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Reconstruction of a Mediterranean coast archaeological site by integration of geophysical and archaeological data: The eastern district of the ancient city of Nora (Sardinia, Italy)

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ABSTRACT

The archaeological site of Nora is built on a large peninsula that marks the Gulf of Cagliari (Sardinia island, Italy) at its southernmost part. As for most of the ancient coastal cities, the study of Nora is rather complex because of the partial (or complete) burial or submergence of the archaeological remains and their degradation induced by the progressive seawater entry. In recent years, an extensive multi-disciplinary research project, which involves disciplines varying from archeology to earth sciences, has started. In particular, in this paper the results of a high-resolution multi-methodological geophysical prospecting focused on the coastal area between land and sea, not considered in previous urban and marine archaeological researches, are reported and integrated with new archaeological data. The interpretation of the geophysical anomalies is well supported by the results of an archaeological excavation in the north-western sector of the survey area and suggests, in the eastern (not excavated) sector, the presence of buried structures that could lead to redraw the urban settlement of the area, with housing blocks connected by paved open spaces. Furthermore, the geophysical survey clearly identifies the sharp lowering of the andesitic bedrock from the foot of the Coltellazzo hill to the west, offering fundamental data to reconstruct the paleo-environmental landscape of the ancient settlement.

1. Introduction

The archaeological site of Nora is located on the southern coast of the Sardinia island (Italy) and is founded on a large peninsula that marks the Gulf of Cagliari at its southernmost part (Fig. 1a). The early Phoenician phases of this western Mediterranean ancient city date back to the mid-8th c. BC (Bonetto, 2013), but the development as an urban center took place throughout the Punic and Roman Republic periods (late 6th-2nd c. BC) (Bonetto, 2018). Nora acquired the *ius romanum* as *municipium* in Augustan age (1st c. BC - 1st c. AD) (Bonetto, 2002), but the climax of its monumental development is clearly attributed to the Severian age (195–235 CE) (Bejor, 1994; Ghiotto, 2004; Fabiani, 2013).

As for the most ancient cities built on coastal shorelines, the archaeological study of Nora is rather complex due to the archaeological remains partially (or completely) buried or submerged and their degradation or destruction caused by the seawater ingress. The first studies at Nora, which have supported the well established stratigraphic excavations carried out since the rediscovery of the ancient city in the fifties of the last century, consisted of bathymetric surveys and topographic and geomorphological analyses mainly focused in the peri-urban marine areas (Schmiedt, 1965; Macnamara and Wilkes, 1967; Winterstein, 2001; Bonetto et al., 2012b; Bonetto, 2014). The underwater archaeological research in Nora is then continued until the most recent interventions by the Archaeological Superintendence of Cagliari (Sardinia, Italy) (Solinas and Sanna, 2006; Bonetto et al., 2017), with the main aim to study the underwater archaeological remains at medium-high depth with reference to their distance from the coast. Parallel to the aforementioned activities, in the last decade Bonetto et al. (2016) started on an extensive research project focused on the study of the relationships between the ancient city of Nora and the surrounding marine space. Unlike the past studies, this project pays attention on the welding area between land and sea that has not been considered in the previous urban and marine archaeological researches. Such a physical space, between the shoreline and the depth of about three meters from the ground level, is crucial for understanding the city and its relationship with the sea as well the degradation level of the hidden archaeological heritage due to the progressive entry of seawater. The project is based on a highly multidisciplinary approach that involves disciplines related to earth sciences and archaeology in order to address the following main themes: i) sea level and shoreline

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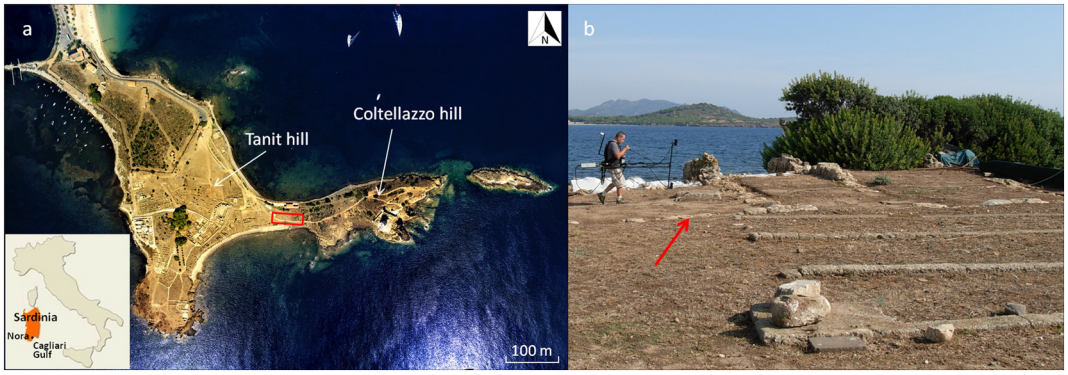

Fig. 1. a: Aerial image of Nora Peninsula (Sardinia, Italy). The red rectangle indicates the geophysical survey area. b: Masonry elements (indicated by a red arrow) visible on the ground surface within the geophysical survey area. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

variations; ii) extension of the buried/submerged parts of the ancient city; iii) nature and role of the submerged buildings; iv) relationship between man and sea; v) role of the marine spaces in front of the coast. In particular, in this paper the integration of information coming from geophysical and archaeological research are presented and discussed, whilst for the preliminary results provided by the combined use of geological, geomorphological and topographical studies with underwater and terrestrial archaeological researches the reader is referred to Bonetto (2016).

The geophysical and archaeological prospecting was aimed at providing a contribution to the second issue of the project in an area considered critical for the geological assessment of the small peninsula that hosts the ancient city and the settlement dynamics developed over time. Specifically, the survey has involved the morphologically depressed area that links the Coltellazzo volcanic relief and the Tanit hill (see Fig. 1), where the most remote and intense attendance likely took place, which lasted from the Phoenician age (7th c. BC) to the late Antiquity (6th c. AD). The goal was to investigate the medium to shallow depth geological assessment of the selected area with the dual purpose of reconstructing the buried wall structure, whose crests were partly visible on the surface (see Fig. 1b), and to identify further possible buried anthropic remains, whose knowledge could provide useful hints for delineating the true buildings extension and the ground plan of the eastern sector of the city in the ancient age. The subsequent archaeological excavation, carried out in the area where anthropic remains were clearly observable, has allowed not only to validate the interpretative hypothesis provided by the geophysical data, but also to strengthen the archaeological interpretation of geophysical anomalies observed in the remaining part of the investigated site, i.e. towards the Coltellazzo relief.

2. Geological and geomorphological setting of Nora

The ancient Roman city of Nora is located on the Sardinian southwestern coast (Italy) characterized by an alternation of promontories and beaches with retrograde lagoons. The city rises on the Capo di Pula promontory, which has a sub-triangular shape limited at east and south by *Punta del Coltellazzo* and *Punta* "*e su Coloru*" headlands, respectively (Fig. 2). Moreover, two morphological highs, Capo della Torre di Sant'Efisio and Colle di Tanit, emerge in the Coltellazzo area and in the central portion of the peninsula, respectively (see Fig. 2). In particular, Colle di Tanit is originated from a volcanic island connected to the mainland through a sand pillow, about 80 m wide, that actually surrounded a lagoon delimited to the south by a quaternary coastline. The plain around the ancient city was formed in the Upper Tertiary and is bathed by some rivers, the main ones being Rio Pula and Rio S. Margherita.

The geological setting of the area is generally characterized by volcanic rocks formed in the Oligo-Miocene and, in particular, by andesite-amphibolus lava from light grey to brownish brown in colour, described in literature as andesitic and volcanic conglomerates, respectively (Di Gregorio et al., 2006). The volcanic substrate outcrops in three points of the peninsula of Nora: in the promontory of Sant'Efisio (east side), near Punta "e su Coloru" (south side) and at the centre of the peninsula in correspondence of Colle of Tanit. As it concerns the sedimentary deposits overlapping the volcanic substrate, several outbreaks of Tyrrhenian deposits with a thickness not exceeding 3 m above sea level are found in different parts of the peninsula. These deposits are constituted mainly by conglomerates and sands with some fossils, like *Strombus bubonius*, *Conus testudinarius*, *Patella Ferruginea* (Di Gregorio et al., 2009). In particular, the geophysical survey area is located near the promontory of Sant'Efisio, where a singular sedimentary Thyrrenian sequence has been recognized consisting of levels of grainstone with different granulometry, predominantly formed by an organogenic component (about 60%) including bioclasts and shellfish shells (Kindler et al., 1997).

3. Geophysical prospecting at Nora

The geophysical survey at Nora has been carried out through a multi-methodological approach consisted of application and integration of the following prospecting methods: magnetic, frequency domain electromagnetic, ground penetrating radar and direct current electric resistivity. The measurements were performed on the soil surface by using high-resolution data acquisition techniques, which allowed a 3D reconstruction of the investigated subsoil, mainly in terms of electrical resistivity and magnetic susceptibility parameters. As it is well known, in archaeological research the identification of high resistivity (i.e. low conductivity) values indicates the presence of structures resistant to the passage of electric current (e.g., cavities, stone walls or foundations), which generally are hosted in a more conductive environment by virtue of the fluid circulation in mostly sedimentary soils (e.g. Drahor et al., 2007; Thiesson et al., 2009; Di Maio et al., 2012; Argote-Espino et al., 2016; Di Maio et al., 2016b). The presence of magnetic anomalies is, instead, a consequence of the contrast between magnetic properties of anthropical building materials and those of the hosting soil or rock (e.g., Schmidt, 2007; Saey et al., 2012; Di Maio et al., 2016a). As these anomalies are closely linked to the alignment of the causative sources, their space distribution gives information on the geometry of the buried magnetic bodies (Piro et al., 1998).

First, magnetic (MAG) and frequency domain electromagnetic (FDEM) induction techniques were applied for a preliminary exploration of the selected area. Successively, high-resolution surveys of electrical resistivity tomography (ERT) and georadar profiling (GPR) were carried out to better define the observed MAG and FDEM anomalies. Fig. 3 shows the survey areas for each used prospecting method.