

STONE IN THE CITY. EXTRACTION SITES AND SPOLIATION OF STONE MATERIAL IN THE CITY OF NORA (South -West Sardinia)

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Abstract. *The paper intends to focus to the historical extraction sites and to the movement of construction materials, without neglecting the spoliation of monuments, to identify the plots between geology and urban structure (Bonetto, 2012). The purpose of this paper is to create a different point of view in order to get a comprehensive picture of the urban form and characteristics, and also to define the social, cultural and economic context. Then, a replicable case study is presented (the archaeological city of Nora in Sardinia, Italy), with the aim of identifying main urban processes that take into account the ancient supply and circulation of building materials essential for the urban formation. Finally, study's findings are discussed. The paper concludes by to investigate the correlations between urban building and the stone materials, whose extraction was proximal, and whose masterful use has allowed the construction of the city of Nora.*

Keywords: *construction materials, archaeological city, Nora (Sardinia), cultural tourism, paths itinerary*

1. Introduction: the territory of Nora

The archaeological site of Nora (Figure 1) plays a multiplicity of significances, being the crossroad among the vestiges of several ancient Mediterranean civilizations, the beautiful natural environment of a lagoon, the home of an environmental education center and a refuge for cetaceans and sea turtles, and the place of a major center of popular religious belief in the Cagliari area, the church of S. Efisio. The morphology of this stretch of Sardinian coast is marked by an alternation of promontories, beaches and backshore lagoons. The archaeological site of Nora lies on one of these promontories, whose peculiar shape, originated by three small creeks, has probably influenced the colonization of the site in ancient times (Figure 2). West of the archaeological site opens the lagoon, whose origin is related to the emergence of a quaternary beach berm (Fradis Minoris) and to the sandy accumulation of the Agumu beach.

The outcrop of Fradis Minoris is made up of alternations of carbonate sandstones, and represents a physical link between the archaeological site and the lagoon itself. Nora is an ancient site: excavations performed in recent years

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confirmed that Phoenician frequentation probably begun in the VIIIth century BC.



Figure 1. Location of Nora in Sardinia (Google Earth image)

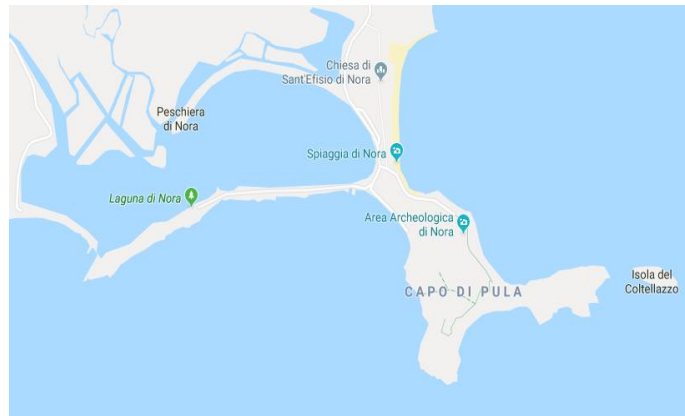


Figure 2. General overview of the Nora area Location of Nora Peninsula in Sardinia (Google Earth image)

From the Punic and Roman times then, the site has progressively taken the appearance of a true city, included in the main commercial trade routes of the ancient western Mediterranean. Roman colonization began around 238 B.C., after the first Punic war: most of the currently visible buildings relate to this phase of Nora's history. Excavation data combined with the epigraphic documents show that the city assumed from now on its greatest expansion and its greatest wealth: documents of restoration of public works or gifts made to the city by some of its rich inhabitants (Tronchetti, 2011). The Punic and Roman times also coincide with an expansion in the surrounding area (Figure 3); in Roman times the territory was populated by villas and small settlements, with several necropolis (Botto and Rendeli, 1992). This situation lasted until the fifth century A.D. From that time on, the city began its disintegration phase, due to Vandal incursions; the promontory remained, however, still inhabited until at least the 7th century A.D., to be abandoned, as well as the rest of the coastal area, up to the eighteenth century, with the exception of some religious buildings, such as the church of S.Efisio, built in the 11th century A.D.

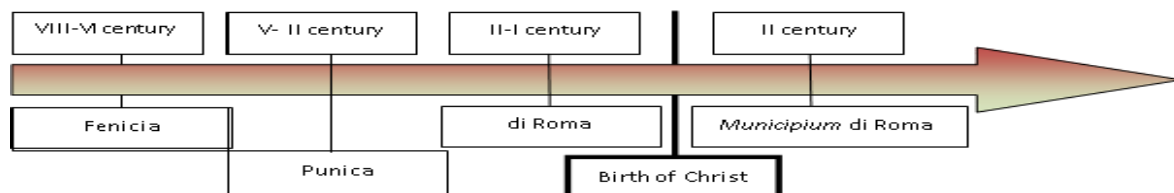


Figure 3. Main Chronological phases of Nora City

1.1. Geological elements: natural landscapes and city building materials

Without the masterful use of the stone, the Mediterranean civilizations would

not have developed. In fact, at each stone construction corresponds a quarry (Gisotti, 2008). The historic quarries are the result of many coordinated, finalized, and non-casual actions, not developable without first having attained a wise knowledge of the territory, its materials and their workability, mode of transportation and implementation potentials ("mining art", Marino, 2007). Our research has been intended to cover not only the urban history of the city of Nora, but to locate the most hidden traces, more neglected in the approach of classical urban readings, to make room for the "short chain", that of ancient building materials, and favor a multidisciplinary approach (Chaminé et al., 2016). In other words, we intended to read the "backstage" of the urban scene to give space to a new approach to analysis in favor of an assessment of urban processes that will take account of supply and circulation of materials in antiquity. In this paper we considered different materials, like the sands required for making mortars, both of river and marine origin (yellow, plio-plestocenic sands). A further element to consider are the geological and hydrogeological risks that have been among the main drivers of urban abandonment. The intention is to create another point of view in order to obtain an exhaustive picture of the "technical" characteristics of urban buildings and to define the social, cultural and economic context, as well as to understand the existing relationships between the city and the geo-resources in its territory (Previato, 2016). It is intended to draw attention to the extraction sites and the circulation of building materials, without neglecting the spoliation of the monuments, to locate the weaves between geology and urban structure (Bonetto, 2012), and to represent how the historic cities possessed an unconscious smartness approach (Dhingra et al., 2016), the forerunner of the recent smart city paradigm (Dameri et al., 2016).

2. The building materials as an opportunity for active cultural tourism

In the city of Nora, stone is undoubtedly the preferred and most spread construction material. The choice of stones to be used in urban buildings and infrastructures of the city was masterful (Figure 4); the optimization and use of these materials is seamlessly testified since the late VIth century B.C. until at least the IVth-Vth century A.D.

It was during his trip in Sardinia (1857), that Alberto Ferrero La Marmora recognized in the peninsula of Is Fradis Minoris, traces of quarrying engraved in the "quaternary gres", a sandstone widely used in the buildings of the city (Della Marmora, 1857).

Then Gennaro Pesce showed a lively interest in building materials and building techniques in use at Nora, providing indication on architectural aspects and then dedicating a specific insight into "building materials, wall structures and architectural taste in the area of Nora IV ", in Roman imperial age (Pesce, 1957).

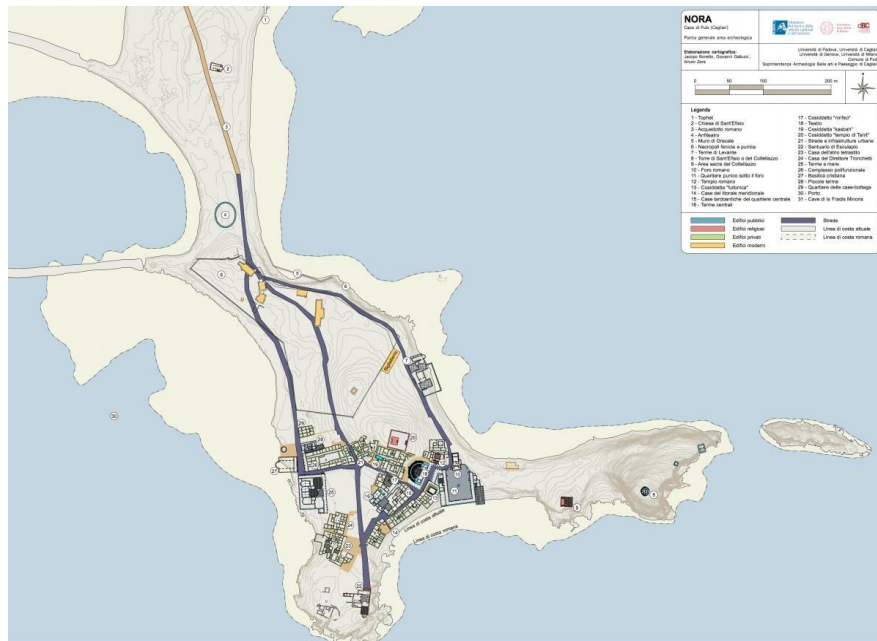


Figure 4. Planimetry of the city. (<http://nora.beniculturali.unipd.it/>)

Likewise, G. Pesce (1957) provided a list of the stone materials "most frequently used in Nora for building". Based on recent studies and geological surveys, the list may be updated as follows: 1) carbonate sandstones (Quaternary: commonly known as the "Panchina tirreniana Auct."); 2) siliciclastic, red-violet sandstones (Eocene-Oligocene: part of the terrigenous continental "Cixerri Fm."); 3) grey-violet andesitic lavas, often with brecciated textures (Oligocene-Miocene: "Andesiti di Monte Arrubiu" Fm.); 4) white-yellow limestones (Miocene: mostly of the "Tramezzario" and "Pietra cantone" members of the "Calcari di Cagliari" Fm.); 5) pyroclastic, grey tuffaceous rocks (Oligocene-Miocene: popularly known as "trachytic" tuffs).

To these rock types must be added various kinds of Paleozoic schists and different varieties of grey-white marbles. About the origin of the identified stone materials, recent geological maps and literature show that the first three types of stone are clearly "native" materials whose outcrops are located very close to the Nora city center. The other two kinds of stones were transported from the outside: the "Tramezzario" and "Pietra cantone" limestones surely came from the quarries in Cagliari, while the "trachytic" tuff could have been quarried from some pyroclastic layer north of Nora, as in Monte Arrubiu volcanic dome (Sarroch), or have been transported from an unknown Sulcis area. The careful reading of the history of the city through the materials allows to identify the real urban processes and the main informational layers of the building. They always occurred with obvious objectives of optimization, performance and low entropy, similarly as that recently is contemplated in the smart city paradigm (Dameri et al., 2014). In fact, for "Smart Cities" (IESE-Cities in Motion, 2017) are intended "the territories in which the Communities use resources in an efficient and sustainable manner [...] are attractive in terms of quality of life and services to

citizens [...], and are capable of enhancing its own cultural and economic peculiarities to increase the competitiveness of the territory”. This definition seems to be the most suitable to open a chronologically backward confrontation. In particular, if in the past the prerequisite for foundation and urban development was the combination of geomorphologic elements and geological resources, in the contemporary world the prerequisite of smart city is a dense and complex network of sensors able to monitor the city in real-time and possibly to increase it (Carta, 2016). The compact urban weave of the city of Nora originates precisely from the interaction between the geomorphological features typical of the coastal area and the availability of natural and geological resources. It was the combination of these elements which have allowed the birth and urban development, and the preservation of a large archaeological city heritage (MiBAC-OpuscoloPaestum, 2008). Specifically, the “short chain” of materials and resources conferred to the city of Nora, like all ancient cities (De Seta, 2017) a significant value of objective environmental sustainability (Mandich et al., 2016). In the contemporaneity known as "information", the identification of building materials and stone extraction sites gives completeness to historical events by expanding the perspective to the neighboring territory, also in accordance with the recent directive on cultural goods and activities and of tourism (2016) – Anno dei Cammini d’Italia (MiBAC, 2016), open its doors to cultural tourism (Osservatorio Nazionale del Turismo, 2016) and to active tourism (Locci, 2010). In fact, in the light of what has just been highlighted, the city of Nora has an ecological footprint (Grimm et al., 2008) referable to building materials much wider than its urban area (Previato, 2016). The deepening and dissemination of ecological footprints in the field of archaeological cultural fruition therefore provides a more complete picture of the city system in the past and offers interesting insights (Brenner et al., 2014) for the contemporary city (Rapporto Recycle Legambiente, 2016).

3. Proposal cultural enhancement and valorization of Fradis Minoris extraction site

A territorial analysis that includes the study of the building materials, from extraction sites to the skillful use in the urban context, may originate a new metodological approach of valorization (Colletta et al., 2016) of these sites at both ends of the productive chain, favored by their proximity that well agrees with an unitary fruition. (Figure 5). Our attention was particularly focused on the most spread rock-type used in the Nora’s buildings, the Quaternary carbonate sandstones extracted in the ancient quarries of Fradis Minoris, and then contextualize them within the archaeological landscape to which they belong: the archaeological area of Nora and the archaeological museum "Giovanni Patroni" in Pula (Sardegna Cultura, 2018). In fact, the aim is to reduce the negative perception of the extraction sites, to instead confer on it the active role

of "productive archeology" (Mannoni, 2003), through territorial contextualization and narration of the extraction and processing of building materials. This peculiarity allowed us to study the various stages of use of the stone and to propose a valorization based on the idea of highlighting the still existing links between the urban places of the city, by means of an itinerary following the path of the materials in time.



Figure 5. The quarry of Is Fradis Minoris with respect to the archaeological area of Nora (Google Earth)

The research allowed to acquire a set of data finalized to develop a spatial analysis of the movement of the stone from extraction sites to the places of final destination and use. Research activities included: 1) recognition and survey of the Fradis Minoris extraction sites, finalized to a reconstruction of the quarry landscapes as a whole, including identification of the geological, stratigraphical, and geomorphological features of the deposit and its geometry; 2) reconstruction of the extension, layout and structure of the quarries, with the individuation of the extraction fronts, the spoil heaps, the working areas, and the related ways of transport of the materials; 3) individuation of traces of quarrying and stone working tools, and of the remnants of loading and harboring facilities for the ships; 4) characterization of the stone materials from rock outcrops, in particular as regards their mineralogy and petrography, both by optical microscopy and XRPD (X-Ray Powder Diffraction) analyses, essential for future reconstructions of the final destinations and the diffusion of the stones at local and, eventually, at regional scales; 5) recognition in the city of buildings, monuments and artefacts built with stone materials macroscopically comparable with those extracted in Fradis Minoris. A further issue regards the vulnerability of the ancient quarries. The quarries of Fradis Minoris, located to the west of the Nora promontory (38°59'10.55"N, 9°00'19.77"E), represents a unique example of stone material extraction. It is possible to recognize a well-structured working chain of stone extraction and subsequent transport by sea. The total extension of the site can be evaluated of about 1,2 ha. The general layout of the quarries is linear, with E-W oriented extraction fronts, corresponding to the different working areas, which run for over 300 m along both sides of the narrow peninsula (Figure 6); the seaside fronts are still well-exposed, while fronts overlooking the lagoon are in part under the vegetal cover.

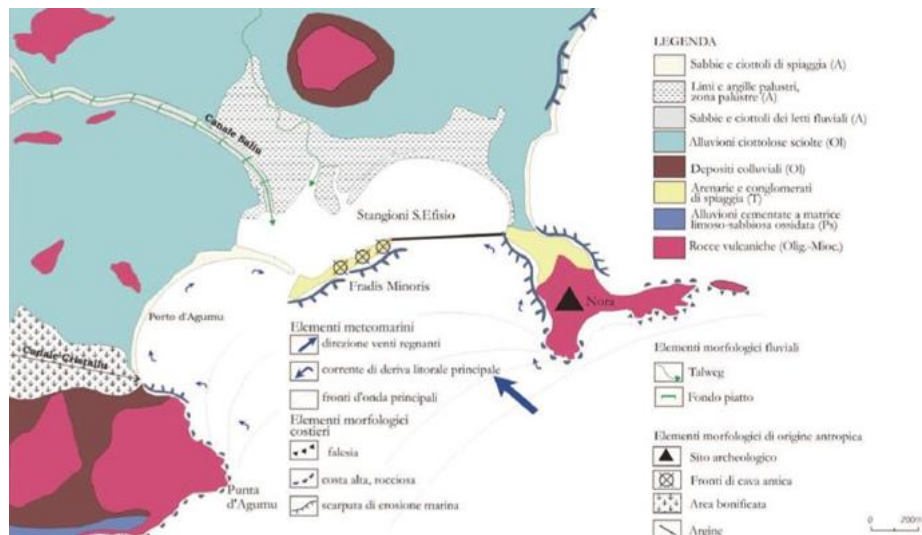


Figure 6. Geological quarry of Fradis Minoris (G Balletto et al., 2010)

The fronts on the seaside are fairly preserved, despite the erosional action of sea; all the lowermost working areas are currently submerged (Antonioli et al., 2017). The quarry fronts and the basal bedrock surfaces are marked by negatives of blocks, with a prevalence of the 90x50x50 cm type. These dimensions are comparable with those observed in the buildings of the ancient city. Marks of ancient working tools (chisels, pickaxes, heavy picks) are widespread on quarry faces. The average height of the fronts is of about 2m. No true spoil heaps are currently visible in the site above the fronts, but much of the sandstone pebbles that are found along the intertidal zone on the seashore are probably original rock fragments derived from quarrying and block reduction. The Pleistocenic sequences of this area are among the best known in Sardinia (Ulzega et al., 1986; Kindler et al., 1997); they rest on a substrate made of tertiary andesites, and colluvial sediments and paleosols of uncertain age. From the main reference sections (Nora and Fradis Minoris), two main overlapped sequences have been distinguished: 1) a basal sequence, 1,5 m thick, well exposed in the eastern Nora peninsula, prevalently made of medium-coarse grained sandstones with high-angle cross-stratification and other sedimentary features indicating an high-energy depositional environment, interpreted as subtidal (Kindler et al., 1997) - 2) an upper sequence 2,5-3 m thick that crops out for the most part in Fradis Minoris, including a basal coarse conglomerate, covered by cross-bedded, coarse to medium-fine grained carbonatic sandstones, showing the sedimentary features of a shallowing upward depositional environment, from shoreface to foreshore (Kindler et al., 1997). The Fradis Minoris basal conglomerate is characterized by fragments of sequence 1) sandstones, abundant volcanite cobbles, and a carbonatic sandstone matrix. The sandstone sequence is marked by several *Lithotamnium rodholits* (red algae) levels, and reworked rodholits are also present in the uppermost part, above a distinctly bioturbated level. A carbonate crust (calcrete) that covers the sandstone outcrop is interpreted as a

paleosurface of erosion covered by a paleosoil (Ulzega and Hearthy, 1986). The Fradis Minoris quarry was identified during one of the archaeological prospecting campaigns carried out by Nora's archaeological mission (Bonetto, 1991); the comparison of stones both from the quarry and in the built environment in the city, highlighted the compatibility of the materials. Comparison is facilitated by macroscopic lithological characters of the stone, as the occurrence of layers with Lithotamnium rhodoliths, which are typical of the quaternary sequences in Fradis Minoris. In particular, observations in the Nora city theater (Melis et al., 2000) (Figure 7), marked by wide use of the Quaternary sandstone, lead to the fact that in Roman times the outcrop of Fradis Minoris was extensively quarried for the extraction of building materials used for this building, thus identifying its mother quarry (Gisotti et al., 2008). Evidences of the use of Fradis minoris sandstones in the previous era are still under study, although macroscopic material analysis suggests their exploitation for the construction of some Punic Age buildings (Figure 7).

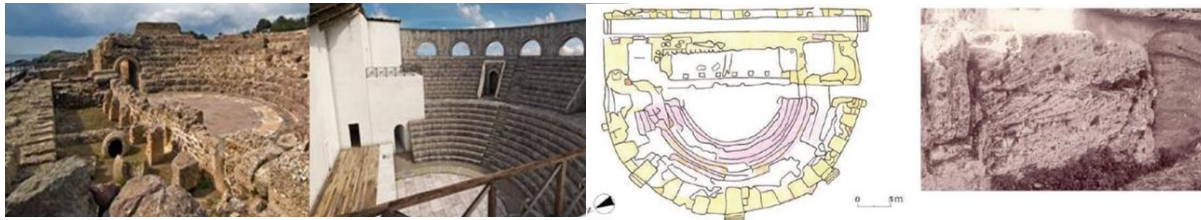


Figure 7. Nora theatre and its 3D reconstruction (<http://nora.beniculturali.unipd.it/gli-edifici/edifici-pubblici/teatro/>) and materials from Fradis Minoris in the construction of the Theater (P.Mistretta, Dionisio XXXV)

4. A proposal for valorization

At present, Nora and the lagoon site receive a large flow of visitors throughout the year (ranked third in 2016 among state museum complexes in Sardinia for a total of 68,235 visitors), but the quarry of Is Fradis Minoris and, in general, the correlations with the origin of the building materials, are not included in the current circuits of visit, both in the archaeological site and in the environmental education center where the quarries are located. Analysis of the urban fabric of the city, located in the context of the material resources of the territory, evidence the tight link between the extraction sites of stones and the built environment where stones were used. This is supported by observations and lithological analyses both in the rock outcrops in the quarries and surrounding area, in the quarry fronts (e.g negatives of blocks) and in the archaeological site (e.g. block dimensions in major buildings). Based on these results, the proposal for valorization provides a tour itinerary that allows the visitor to follow the path of the stone from the quarry to the monument, until its reuse in other artifacts (Figure 8).

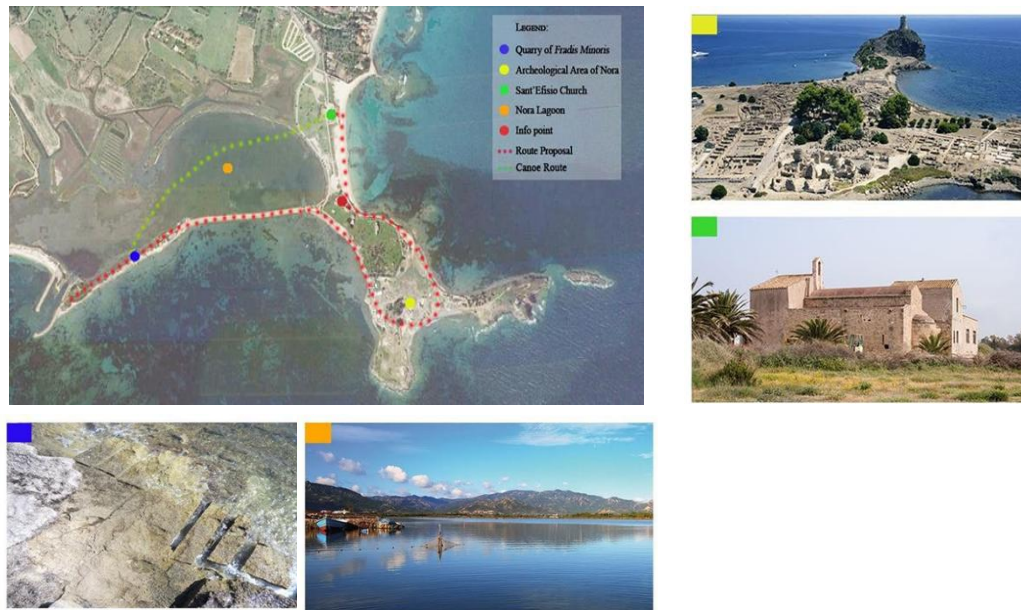


Figure 8. Tur itinerary proposal and main places of interest (blue: quarry; yellow: archaeological area; orange: Lagoon; green: Sant'Efisio church)

The proposed itinerary include a “traditional” part, structured in paths equipped with descriptive panels of stone circulation and use over time, and a 3D virtual tour (three-dimensional reconstruction of Nora), to allow an immediate comparison between archaeological remains and the original state of the sites. Within the quarries, the layout can be more articulated, to highlight both the anthropic aspects (stone extraction and processing), as well as geological and naturalistic aspects. Exploiting the concept of open-air museums (Edwards et al., 1996), in the ancient working areas there could be placed reconstructions of tools and machines, while in the summer special diving trips will allow to visit the lower, currently submerged quarry areas and fronts. To preserve the site from degradation it will be provided a partial coverage, with a transparent structure, of better preserved quarry fronts and other features of greater interest, also providing wooden walkways for visitors. The itinerary, spatial and temporal, can be traveled in by observing the material in its place and following its movement in time towards the use in Roman times within the Nora site, and then to move to the XI sec A.D., when the dismantling of pre-existing Roman sites provided the material for building the church of Sant'Efisio. The quarries, in addition to representing a departure (or arrival) point in the pathway that joins it with the archaeological site and the church of Sant'Efisio, offer a further opportunity for touristic fruition, by the realization of itineraries of environmental interest. Again, this is the case of the latest and extended open-air museum concept (Zaidner et al., 2016) In which the most significant geological sections will be an object of immediate tactile perception, highlighted by panels and other visual devices that will give rise to awareness of the evolution of the

site as a temporal record of a number of phenomena related to coastal dynamics.

5. Conclusion

The multidisciplinary study of the archaeological site and the main quarries of Nora has led to the delineation of the "archaeological landscape" of the analyzed area. This is the "archaeological landscape" where archaeological factors fit into environmental factors and vice versa, creating a series of elements that can be considered a multi-thematic itinerary. In addition, by exploiting the time factor on different scales, it is possible to create a multiplicity of concepts, apparently unconnected, where the quarries occupy a prominent role, as they represent both the starting point and the union of various elements of the itinerary. The proposed noninvasive approach relates both archeometric aspects related to the quarry / monument relationship and the paleogeographic links to the lagoon. Fradis Minoris has the prerequisite to contain important paleo-environmental and archaeological information, similar to that of other historic quarry sites set on quaternary sandstones in western Mediterranean. What makes this site so unique is to be an exceptional showcase for contemporary observation of anthropic and naturalistic data. Overall, the study carried out is a further proof of how a site of historical quarry is not to be understood as a negative element of the landscape, but as a place rich in elements that can be valorized, in which the interaction between natural and artificial features has created unusual scenarios and great suggestions.

Summary

This study focuses on themes related to historical extraction sites and to the movement of construction materials. The chosen field of study is the archaeological city of Nora (Sardinia, Italy) with the aim of identifying main urban processes that take into account the ancient supply and circulation of building materials essential for the urban formation. Our attention focused the Quaternary carbonate sandstones extracted in the ancient quarries of Fradis Minoris, used in the Nora's buildings. In fact, the aim is to reduce the negative perception of the extraction sites through territorial contextualization and narration of the extraction and processing of building materials. Finally, the paper concludes by to investigate the correlations between urban building and the stone materials, whose extraction was proximal, and whose masterful use has allowed the construction of the city of Nora. Infact, the "archaeological landscape" of Nora, manifest archaeological factors fit into environmental factors and vice versa, creating a series of elements that can be considered a multi-thematic tourism itinerary.

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