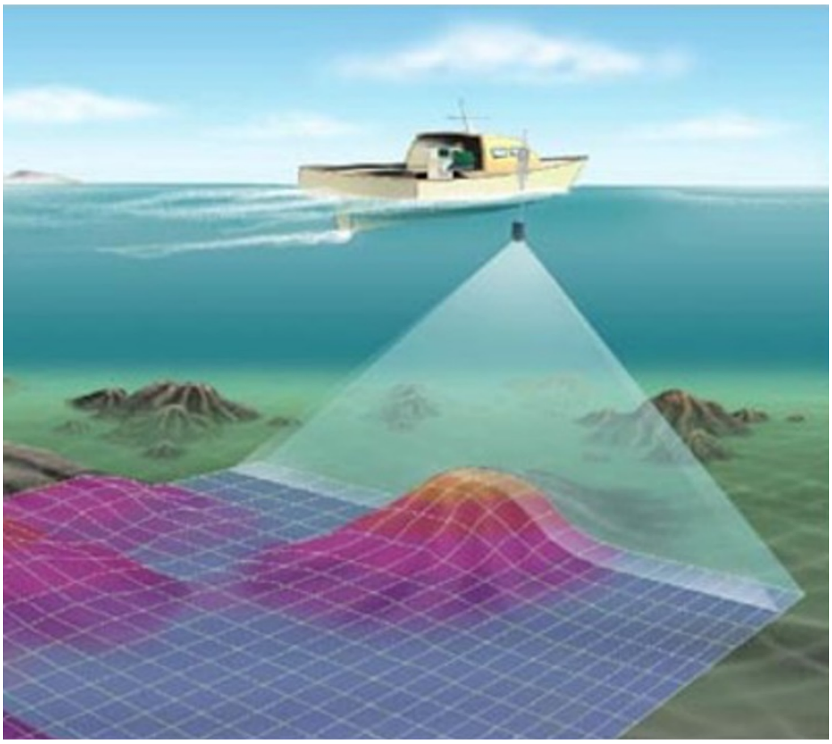

Figure 1. Multibeam bathymetric sonar.

Representation is a core aspect that allows for a comprehensive access to the underwater world (e.g. Wille, 2005). Inventory, mapping, classification and monitoring procedures have been developed in the last decades by the scientific community to build representations of underwater seascapes. These maps and classifications are crucial to develop strategies for the conservation of marine ecosystems and landscapes, and for a number of policy and management issues (Brown et al., 2012; Violante et al., 2012; Violante, 2015; Harris and Baker, 2020).

Among new technologies that enable the representation of submarine seascapes, marine geophysical surveys provide fast and cost-effective tools now widely applied to the reconnaissance and management of underwater resources. Geophysical surveys are non-destructive methods of investigation that allow to preserve the artefacts and landscapes as well as the context in which they are found. This is of special relevance for maritime archaeological heritage, which is lost forever if destroyed (Violante, 2018; Violante et al. 2019; Violante, 2020). This paper summarizes the geophysical technology used to obtain the 3D seabed reconstructions shown in the video titled “Invisible landscapes: a journey beneath the sea in the Bay of Naples, Italy”[1], produced for the Blue Planet Economy (BPE) European Maritime Forum 2021. It also

[1] https://youtu.be/5Uy4bxW9GLM

describes the main features of the submarine landscapes of the Bay of Naples that are presented therein. The Acoustic Remote Sensing research unit of the ISPC-CNR accomplished bathymetric data analysis and interpretation that were used to produce seabed digital elevation model (DEM) and 3D video animations. This unit is part of the Remote Sensing, Spatial Data Science Lab (RES-Data LAB)[2], which integrates Remote Sensing methods and Spatial Data Science for the study and dissemination of the natural and cultural heritage.

2 MULTIBEAM BATHYMETRY

Bathymetry deals with the topography of the seafloor. It describes the measurement of water depth in oceans, seas, lakes, rivers, estuaries, and canals. In its most basic form, bathymetric information usually consists of data points that have XYZ coordinates. X and Y are the position (e.g. latitude and longitude) and Z is the depth measurement. Knowledge of bathymetry is important for a wide variety of uses starting with the fundamental understanding of environmental dynamics such as ocean circulation, tides, sediment transport, environmental change, and underwater geo-hazards, along with ensuring navigational security by providing surface and sub-surface information (IHO, 2014). Bathymetric data can be visualized as 3D computer models and they are commonly represented on charts and maps using contours and depth values, in the same way that land maps use contours and heights. For the aim of this paper, bathymetric data are important as they provide high-resolution depth measurements which are used for the production of high-quality bathymetric maps and for detailed reconstruction of submerged landscapes.

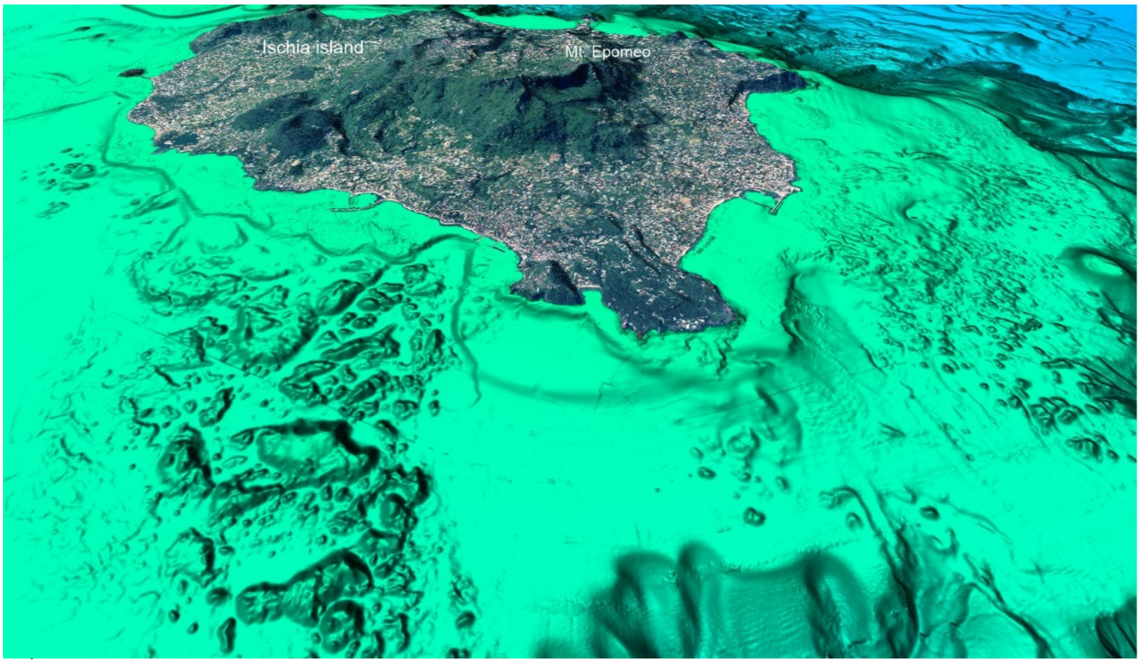

Figure 2. Hummoky landscape off Ischia Island.

Depth measurements (bathymetry) can be gathered from any vessel with sonar equipment as part of a hydrographic survey. These systems were introduced during World War II to detect enemy submarines and underwater obstacles. The basic concept of a bathymetric sonar is the ability to "see" underwater with sound. When a sound is emitted in the water it creates a pressure wave that moves away from the source. If a pressure wave encounters a sudden change in the

[2] https://www.ispc.cnr.it/en/2021/11/02/res-data-lab/

properties of the material in which it propagates (i.e. the seafloor), a part of the acoustic wave will change its direction of propagation. The portion of the acoustic wave that reverses its propagation direction is the echo, which echo sounders (sonars) are designed to exploit for depth measurements.

Nowadays, acoustic seafloor mapping is dominated by the multibeam sonar (figure 1) (e.g. Hughes, 2017), which can perform a large number of depth measurements along a wide strip of seafloor terrain perpendicular to the ship's track, after the transmission of a single acoustic signal. This system is primarily designed to produce quantitative bathymetric data by measuring the acoustic time of flight to the seabed as a function of angle from nadir. Using trigonometric functions, the travel times are converted into a set of points, each with a vertical and horizontal coordinate, relative to the multibeam sonar (depth and position). Water depths are finally obtained by applying the speed of sound in the water column (the sound/velocity profile). Because of the non-vertical measurement geometry, it is absolutely essential that full X-Y-Z inertial motion sensors should be installed and operated on the survey platform along with the multibeam sonar.

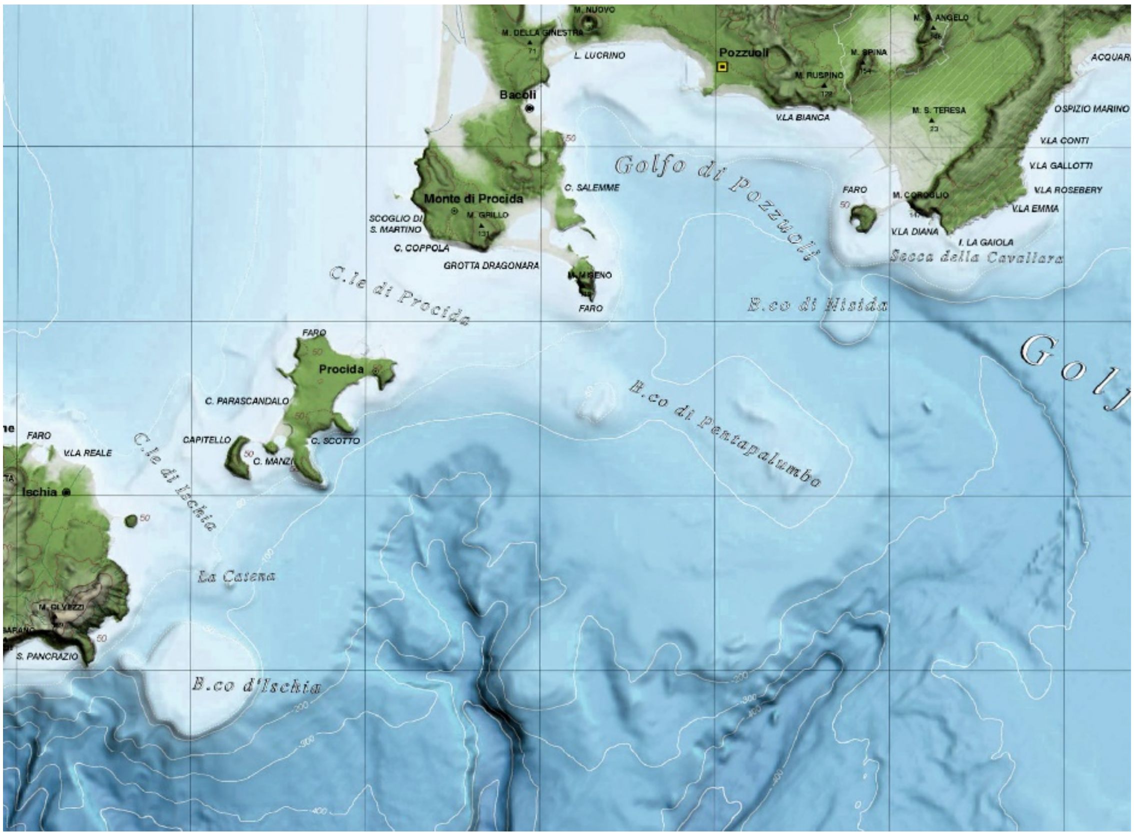

Figure 3. Volcanic bank in the northern sector of the Bay of Naples.

Multibeam sonars appeared in the late 1970s and underwent significant development in terms of technology and performance from then on. Improvements are still implemented today. Modern multibeam sonar systems (MBES) cover a relatively large area from a safe distance above the target, while resolving the 3D shape of the object with centimeter-level resolution. These techniques generate results with high spatial resolution, repeatable and quantifiable, which can be easily integrated with other scientific and terrestrial data.

3 SEABED LANDSCAPES OF THE BAY OF NAPLES

The Bay of Naples includes among the most active volcanoes, namely Somma-Vesuvius, Campi Flegrei, and Ischia Island. These volcanoes delivered a huge amount of volcaniclastic deposits to the marine areas, which significantly contributed to shape the submarine landscapes (Violante, 2009; Violante et al., 2017). At Ischia Island, volcanic activity triggered a number of catastrophic landslides, most of which entering into the sea with high tsunamigenic potential. Coastal and submarine volcanic activity is testified off Campi Flegrei and in the Pozzuoli Bay, where several underwater eruptive vents occur as submerged volcanic banks at depth ranging from -30 to -150m (D’Argenio et al., 2004).

3.1 Ischia Island submarine landslides

Large aprons of avalanche deposits spread out off Ischia Island, extending over a total seabed area of ca. 200km^2 (figure 2). They formed as a consequence of large-scale sector collapses of the Mt. Epomeo, which is the main volcanic structure of the island (de Alteriis and Violante, 2009). Such deposits are characterized by megablock structure – deformed and fractured large blocks up to some hundred meters in diameter. The surface topography of the deposit is characterized by irregular hills and depressions typically known as “hummocky topography”. Hummocky topographies shape the seabed landscape in the Southern, Western and Northern marine sectors of the Ischia Island with hill structures up to 900m in diameter. The estimated total volume of these submarine landslide deposits ranges from 1.5 to 3km^3.

4 CAMPI FLEGREI VOLCANIC BANKS

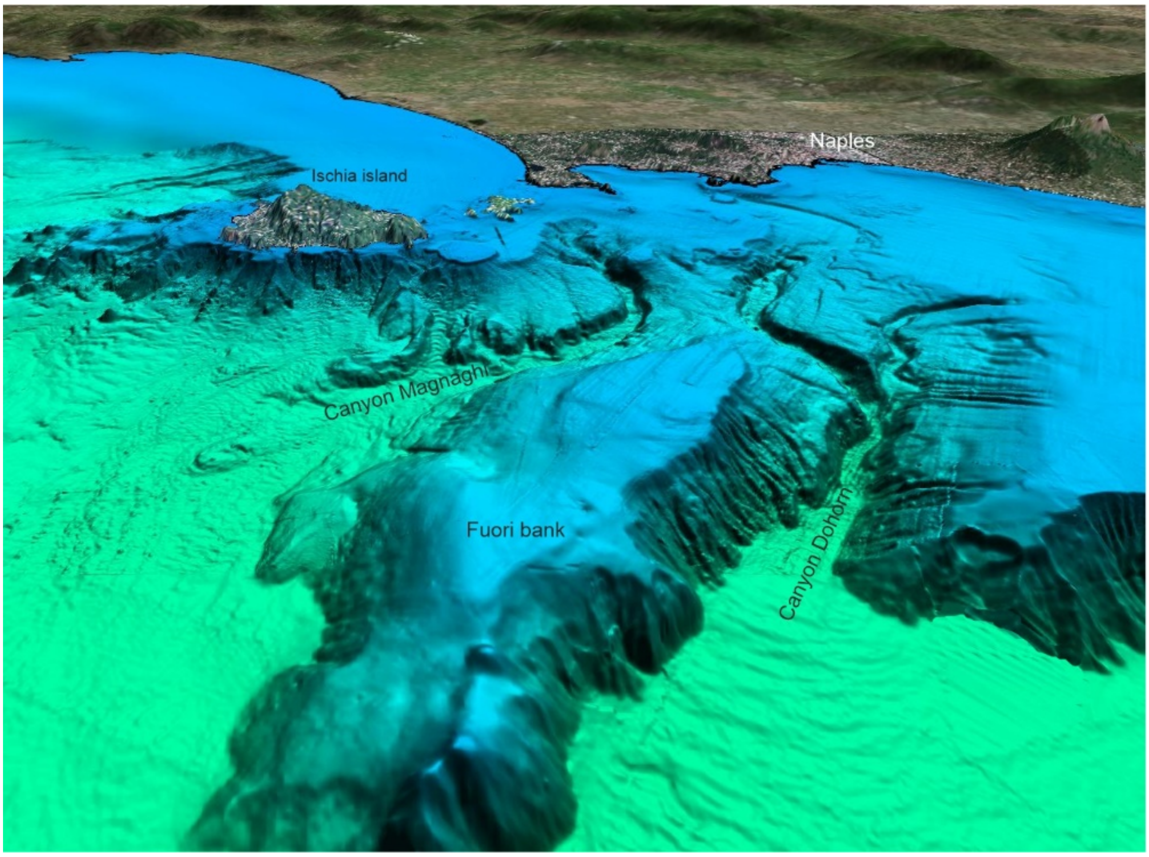

Figure 3. The Dohorn and Magnaghi canyons.

A number of submerged banks characterize the seabed landscape in the Northern sector of the Bay of Naples (figure 3) (Sacchi et al., 2009; Milia, 2010). These banks are remnants of ancient volcanoes eroded by the sea. In particular, four main volcanic banks occur off Ischia and Procida Islands and in the proximity of the Pozzuoli Bay: the Nisida and Ischia Banks with circular shape in plan view and flat surface at their tops, and the Penta Palummo and Miseno Banks with a more articulated morphology. The Ischia and Nisida Banks are respectively at an average depth of 35 and 75m with the Ischia Bank, attaining more than 2.5km in diameter. The Penta Palummo is at an average depth of 135m, while the top of Miseno Bank occurs at a depth of ca. 70 m. The Penta Palummo and Miseno Banks are respectively 1.5km and 3km across.

4.1 Naples submarine plain

A wide coastal submarine plain (the continental shelf) develops off the Neapolitan coast up to a distance of more than 20km and maximum depths of ca. -200m (Violante, 2002). It has an average slope of less than 1° and is mostly composed of soft bottom consisting of sand and mud transported by rivers and/or originated from volcanic eruptions. This marine area marks the interface zone between open water and terrestrial realm where humans interact most directly with the sea. Most of sea economy activities, firstly fisheries, are found within this environment. Due to increasing human pressures, submarine plains are particularly sensitive to transformation, exposing urban populations to marine-related hazards.

4.2 Dohrn and Magnaghi Canyons

The seabed landscape of the Bay of Naples is dominated by two deep incisions, the Dohrn and Magnaghi Canyons, which develop from the seaward edge of the Naples submarine plain down to a depth of ca. -2000m (figure 4). These canyons are characterized by steep sides hundreds of meters high that are engraved by a dense network of gullies (Violante, 2014). They represent a critical link between coastal waters and abyssal depths, by transferring sediments, nutrients and even litter and pollutants to the deep seafloor.

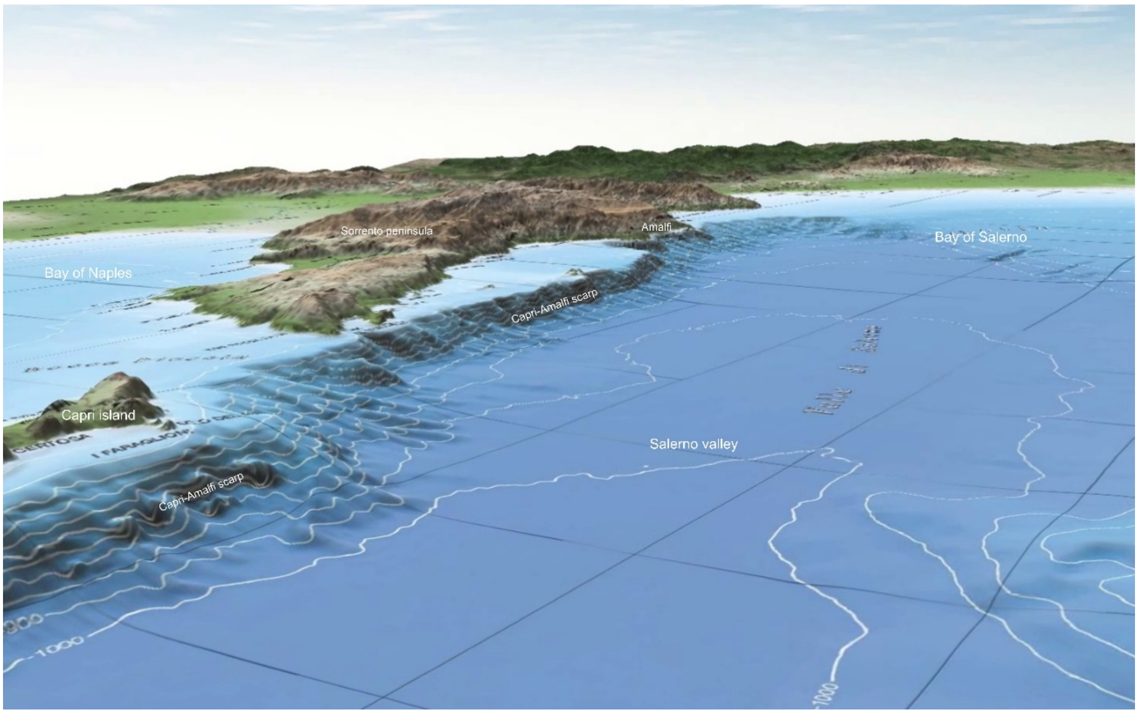

Figure 4. The Capri-Amalfi Scarp and the Salerno Valley.

The upper section of the Dohrn Canyon consists of two major curved branches that converge into a main valley. The branches of the Canyon are ca. 15km in length while the main valley is about 10km long. The Magnaghi Canyon is characterized by a triple incised head and has a total length of 25km. It runs at the base of the submerged Southern flanks of Ischia Island with an overall semicircular shape. The Dohrn and Magnaghi Canyons are separated from each other by the Fuori Bank, a NE-SW elongated seamount (25 x 10km), which rises up to 1700m from the surrounding seafloor.

4.3 Capri-Amalfi Scarp

A large submarine slope, the Capri-Amalfi Scarp, separates the Bay of Naples from the Bay of Salerno (figure 5). It develops off Amalfi and Capri seamless with a difference in height of more than 800m. This submarine slope bounds to the North a large, submerged valley up to 50km long and 15 km wide, namely the Salerno Valley. A dense network of gullies characterizes the surface morphology of this submerged landscape, partly reflecting the hydrographic pattern of the corresponding emerged sector (Violante, 2015).

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