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THE MESSAGE FROM THE URBAN SEDIMENTARY ARCHIVES: EXAMPLES FROM THE ROMAN PISA-SAN ROSSORE (CENTRAL ITALY) AND PRE-ISLAMIC SUMHURAM (SOUTHERN OMAN) ARCHAEOLOGICAL SITES

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ABSTRACT: In this paper we summarize and compare results of previous geoarchaeological studies on urban environments carried out by the authors in Central Italy (Pisa-San Rossore) and Southern Oman (Sumhuram). The aim is exploring the strategy of human adaptation to coastal settings selected for founding still existing (Pisa) or vanished (Sumhuram) urban centres, during the climate warming of the Roman Age. Under warm climatic conditions, despite their distant locations, these urban areas were both devoted to commercial exchanges. The Pisa-San Rossore was a suitable fluvial wharf based on a pre-existing channel and serving the Roman Pisa, whereas Sumhuram was a pre-Arabic strategic trading outpost founded on the rocky coast facing the Gulf of Aden by people coming from the southern Yemen. The stratigraphic, sedimentologic and palynologic data collected in the two sites allowed the identification of the effects of a warm climate, expressed by hydrological events. At Pisa-San Rossore these were recurring catastrophic overbank floods generated by channel instability of the Arno River adjacent to the wharf area. Despite the high hydraulic hazard, the local people exploited the site up to its definitive siltation, a behaviour hinting to resilience and calculated risk with respect to the economic advantage. At Sumhuram, an enhanced monsoon circulation, over southern Oman, between the second century B.C. and the first century A.D., sustained a moisture higher than in preceding and following phases of town existence. This condition favoured the maximum commercial and cultural flourishment of the town. The two case studies indicate that geoarchaeology is a suitable tool for assessing the strategy of resilience and exploitation of the land surface by humans across rapid environmental changes as those occurring nowadays and expected in the near future. The value of the knowledge acquired through a geoarchaeological approach goes beyond the reconstruction of ancient human patterns; it provides contributions for establishing present and future sustainable relations between Humanity and the Earth learning from the past.
Keywords: Rome (Italy), urban geomorphology, urban landscape, Tiber River, Aqua Mariana, Nodicus River.

Keywords: Geoarchaeology, community adaptation, Roman Age, Central Italy, Southern Oman

1. INTRODUCTION

Geoarchaeology is based on a set of disciplines and methods of the Earth Sciences exploited for reconstructing how the environmental setting influenced and was modified by ancient human occupation of the territory and the physical processes that brought to the formation of an archaeological site (Butzer, 1971). In this perspective Geoarchaeology is often perceived as a discipline solely functional to the archaeological studies. Nevertheless, the interaction between Geosciences and Archaeology opens to wider potential meaning and application, exploring the stratigraphical record to understand how ancient human communities adapted to and controlled the dynamic environment. The geoarchaeological evidence, thus, may provide arguments for a rational planning of present and future land occupation, particularly in highly urbanized areas sensitive to both growing human pressure and the wide range of geomorphic hazards.

We summarize here two case studies discussed in detail in previous papers and dealing with the adaptation of urban communities settled between the 3rd century B.C. and the 5th century A.D. in Central Italy (Pisa-San Rossore site, Benvenuti et al., 2006; Mariotti-Lippi et al., 2007) and on the southern coast of Oman (Sumhuram site, Mariotti-Lippi et al., 2011). The related urban centres were places of intense commercial activity connected to the trading network of the Mediterranean Basin, Red Sea and Indian Ocean as revealed by geoarchaeological (Gorain & Morhange, 2001; Marriner & Morhange, 2007; Morhange et al., 2016) and archaeological (Schiettecatte, 2012; Seland, 2014) studies on the ancient harbours located along their coasts

2. THE GEOARCHAEOLOGY OF THE TWO SITES

2.1. The Etruscan-Roman Pisa-San Rossore ship site

The exceptional and unexpected vestiges of an urban fluvial wharf were casually discovered in the late 1998 in the shallow subsoil of Pisa (Central Italy) on the coastal plain of the Arno and Serchio rivers (Fig. 1A; Bruni, 2000; 2002). This lowland, shaped by the late Holocene fluvial dynamics, bounds at the surface a clastic infill up to 100 meters thick accumulated during the

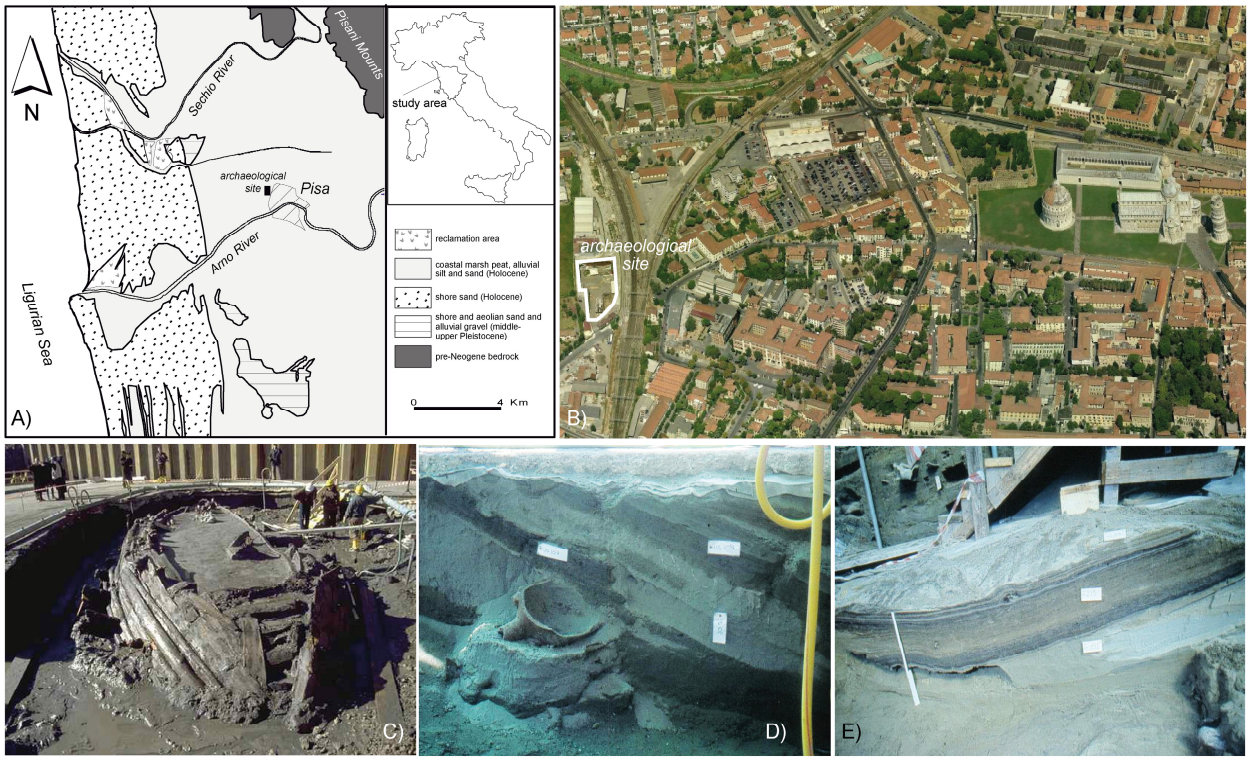

Fig. 1 - A) schematic geological map of the terminal plain of the Arno and Serchio rivers with location of the Pisa-San Rossore site; B) oblique aerial view of the Pisa downtown: the archaeological site is adjacent to the famous Piazza dei Miracoli with its Leaning Tower (on the right in the photograph); C) a well-preserved ship unearthed for recovery; D) detail of cross-stratified sandstone of U1 bearing a fragmented amphora belonging to the ship's cargo; E) the vegetal debris-rich mudstone draping the sandy cross strata of U1;

last glacial lowstand of sea level and the following transgression (Aguzzi et al., 2005; 2007).

An excavation on a surface of about 3000 m^2 done for a new building of the Italian Railways Company and located few hundred meters west from the Leaning Tower (Fig. 1B), unexpectedly intercepted several shipwrecks (Fig. 1C) and a huge amount of varied materials related to the ships' cargoes. The excavation (Fig. 2), deepened at about 5 meters below the topographic surface, revealed at its southern end the remain of a wood palisade and other materials radiometrically bracketed between the 9th and the 2nd century B.C. (Belluomini et al., 2004; Martinelli & Pignatelli, 2008). Together with the remains from the central and northern areas of the site, encompassing the whole Roman Age (from about the 1st century B.C. to 5th - early 6th century A.D.; Bruni, 2003; Camilli, 2005), the archaeological record attests to the exploitation lasted for a millennium of an urban harbour evidently strategic for the economy of the ancient Pisa but unknown until its casual discovery.

Several sections, made available for the recovery of the shipwrecks and related materials, allowed to define a stratigraphic architecture consisting of five sedimentary units (U0 to U4; Fig. 2) encasing the archaeological remains and mostly made of sand with subordinated mudstone (Benvenuti et al., 2006). U0, scarcely exposed in the southern-central areas of the site, represents a complex sand-rich body encasing late Etruscan-Roman materials. U1-4, well exposed in the sections of the central-northern areas of the site, consist of cross-stratified coarse-medium sands predominantly dipping to northwest (Fig. 1D) and bearing entire ships oriented transversally to the dip direction of cross beds. The latter are in turn covered by thin blankets of laminated sandy silts and clays rich in vegetal debris (Fig. 1E). Each unit, therefore includes a thicker coarse-grained portion, bearing the large-size materials ranging from entire ships to amphorae, capped by a veneer of fine-grained sediments. This lithological alternation attests to a fluctuating regime of sediment transport and deposition, the latter referred to as many pulses of catastrophic floods sweeping away the ships from their berths and dispersing their cargos in the sandy sediment load. These floods resulted from the crevassing of an adjacent active river channel, actually the Arno River still today located one-kilometer ca south of the site. The overbank floodwater funneled by crevasse channels spread into an abandoned channel, exploited as a wharf, where deposited sedimentary lobes frontally accreting toward NW. This relic of a pre-existing river course, beheaded by a channel avulsion, was evidently still connected to the sea located about three kilometers from the Roman Pisa (Pranzini, 2001). Such a slack-water way favored the suitable transit of a fleet of small ships transporting goods and people from and to the town. Shallow cores drilled in the site and in the immediate surroundings, allowed to reconstruct the local environmental setting beyond the limits of what directly observable in the site.

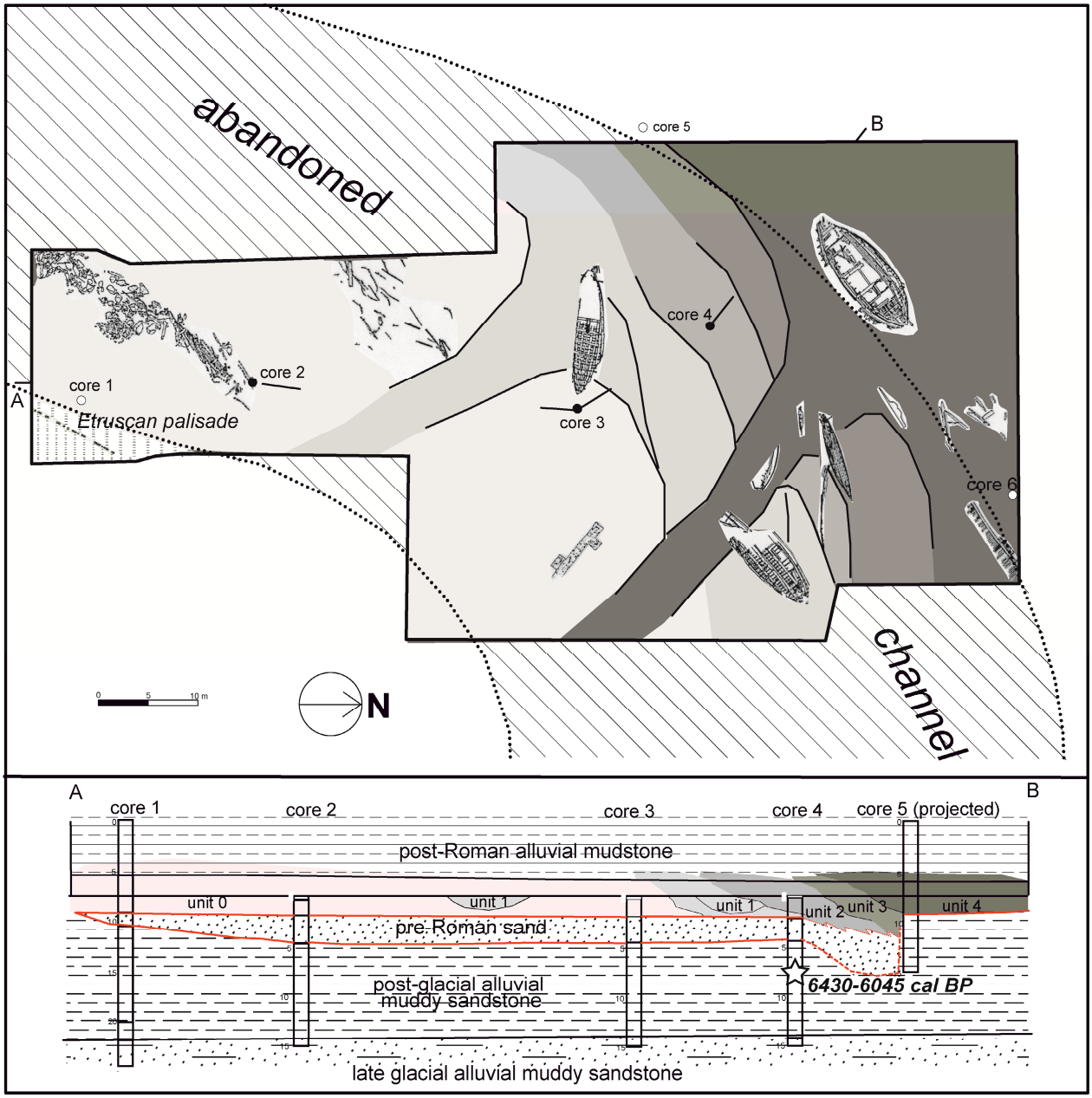

Fig. 2 - Distribution of the ships and other archaeological material unearthed in the early 1999 and associated to U0-4 (Benvenuti et al., 2006). The geologic section A-B is based on cores stratigraphy integrating the limited exposures created by the archaeological excavation. The cal C14 age in core 4 is relative to the dating of a Cerastoderma shell.

The core stratigraphy (Fig. 2) indicates that the established units are confined into a concave-plane lens encased in mudstones, confirming the channelized nature of the deposits. The basal mudstones are the infill of a lagoon which occupied the Pisa plain during the early Holocene as the consequence of a post-glacial rise of sea level and subsequent flooding of the coastal areas (Benvenuti et al., 2006). The overlying mudstone represent post-Roman-Modern floodplain deposits. The channel was incised after about 6,000 years ago as indicated by the radiocarbon age of Cerastoderma shell from the top of the underlying lagoonal mudstones (Benvenuti et al., 2006). The core correlation suggests that the channel was deeper toward north suggesting a meandering geometry (Fig. 2).

Pollen analyses performed on samples collected in the muddy deposits of the different units (Mariotti-Lippi et al., 2007 for details) showed: 1) significant percentages of Abies and Fagus in the pre-Roman sediments of U0 pointing to the cold-temperate climate of the Etruscan period; 2) the presence of mixed oak woodland taxa, in the muddy deposits capping U1-4 in agreement

with the Roman warm period. The occurrence of hygrophilous plants in pollen spectra dominated by herbs increasing from U1 to U4, accounts for soil waterlogging in the plains surrounding the site throughout the Roman Age.

2.2. The Pre-Islamic Sumhuram citadel

The Sumhuram walled citadel, located on the southern coast of the Sultanate of Oman (Dhofar Region; Fig 3A), was founded by people coming from the Reign of Hadramawt in southern Yemen. The urban settlement on this coastal area, close to the founder's homeland, was motivated by a strategic position for controlling the commercial exchanges between the Mediterranean and India. A particularly important commodity for long-range trading controlled by Sumhuram was the frankincense extracted by the tree *Boswelia sacra* thriving in the interior of Southern Oman (Raffaelli et al., 2011). The town's development occurred into three distinct phases (Avanzini & Sedov, 2005). During phase 1 (third to first century B.C.) the town flourished under widespread commercial exchanges, as documented by a variety of Mediterranean and Indian handicrafts recovered from the related archaeological horizons. A short-lived abandonment with possible partial destruction of the town, occurred between the late first century B.C. and the early first century A.D. The following phase 2 (first to third century A.D.) and phase 3 (third to fifth century A.D.) were characterized by town development until its definitive abandonment with the onset of the Islamic occupation. Five constructional stages succeeded during the town lifetime as documented by a detailed analysis of the buildings (Buffa & Sedov, 2008).

The citadel (Fig. 3B), stands at about 25 m a.s.l. on the left bank of the Wadi Darbat-fed Khor Rori estuary (Fig. 3C), presently barred at its mouth by a sand shoal. The location is on a flat erosional surface sculpted onto Paleogene limestones which also form the NE-SW trending escarpment of the Jabal al Qara, a mountain range up to 2000 meters high separating the arid interiors from the Dhofar coastal lowland (Fig. 1A). This physiography accounts for a summer monsoonal moisture along the Dhofar coast sheltered by the Jabal al Qara escarpment and favouring the development of permanent vegetation, a peculiarity in South Arabia.

In the late 2006 a specific section (A68; Fig. 3D) was made available thanks to the archaeological excavations done in the frame of the activities carried out by the Italian Mission to Oman (Avanzini, 2008). The section, located in the NW part of the town at the end of a narrow street between the houses (Fig. 4A), was described and sampled respectively for the deposits stratigraphy and sedimentology and for a high-resolution palynological analysis (Mariotti Lippi et al., 2011). The site stratigraphy is characterized by the alternation of two main types of deposits (Fig. 4D) for a total thickness of about three meters. Anthropogenic deposits (AD) consist of a chaotic mix of debris including angular clasts of limestone, brick fragments, charcoal and ash and organic remains mostly represented by terrestrial vertebrate and fish bones. Waterlain deposits (WD) are made of centimeter thick beds of sandy loam grading upward into silt loam occasionally bearing granulae and small pebbles. In terms of accumulation processes, AD is referred to deliberate dumping of domestic garbage in the streets of the town, mixed with occasional rock fragments possibly resulting from wall wasting. WD accumulated by waning flow of water running along the streets that can be referred both to intentional discharge or to surface run-off from heavy rainfall. The alternation of AD and WD characterizes three distinct stratigraphic units (Fig. 4B) with the basal and topmost units 1 and 3 dominated by AD and the intermediate unit 2 characterized by a prevalence of WD. The integration of radiocarbon chronology and archaeological evidence indicates that units 1-2 and unit 3 developed during phases 1-2 and 3 respectively. A charcoal in the WD-dominated unit 2 (Fig. 4A) yielded a calibrated radiocarbon age of 210 B.C.±10 A.D. (2σ) corresponding to the late phase 1 when the town experienced a great commercial and economic flourishment.

A fine sampling of AD and WD along the section allowed a detailed palynological analysis resulting in the recognition of different pollen groups attesting to variable distance of pollen transport (Fig. 4C). The short distance group (0-5 km) represents the plants still growing today on the beach and the margins of the coastal plain as well as hygro- and hydrophilous plants of the estuaries and wadis. The medium distance group (about 5-25 km) includes plants growing on the inner plain at along the Jabal al Qara escarpment. The long-distance group (>100 km) represents the plants growing in the Oman desert areas, on the mountains of Yemen up to those growing in Africa and/or in the Mediterranean area and beyond. The distribution of the pollen record in the three units shows a relative abundance of the long-distance group in the WD of Unit 2, being indicative of a greater strength of the monsoonal circulation during the development of this unit than of units 1 and 3.

3. DISCUSSION AND CONCLUSIONS

The geoarchaeological analysis of the two sites, selected for settling towns, provides arguments for assessing the adaptation strategies to different coastal settings under the influence of an overall warm climate.

The Pisa-San Rossore site offers a picture of an alluvial environment adjacent to an urban center that concurrently favored and conditioned the human occupation and the related activities. In this perspective the site records the human interaction with active geomorphic processes, such as floods, competing with an urban development. The sedimentological and stratigraphic lines of evidence, joined to the palynological data collected in U1-4, point to the succession of four major stages of catastrophic alluvial events (Fig. 5) occurred during the Roman Age which caused a marked channel instability of the terminal Arno river reach. This instability resulted in the repeated channel crevassing and flood invasion of an adjacent abandoned channel exploited as a natural dockyard strategic for the commercial exchange from and to the Roman Pisa. These catastrophic events occurred under the influence of a warm climate following to and preceding the Iron Age and early Middle Age cold periods respectively (Lamb, 1996). The climate

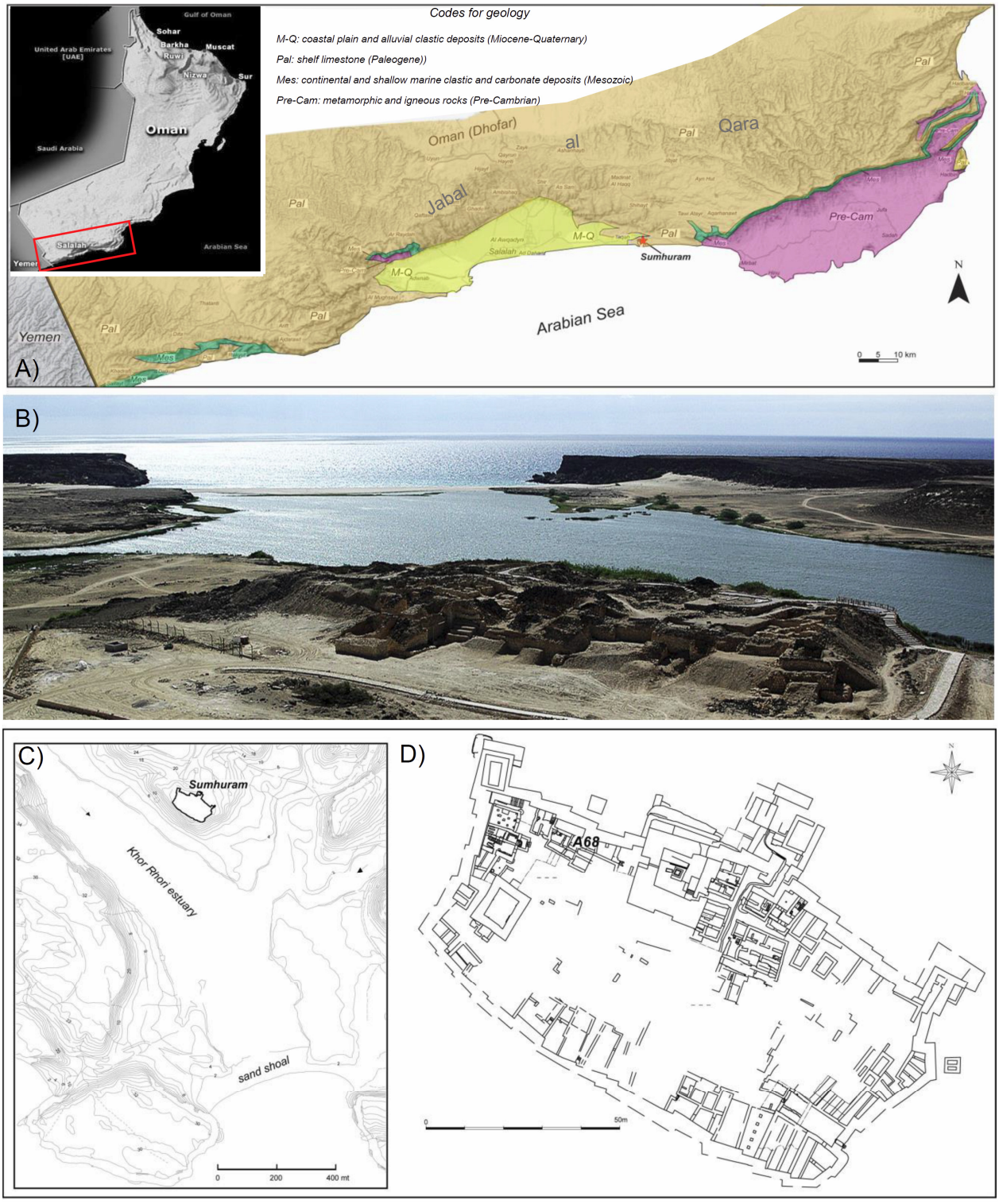

Fig. 3 - A) physiography of the Dhofar Region of Southern Oman with annotated geology. The location of the Sumhuram town is shown; B) panoramic view of Sumhuram looking toward the outlet of the Khor Rhori estuary barred by a sand shoal; C) topography of the area including Sumhuram; D) detail of the Sumhuram structure with location of section A68

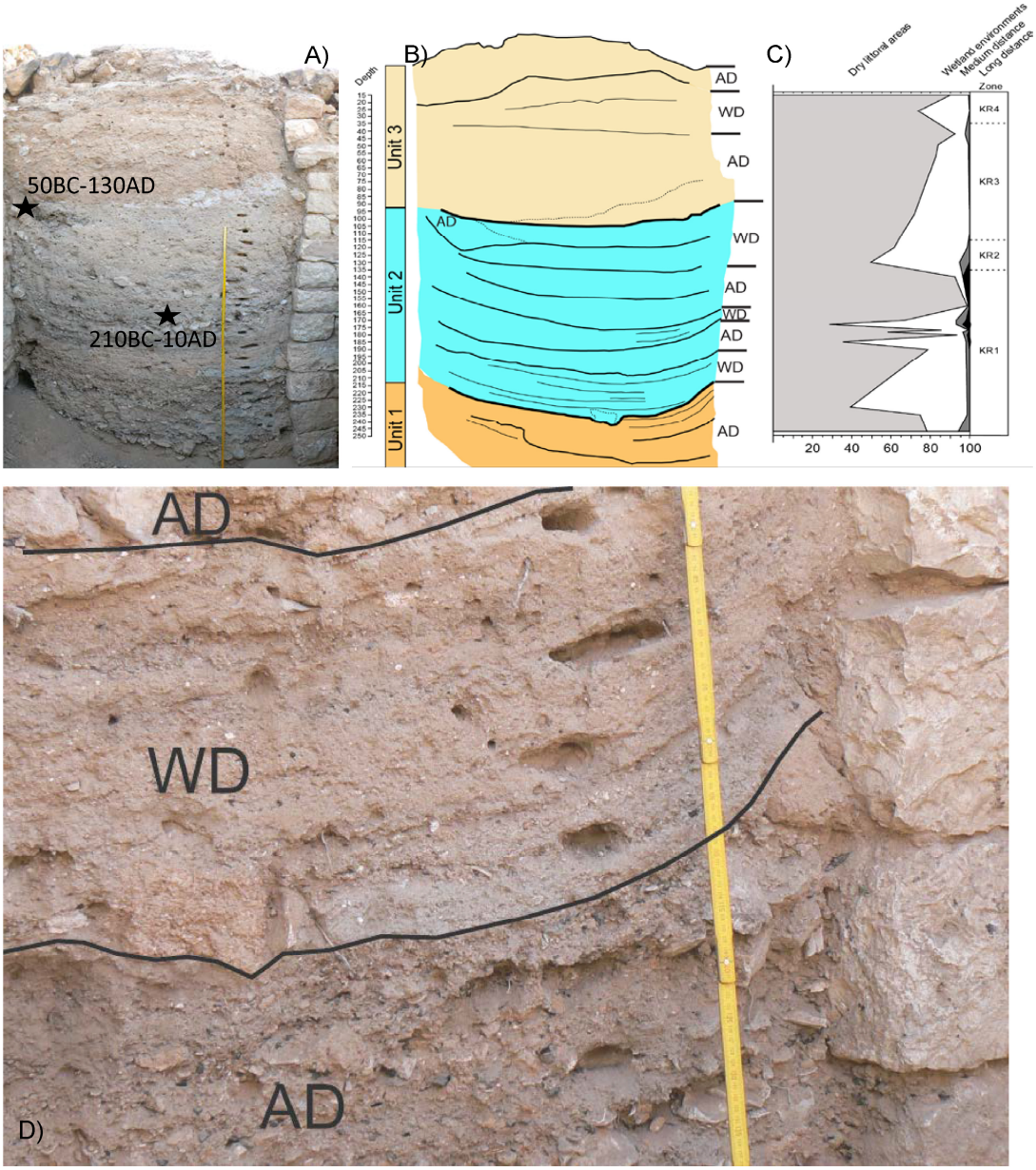

Fig. 4 - A) view of section A68 logged for the stratigraphy and sampled for palynological analysis (Mariotti Lippi et al., 2011): two cal C14 dates obtained from charcoal within the succession are shown; B) the subdivision of the stratified deposits in the section in AD (anthropogenic deposits) and WD (waterlain deposits) layers in turn grouped in the three units; C) the pollen spectra reconstructed for the three units; D) details of AD and WD alternation in unit 2, the meter rod for scale.

regime was characterized by a monsoon-like mode of rainfall distribution determining high-magnitude and/or frequent floods in the river catchments of Central Italy (Fig. 5; Benvenuti et al., 2006).

The Sumhuram site provides a different scenario emerging form the geoarchaeological record. This tells about the ordinary life inside an urbanized trading outpost punctuated by non-anthropic physical processes leaving subtle traces in the record. The WD layers of unit 2 attest to street flooding episodes washing the garbage debris and leaving thin graded layers. The palynologic signature of the WD (Fig. 4C), characterized by a relative abundance of pollen indicative of a wet-environment vegetation together with long-distance pollens, support an hypothesis of occasional running water along the streets related to monsoon-driven heavy rainfall rather than to the intentional discharge of water by the inhabitants. Finally, this sedimentary record is a proxy of a fluctuating monsoonal influence over the site during the three phases of urban development. The

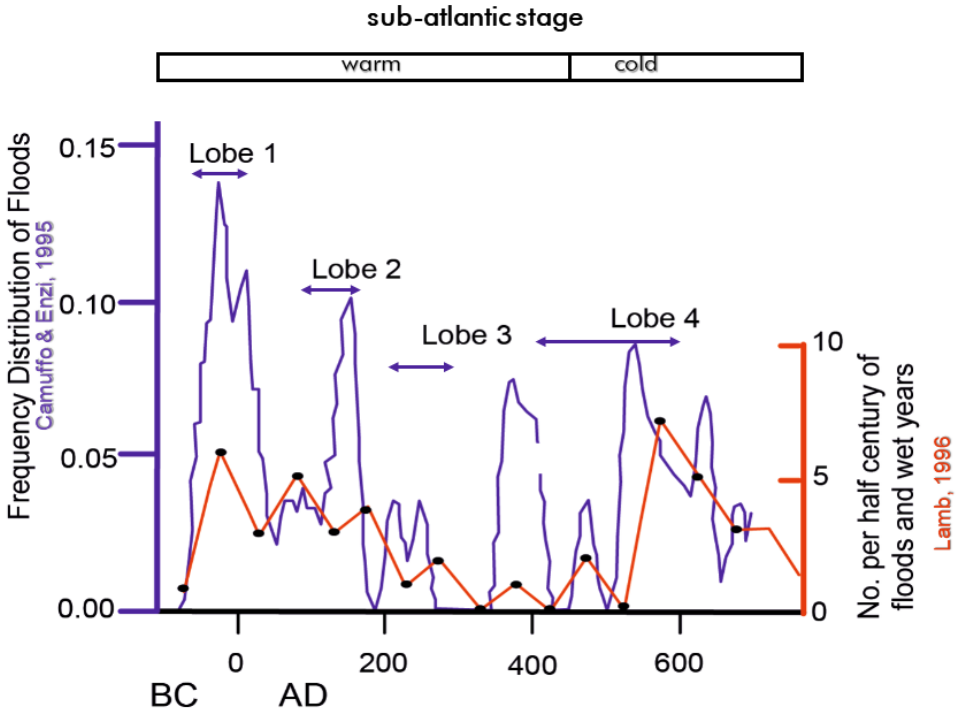

Fig. 5 - The chronologic range of U1-4 (double arrows) defined in the Pisa-San Rossore site plotted against the record of the flood frequency of the Tiber River at Rome (Camuffo & Enzi, 1995) and historical hydro-climatic data for Italy (Lamb, 1996). The good correspondence between the catastrophic floods of the Arno River and the regional proxy of hydro-climatic events across the Roman Age, extends the significance of the geoarchaeological record beyond the limits of the site (Benvenuti et al., 2006 for details)

monsoon circulation was stronger during the development of unit 2 than during the formation of units 1 and 3 dominated by anthropogenic deposition (Mariotti Lippi et al., 2011).

The two discussed sites, located about 5,000 km apart, witnessed a dense human occupation and intense activities mostly related to commercial exchanges across the Mediterranean Sea, the Red Sea and the Indian Ocean. The physical settings selected by the respective communities where significantly different besides both facing coastal areas. The Pisa-San Rossore was a functional place for the development of the Roman Pisa, a town settled on the terminal plain of the Arno and Serchio rivers. The latter, as today, were perennial streams fed by relatively large catchments and subjected to a seasonal variation of discharge typical of the hydro-climatic regime of the Mediterranean region. Sumhuram, was settled on a rocky coast adjacent to the Khor Rhori estuary under a climatic setting typical of the subarid tropics variably affected by the monsoon circulation.

The Pisa-San Rossore was a site bearing a potential high hydraulic risk, evidently calculated in respect to the economic advantage given by transferring goods directly from and toward the contemporary Pisa downtown. Sumhuram was a safe place from geomorphic hazards being also located on a strategic position for the commercial and military control over the Gulf of Aden.

The available chronology for the two sites allows to compare the respective community's adaptation to the effect of the warm climate that characterized the period between the first century B.C. and the first century A.D. In this interval the urban wharf of Pisa was affected by catastrophic floods which destroyed ships and dispersed their cargoes never recovered, as indicated by the archaeo-sedimentary record of U1. In the meantime, Sumhuram experienced the end of its maximum flourishment during phase 1. Given the record of a stronger monsoon circulation over southern Oman between the second century B.C. and the first century A.D., the development of the settlement was supported by higher seasonal rainfall in turn causing also more continuous discharge of the Wadi Darbat. The latter allowed the Khor Rhori estuary to be opened to the sea, differently from the present clogging by a sand shoal, favouring the establishment of an harbour at the town footslope (Avanzini, 2011).

In conclusion, what was a threat for Pisa, differently was an opportunity for Sumhuram. The respective communities cohabited with the dynamic physical conditions until the sites abandonment. Flood after flood, the Pisa wharf underwent a complete silting being exploited for its economic suitability besides the recurrent destruction. The Sumhuram people after the first century A.D. experienced a progressively drier climate that evidently interacted with political and economic events bringing to the fall and abandonment of the town. A reduced moisture over the area may have shrunk the availability of freshwater and as occurring today, determined the clogging of the estuary outlet, a condition that prevented the

approach of commercial ships toward the town.

The geoarchaeology of the two sites provides clues from the past for assessing the strategy of resilience and exploitation of the territory behind the potentially negative impact of its physical processes, that can help in building rational and sustainable relations between the present and future human communities and their environment.

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