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Late Holocene palaeoenvironmental evolution of the northern harbour at the Elaiussa Sebaste archaeological site (south-eastern Turkey): evidence from core ELA6

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Abstract: The ancient site of Elaiussa Sebaste (SE coast of Turkey) was one of the main trading harbours of the Mediterranean, growing in the Augustan period and maintaining its prestige until the Byzantine era. The Arabic invasion that occurred in the second half of the 7th century AD marked its definitive abandonment. A very prominent historical topic concerns the palaeoenvironmental evolution of the northern and southern harbours of Elaiussa Sebaste, including their decline and burial. A wide interdisciplinary study plans to analyse 8 cores drilled in the modern plains, which correspond to the setting of the 2 harbours basins. This geoarchaeological investigation aims to provide a first model of the environmental evolution recorded in the northern port basin, obtained by means of litho- and biofacies analyses from one of the 8 cores (ELA6) that best represents a good reference-succession in order to interpret this evolution. It consists of sediments deposited in a timespan from the 2nd century BC to the 6th century AD, corresponding to the developments of the ancient town and its harbours. The geophysics evidences the depth of the bedrock and the overlaying deposits. Sedimentology, macropalaeontology, and micropalaeontology define a sequence of shallow marine palaeoenvironments, with clear influence of fresh water. The palynology focuses the attention on a short core-interval corresponding to the timespan of 150–190 AD approximately, when the human impact might have controlled this evolution by building and cultivating. A hypothetical scenario might link some natural events (i.e. the uplift of the area, the increase of the sedimentation rate) to the human impact. These causes may have resulted in the siltation of the harbour that finally ended all harbour-related activities. During the timespan of the 2nd century BC to the 4th century AD, the northern harbour of Elaiussa-Sebaste may represent a good test to apply the Ancient Harbour Parasequence.

Key words: Geoarchaeology, ancient harbour, Roman age, sedimentology, foraminifers, molluscs, ostracods, pollen

1. Introduction

Geoscientific methods (mainly sedimentology, palaeontology, pollen analysis, and geophysics) are increasingly applied to archaeological research (e.g., Bernasconi et al., 2006, 2007; Marriner and Morhange, 2007; Algan et al., 2011; Di Rita et al., 2011; Stock et al., 2013; Schneider et al., 2014; Seeliger et al., 2014). They can be used in various fields of research since they can be very interesting tools in helping to define ancient environments, the origin of human settlements, and the natural and human processes that have controlled the evolution of the territory.

The ancient site of Elaiussa Sebaste, located on a NS-elongated promontory along the south-eastern coast of Turkey (Figure 1), was one of the main trading centres of the Mediterranean. It developed during the Late Hellenistic and Augustan periods (2nd century BC to 1st century AD, reaching its apogee during the Antonine (2nd century AD) and Severian (late 2nd to 3rd century AD) ages and maintaining its prestige until the Early Byzantine period. The Arabic invasion that occurred in the second half of the 7th century AD marked its definitive abandonment (Equini Schneider, 2010).

Because of its geographic position and morphological configuration, Elaiussa Sebaste was the junction of the most important shipping and land routes between Syria, Egypt, and the Anatolian peninsula. Thriving maritime activity took advantage of two harbours, positioned respectively on the north and south sides of the promontory. These port facilities presumably ceased trading after the city was abandoned.

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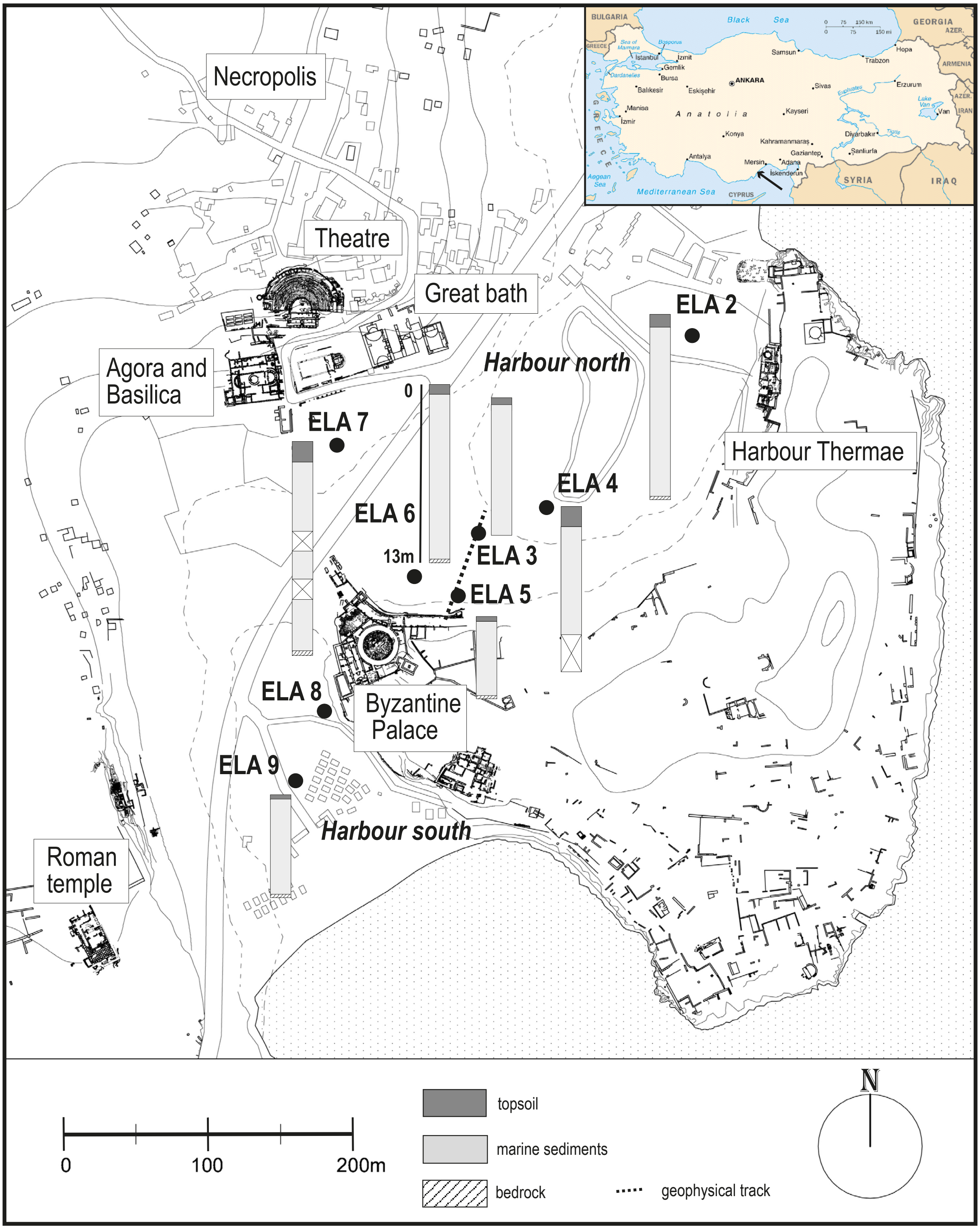

Figure 1. Geographical location of Elaiussa Sebaste including the main archaeological sites, the cores location, the lithostratigraphy, and the geophysical track.

Archaeological excavations carried out over the two last decades (Equini Schneider, 1999, 2003, 2010) provided a large amount of data, allowing for the reconstruction of the history of the ancient city. To date, however, information remains limited as to the geological processes that controlled the evolution of this coastal sector during the last 2000 years. In this respect, the geomorphologic analysis has revealed complex interactions among tectonics, erosion, and sedimentation in this coastal area in both emerged and formerly submerged settings facing the archaeological site.

This geoarchaeological investigation is addressed to the study of a set of eight cores located in this harbour area. The aim is to provide new data for an interpretation of the environmental evolution recorded in the northern port basin, inserting it in the historical context of employment. New findings for this study have been obtained by means of litho- and biofacies analyses of sediment recovered from the long core ELA6, which may represent a good reference-succession in order to interpret this evolution. Additional information has also been derived from geochemical analyses and from a geophysical survey conducted in the study area.

2. Study area

2.1. Geologic and geomorphologic setting

The geological literature concerning the area of the Elaiussa Sebaste settlement is scarce. Previous works concerning geomorphology, sedimentology, gravimetry, and mineralogy were done by Toro and Di Filippo (1999), Di Filippo and Toro (2003), and Ballirano et al. (2003). Although no precise information is available on the structural geology of this site, tectonic uplift phases have been recognised as responsible for several raised shorelines along the Hatay coast, between Turkey and Syria (Pirazzoli et al., 1991). In particular, the region was affected by two uplift movements dated at around 2500 and 1500 years BP.

This settlement developed along a coastal belt characterised by modest hills and plains, and on a promontory for a total area of 23 ha. In general, it is included in the Mersin area, mainly characterised by limestone substrate.

Despite the scarcity of the geological literature regarding the area of the settlement, some geological aspects can be underlined to better interpret our geological data and to determine the environmental evolution of the area. As previously mentioned, 2 harbours existed during the Roman-Byzantine periods. They were built on a coastal area where the outcropping lithotypes are represented by well-stratified light Middle Miocene limestones with very abundant fossils (molluscs, sea urchins, corallinacean algae, corals, etc.) (Toro and Di Filippo, 1999; Ulu, 2002). These beds present a gentle downward slope southwards and also constitute the bedrock of the harbours' basin. Moreover, the eastern side of the ancient north harbour presents rocky shorelines characterised by subvertical walls. Karstic features are also present.

During the historical period, the 2 harbours were separated by an isthmus that, according to the above-mentioned authors, probably did not exist during prehistoric times (Toro and Di Filippo, 1999). The isthmus formation was undoubtedly an important event for the evolution of the area, including the siltation of the harbours. The morphology of the port basins has been estimated by means of a gravimetric investigation (about 250 measurement points) combined with a seismic prospection (Di Filippo and Toro, 2003).

The sediments began accumulating in these basins to the north and south of the isthmus. Today, 2 plains with elevations not exceeding 2 m above sea level are present; their deposits consists of sands-silts mainly related to an aeolian origin, coming from the southwest, together with "colluvium" sediments. The origin of the sandy dune, which presently covers a relatively large sector of the promontory, is considered a sediment accumulation coming from northern sectors, as suggested on the basis of sedimentological and mineralogical analyses of the sandy sediment (Ballirano et al., 2003). At present, these deposits are overlaid by "terra rossa" (Toro and Di Filippo, 1999; Di Filippo and Toro, 2003). Toro and Di Filippo (1999) also reported some hydrogeological data. The surface circulation is virtually absent, in agreement with the nature of the calcareous substrate. There is a freshwater or brackish aquifer present even today. Currently, the evidence of this aquifer is represented by a swamp at the centre of the northern harbour basin.

2.2. Historical and archaeological context

Research carried out from 1995 to the present by the Department of Antiquities of Sapienza University of Rome was initially focused on the vast public quarter built on the coastal strip during the Imperial age and subsequently extended onto the promontory, where the first settlement of Elaiussa was located, and in the suburban area. Several monumental complexes have thus been brought to light, including the Theatre, the Agora, the Great Baths, the Roman Temple, the Harbour Baths, and the north-eastern Necropolis (Figure 1). The settlement was fortified with a wall between the 2nd and the 1st centuries BC, but its true monumental development started in the first half of the 2nd century AD, when defensive walls in the "opus quadratum" were erected to replace the oldest wall and the front of the north port was embellished with a colonnaded portico. Between the late 4th and the early 5th centuries the portico and all the wall circuits were partially closed and reinforced for defence purposes.

During the Byzantine era, in about the mid-5th century AD, a palace of remarkable dimensions was erected on the southern edge of the promontory over the structures built during the Hellenistic and Roman periods (Figure 1); it lays with two wings set on different levels connected by a large circular courtyard. The palace was destroyed towards the mid-6th century.

In the late 6th century and into the first decades of the 7th century, the whole quarter surrounding the southern port was transformed into a domestic and manufacturing area. During this period, Sebaste became one of the most important production centres of Late Roman 1 amphorae, transporting wine all over the Mediterranean basin: many kilns for the production of this kind of pottery have been uncovered in the domestic sector and around the southern port, and a huge amount of ceramic waste all around the area attests to the intensity of this production (Ferrazzoli and Ricci, 2007, 2010; Borgia and Iacomi, 2010).

3. Materials and methods

A set of 8 continuous drill cores (ELA2–ELA9), from 5 to 15.5 m in length, were recovered in 2012 from both the northern (ELA2–ELA7) and the southern (ELA8 and ELA9) ancient harbours (Figure 1). The core site surface elevations range from 0.98 to 1.87 m above mean sea level. Drilling was performed with a modular and portable rotary drilling machine for micropiles and coring with a core diameter of 7 cm.

In 2013, a geophysical survey was performed combining ground penetrating radar (GPR), for a total of 430 m profiles, and electrical resistivity tomography (ERT), for a total of 850 m profiles. A Syscal Pro instrument made by IRIS International and equipped with 48 electrodes (spaced 1.5 or 2 m) was used to acquire a total of 8 profiles with integrated Wenner, Wenner–Schlumberger, and dipole–dipole electrode configurations. The objectives of the GPR surveys were to detect and take images of shallow (less than 2 m) archaeological remains and stratigraphic levels, while ERT was used to define the morphology of the calcareous bedrock below the sediments filling the harbours and to correlate the stratigraphic information obtained by the boreholes.

The boreholes were split into 2 halves, described and sampled at the Department of Mathematics and Geosciences of the University of Trieste. The simplified lithology of the examined cores in this study is shown in Figure 1. The preliminary comparison between the 8 cores suggested core ELA6 as a possible reference-sequence for the study area, mainly on the basis of its length (13 m) and good recovery quality, along with the geographic location in the innermost central sector of the northern ancient harbour (Figure 1). Twenty-four bulk samples (~50 cm^3, corresponding to about 2–3-cm-thick core sections) from core ELA6 were examined for grain size, organic carbon and total nitrogen content, mollusc faunas, and microfossils.

The texture of each sample was determined using a Malvern Mastersizer Hydro2000S Diffraction Laser unit for the <2-mm size fraction. The gravel content was determined using an optical microscope. Sand and mud classes were determined using the Udden–Wentworth (Wentworth, 1922) grain-size classification. Grain-size parameters were determined using the Folk and Ward formulas (Folk and Ward, 1957).

Molluscs, foraminifers, and ostracods were examined in 23 samples separated from the terrigenous fraction, using a 0.5-mm sieve for molluscs and a 0.062-mm sieve for microfauna.

Pollen analysis was carried out on 21 samples collected along the ELA6 core, although pollen and nonpollen palynomorphs (NPPs) were found only in the depth interval between 7.20 and 8.00 m. Pollen extraction from sediments followed standard procedures according to Faegri et al. (1989): each sample (~1 g) was chemically treated with HCl (37%), HF (40%), and NaOH (10%). A known amount of exotic *Lycopodium* spores was added to estimate pollen concentrations. Pollen grain identification and counting was carried out by means of a light microscope at magnifications of 400× and 630×, with the support of atlases (Reille, 1992; Beug, 2004) and of the reference collection of the Laboratory of Palaeobotany and Palynology of Sapienza University of Rome. The computer program Psimpoll 4.27 (Bennett, 2009) was used to plot the pollen diagram. Two pollen types of *Quercus* were distinguished: the *Quercus coccifera* type, which includes pollen from evergreen oaks, which are mostly represented in this region by *Quercus coccifera*, and *Quercus* deciduous, including pollen of all the deciduous oaks. The *Sarcopoterium* type mainly includes pollen of *Sarcopoterium spinosum*, a very common species in the region (Yüceol et al., 2009; Everest, 2013).

Four AMS ^{14}C radiocarbon analyses were performed at the Centre for Isotopic Research for Cultural and Environmental Heritage laboratory at Caserta, Italy, using plant materials (charcoal) (Table 1). The calibration of the radiocarbon dates was based on the IntCal13 dataset (Reimer et al., 2013) by means of Clam 2.2 (Blaauw, 2010), which was also used to calculate the age-depth model through a linear interpolation function between dates. One sample (ELA6-19, 10.4 m deep) provided an age that was inconsistent with the stratigraphic order and was rejected in order to avoid negative accumulation rates, since it is in inverted stratigraphic order. The calibrated age ranges are reported in years BC/AD and refer to 2σ range.

Table 1. Accelerator mass spectrometer radiocarbon ages for samples of the studied core.

Sample	Lab. code	Core level	Depth (m)	^{14}C date (year BP)	δ13C	Two sigma range		Calibrated age, cal. year AD/BC
TS_8	DSH5327	ELA6-5	3.54	1679 ± 34	–33	AD 328	AD 435	AD 381 ± 54
TS_10	DSH5329	ELA6-13	7.43	1834 ± 27	–27	AD 122	AD 245	AD 183 ± 62
TS_11	DSH5330	ELA6-19	10.40	1820 ± 27	–32	AD 126	AD 255	AD 190 ± 64
TS_12	DSH5331	ELA6-23	12.48	2064 ± 33	–23	BC 175	AD 4	BC 90 ± 85

4. Results

The cores are of satisfactory quality as in most cases their recovery was continuous (ELA2, -3, -5, -6, and 9; Figure 1); only in 2 stations (ELA4 and ELA7) did the presence of large clasts and groundwater create gaps in the core recovery. The Miocene limestone bedrock was reached at the base of cores ELA2 (13.5 m), ELA5 (6.0 m), ELA6 (13.0 m), ELA7 (15.2 m), and ELA9 (7.5 m). The rough lithostratigraphy, shown in Figure 1, together with preliminary biotic examinations indicate that most sediments are representative of marine palaeoenvironments; the sediments acquire a yellowish colouration in most superficial layers, probably indicating the accumulation of wind-sourced materials. In the following, data obtained from the geophysical survey along with those derived from the analyses of both inorganic and organic components of core ELA6 are presented.

4.1. Geophysical survey

In this paper, we focus on ERT results as they are the most useful in correlating the boreholes stratigraphy. Almost all the acquired ERT data show high quality with a standard deviation between measurements taken with the same electrodes above 5% only for 1.2% of the whole dataset. We therefore inverted the original profiles in order to recover the subsurface distribution of the real electrical resistivity. Because dense vegetation prevented the investigation at the ELA6 core site, we consider the inverted Wenner–Schlumberger profile ERT3, which is the closest to the ELA6 borehole and almost crosses both ELA3 and ELA5 cores (Figure 2). This profile is representative for the entire northern harbour area and shows a northward deepening of the limestone top, down to at least 16 m below the topographic surface. This behaviour perfectly matches the bedrock depths reached by boreholes ELA5 and ELA6.

Moreover, the ERT data highlight a continuous aquifer at about 1.5–2.5 m below the ground surface. The resistivity values of both the saturated sediments and limestone suggest a fresh water aquifer, with a possible limited brackish water ingression only very close to the present coastal line.

4.2. Sediment texture

The grain-size analyses indicate that the sediments vary from sand to silty sand; the sand content varies from 46.8% to 87.7% and the silt from 9.1% to 43.8%, while clay content is in general <20% (Table 2). In particular, the silty sand sediments are very poorly sorted and characterised by a mean size diameter (Mz) ranging from 3.6 to 4.7 φ (from very fine sand to coarse silt). In the sand texture, fine to very fine sand prevails. Superficial sandy sediments are better sorted: Mz varies from 2.4 to 3.5 φ (fine to very fine sand) (Table 2). Toward the top core, the gravel fraction (descriptive data) increases.

The sand texture trend consists of very coarse to coarse sand, medium sand, and fine to very fine sand, as reported in Figure 3. From the base-core to 9.70 m a decrease of

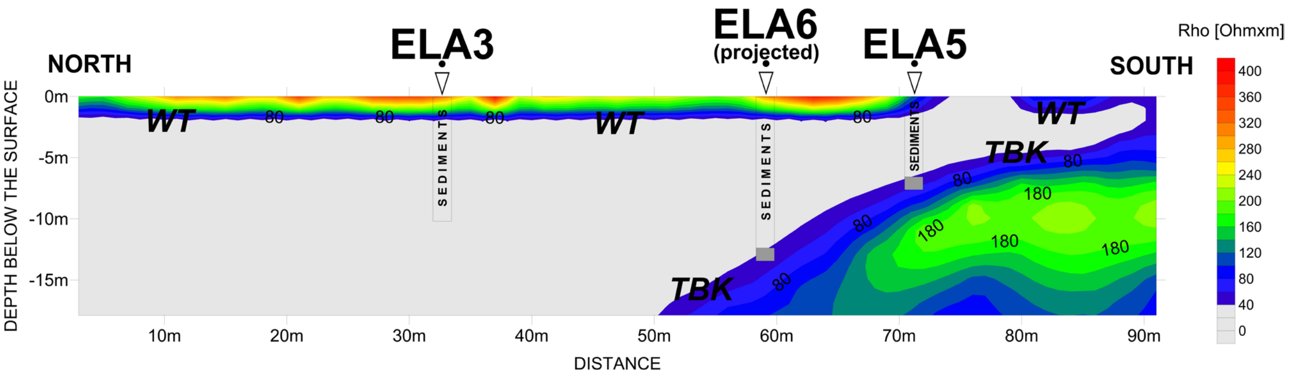

Figure 2. Interpreted inverted ERT profile *ERT3*. WT: water table; TBK: top of the carbonate bedrock reached at 6.0 m and 13.0 m below the surface in cores ELA5 and ELA6, respectively. Please note that resistivity values below 40 Ohmxm are shown in light grey.

Table 2. Grain-size composition of sediments from the core ELA6 as percentage of sand, silt, and clay. Mean size diameter (Mz) and sorting (Sort), expressed in φ (phi), were determined using the Folk and Ward formulas (Folk and Ward, 1957).

Sample depth, m	Sand, %	Silt, %	Clay, %	Mz, φ	Sort, φ
1.30	60.2	25.5	14.3	3.87	3.01
2.00	70.8	18.0	11.2	3.68	2.68
2.60	84.8	10.2	5.0	2.68	1.55
3.17	63.1	21.8	15.1	4.30	2.67
3.86	63.2	24.6	12.3	4.20	2.48
4.32	77.2	15.8	7.0	3.53	1.89
4.96	72.6	19.1	8.3	3.64	2.29
5.47	46.8	40.4	12.8	4.72	2.46
5.97	80.1	12.0	8.0	3.35	1.94
6.82	72.4	18.5	9.1	3.68	2.24
7.12	68.1	25.1	6.7	3.72	2.13
7.43	48.1	43.8	8.1	4.30	2.38
7.85	50.0	42.8	7.3	4.30	2.25
8.40	64.5	29.7	5.8	3.49	2.34
9.20	87.7	9.1	3.2	2.75	1.26
9.46	70.4	22.6	7.0	3.64	2.13
9.70	81.6	13.6	4.8	2.44	1.94
10.40	82.3	13.9	3.7	2.90	1.63
10.90	78.6	17.0	4.4	3.06	1.87
11.40	64.1	26.0	9.9	3.70	2.48
11.98	65.2	28.0	6.8	3.69	2.24
12.48	65.3	29.3	5.4	3.64	2.14
12.94	63.8	30.5	5.7	3.78	2.09

the fine fraction (fine to very fine sand) is evident. The increase of the coarse fraction (medium to very coarse sand) indicates a coarsening-up sequence. The overlying sediment highlights a reversal trend: the finer fraction (fine to very fine sand) increases until a maximum of 84% at 4.32 m defining a fining-up sequence. The increase is irregular and some coarser events are recorded at 8.40 m, 7.43 m, and 4.96 m (Figure 3). From 4 m toward the top, a coarsening-up sequence is recorded. The very coarse sand fraction is associated with a relative increase of the gravel fraction, which comprises a suite of different materials, such as marine molluscs, seeds, grains, and ceramic shards.

4.3. Organic matter

In the studied core, the organic C varies from 0.21% to 3.64%, but in general its content is less than 2% except for levels at 7.43 m, 7.85 m, and 12.48 m, where greater quantities (≥2%) are recorded. In these levels high contents of charcoal fragments together with wood fragments were recovered. The molar ratio C_{org}/N_{tot} indicates the marine origin of the organic matter (ratio: <10) for most of the basal levels (from 11.40 to 8.40 m) and some levels of the upper sequence. At the base of the sequence, except for the level at 12.94 m, in the middle part (from 7.85 to 6.82 m) and occasionally in the upper part (4.96 m and 3.17 m) the ratio value of >10 suggested the continental origin of the organic matter (Pocklington and Leonard, 1979; Goñi et al., 2003) (Figure 3).

4.4. Foraminifera

Identification of foraminifera species follows the Mediterranean systematic proposed by Le Calvez and Le Calvez (1958), Parker (1958), Jorissen (1987), Cimerman and Langer (1991), Levy et al. (1992), Hottinger et al. (1993), Sgarrella and Moncharmont Zei (1993), Meriç et al. (2004, 2014), Bernasconi et al. (2007), and Milker and Schmiedl (2012). The Ellis and Messina online catalogue of foraminifera (http://www.micropress.org) was used for consultation of original taxa descriptions. Interpretation of the Holocene evolution of those foraminifera assemblages examined in the present study was established by comparison with the ecological significance of various associations from several Mediterranean coastal areas (e.g., Jorissen, 1987; Albani and Serandrei Barbero, 1990; Albani et al., 1991; Sgarrella and Moncharmont Zei, 1993; Fiorini and Vaiani, 2001; Donnici and Serandrei Barbero, 2002; Amorosi et al., 2004; Meriç et al., 2004; Melis and Covelli, 2013).

The foraminifera found in the 21 of the 23 examined samples consist of 90 species pertaining to 34 genera; *Bolivina* and *Polymorphina* are reported as spp. The species with a relative abundance of >3% are reported in Figure 4. Most of them are well known in modern Mediterranean coastal settings (brackish water, shoreface, and vegetated shallow marine environments). Some species, such as *Cymbaloporetta bradyi*, *Quinqueloculina patagonica*, and *Spiroloculina antillarum* are described in the Gulf of Aqaba and the Red Sea (Hottinger et al., 1993). The foraminifer assemblage is generally rich and diverse, comprising mainly hyaline and porcellaneous taxa and, very subordinately, agglutinated ones. Species of *Ammonia* and *Elphidium*, hyaline taxa, and *Adelosina*, *Cycloforina*, *Quinqueloculina*, *Sinuloculina*, and *Triloculina* among the porcellaneous ones are the most frequent foraminifers. Among them, *Adelosina dubia*, *Ammonia beccarii*, *A. parkinsoniana*, and *Siphonaperta aspera* are always present, while *Adelosina longirostra*, *Elphidium pulvereum*, *Peneroplis pertusus*, *Quinqueloculina seminulum*, and *Sinoloculina inflata* are distributed in almost all the core sections.

4.5. Molluscs

Molluscan species have been identified using texts on general Mediterranean malacology (Parenzan, 1970;

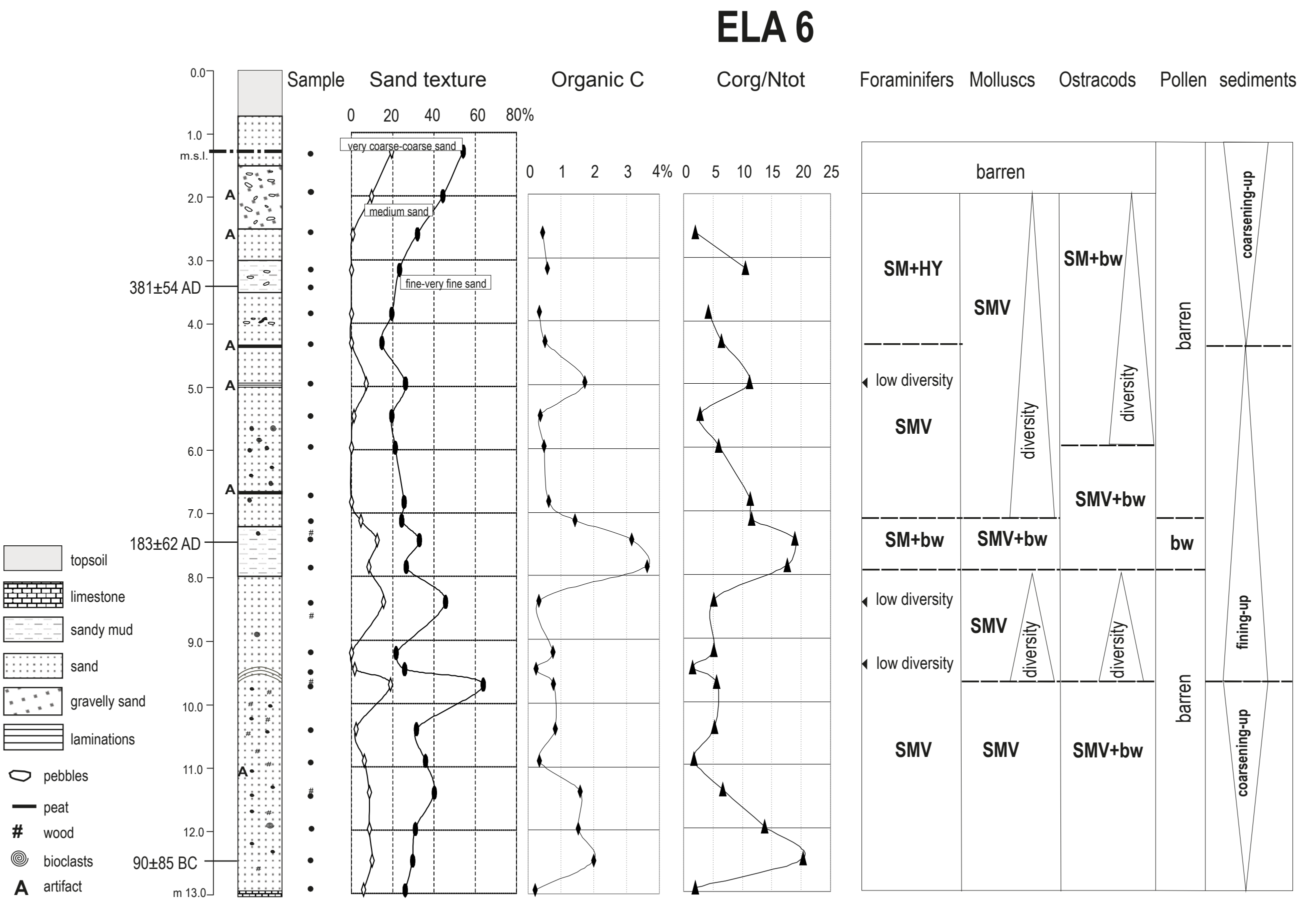

Figure 3. Core ELA6, from left to right: lithostratigraphy, sand (%), organic C (%), C_{org}/N_{tot} contents, and biotic interpretation of the palaeoenvironment. SMV = shallow marine vegetate, SM = shallow marine, bw = brackish water, HY = hydrodynamism.

Giannuzzi-Savelli et al., 1997–2003) as well as contributions more specifically devoted to the East Mediterranean faunas (Pallary, 1911; Barash and Danin, 1982, 1992). As for the palaeoenvironmental interpretation, the molluscan assemblages have been interpreted according to the Mediterranean benthic bionomy of Pérès and Picard (1964), Picard (1965), and Pérès (1982) and according to contributions on Mediterranean ecology and palaeoecology (Bernasconi et al., 1991; Bernasconi and Robba, 1993; Bernasconi and Stanley, 1997).

Molluscan assemblages have been identified in 19 out of 23 examined samples; they are more diversified (either for number of species or number of specimens) in the mid-lower sector of the core, between ~7 and 13 m; in the mid-upper core, molluscs are represented by 1 or 2 species, attaining a maximum of 3 specimens per sample; the whole specimens are generally associated with a large amount of fragmented, unidentifiable shell material.

A total of 44 molluscan species have been recognised and most of them are presently reported in the entire Mediterranean basin (Table 3). Only the gastropod *Rhinoclavis kochi* shows a geographical distribution limited to the eastern coasts of the Mediterranean Sea. Owing to the high shell variability among the *Pusillina* species, against their similar ecological meaning, these taxa have been indicated as the *Pusillina* group.

The most represented species are *Alvania lineata*, *Bittium reticulatum*, and those included in the *Pusillina* group; they are presently related to the Biocoenoses of the Photophilous Algae (AP, sensu Pérès and Picard, 1964) and of the *Posidonia* Meadows (HP, sensu Pérès and Picard, 1964).

4.6. Ostracods

Ostracod assemblages have been identified in 18 out of 22 examined samples; 49 ostracod species were identified (Table 4). Most of them are well known in the Mediterranean Recent and Quaternary literature (Müller, 1894; Bonaduce et al., 1976; Breman, 1976; Montenegro et al., 1998; Pugliese and Stanley, 1991) and, in particular, in the papers of the eastern Mediterranean (among them: Barbeito-Gonzalez, 1971; Athersuch, 1979; Kiliç et al., 2000; Kili, 2001; Kubanç, 2003; Külköylüoğlu et al., 2005;

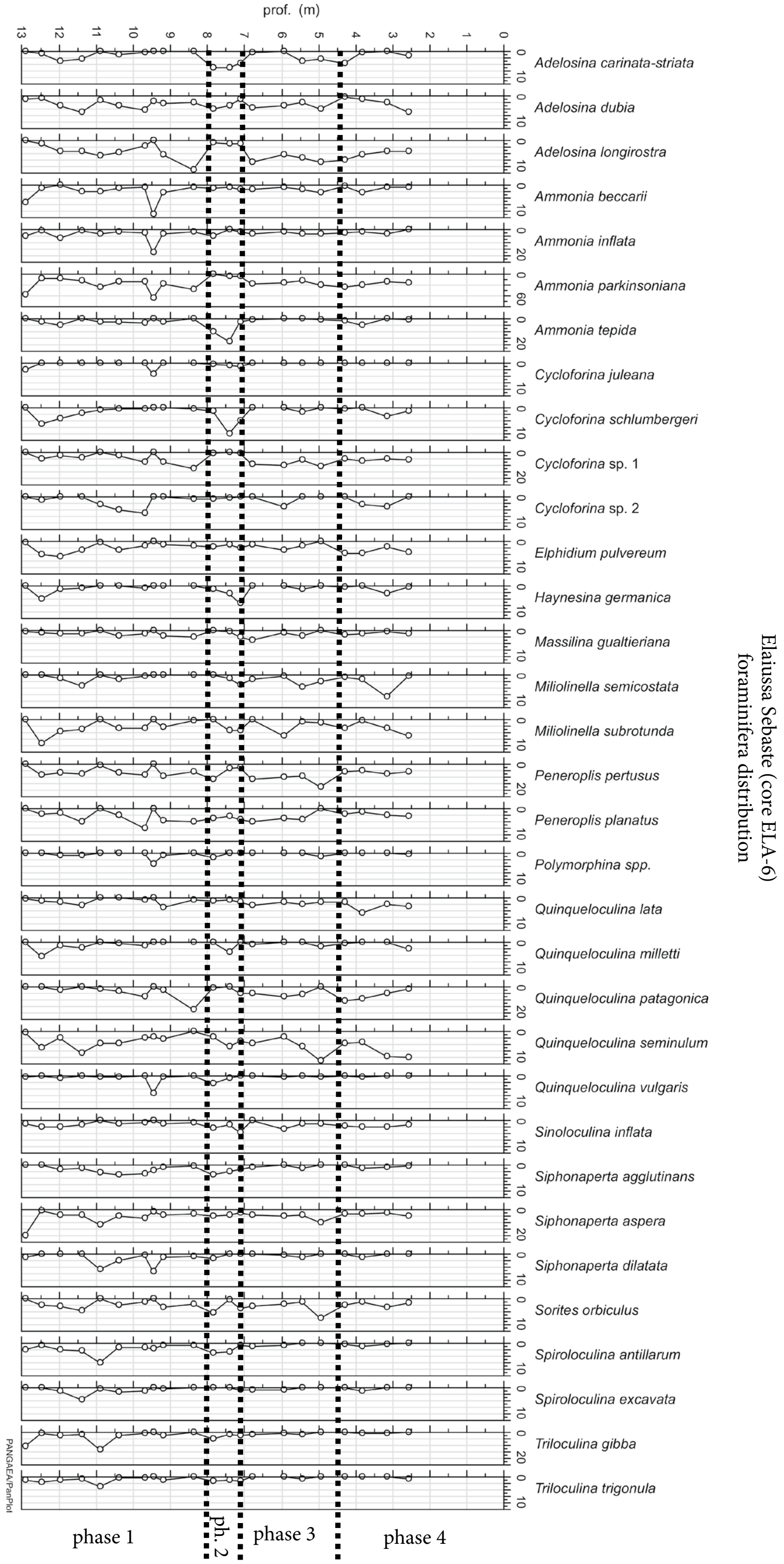

Figure 4. Relative abundance (%) plotted versus depth (m) of the benthic foraminifera in core ELA6. Only the species with a minimum abundance of 3% have been reported.

Table 3. Mollusc occurrences in the core ELA6; the number of specimens for each species is reported. Taxa are listed in alphabetical order. The levels 1.30, 2.00, 3.86, and 4.82 m are not reported since they are barren of molluscs.

Core ELA6																			
Sample depth (m)	2.60	3.17	4.96	5.57	5.97	6.82	7.12	7.43	7.85	8.40	9.20	9.46	9.70	10.40	10.90	11.40	11.98	12.48	12.94
Species																			
Abra prismatica								1											
Abra sp.													1						
Alvamia cimex																	1		
Alvania hispidula									1										
Alvania lineata							1	2	8			4	1	6	3	3		2	3
Alvania sp.	1																		
Bela brachystoma																			1
Bellamya sp.											1								
Bittium reticulatum	1		1				13	33	155	2	6	25	10	23	25	11	6	7	52
Cerithiopsis tubercularis												1			2				3
Cerithium vulgatum																1			3
Cerithium sp.															2				
Chamelea gallina									1			2							
Conus mediterraneus		1															1		
Conus sp.												1							2
Corbula gibba																	1		
Ctena reticulata									2			1							1
Diodora ruppellii									1										
Gibbula rarilineata									4										
Gibbula turbinoides																			3
Gibbula sp.												3							
Glycymeris glycymeris												2							2
Hinia reticulata									7										
Loripes lacteus							4	5	15		1	1		4	1	3			2
Lucinella divaricata									1							1			
Mangelia attenuata												1							
Mangelia wareni												1					1		1
Monophorus perversus												2			1				2
Nassarius sp.																			2
Odostomia sp.															1				
Paphia (*Politapes*) *aurea*									1					1					
Parvicardium exiguum							1	3	3								3		
Parvicardium sp.															1				
Pusillina group				3	1	1	37	37	181		12	8	6	19	7	13	4	14	13
Retusa semisulcata									1										
Rhinoclavis kochii									2					1		1			
Rissoa aartseni														2					
Rissoa auriformis															5				1
Rissoa similis												7		1	5				
Rissoa variabilis						1			3										
Rissoina sp.																			1
Skenea cf. serpuloides					1														
Smaragdia viridis												3		1	1				3
Tellina pulchella														2					
Tellina sp.									1									1	
Thyasira sp.														1					
Tricolia pullus									6				1						
Tricolia speciosa							4		2			3		4	6				6
Turbona cimex									1			1		1	1				5
Venericardia antiquata									1			1		1	2				2
Vexillum ebenus									2			1		1	2				4
Total count	2	1	1	3	2	2	60	81	399	2	20	68	19	68	65	33	17	24	112

Table 4. Ostracod occurrences in the core ELA6; the number of specimens for each species is reported. Taxa are listed in alphabetical order. The displaced specimens are reported with "x". The levels 9.46, 10.90, 11.98, and 12.94 m are not reported since they are barren of ostracods.

Core ELA6																			
Sample depth (m)	1.30	2.00	2.60	3.17	3.86	4.32	4.96	5.47	5.97	6.82	7.12	7.43	7.85	8.40	9.20	9.70	10.40	11.40	12.48
Species																			
Aglayocypris complanata												x							
Aglayocypris triebeli			1	1					6	1	1			1	2	5	3	2	2
Aurila convexa			1	x			1		2					x	2	2	2	1	1
Aurila woodwardi										1	1	1							
Basslerites berchoni			1						2			4				1			
Callistocythere sp.1									1										
Callistocythere sp.2									1										
Candona sp.	x	x	x	x	x	x			x			x		x			x		
Carinocythereis whitei																		3	
Cistacythereis rubra									x			2		1		3			
Cistacythereis caelatura		1	2	3					1			x			1		1		x
Cistacythereis turbida										1								4	
Costa batei										1			1						
Cyprideis torosa					x				x									1	x
Cytherella vulgata												1							
Cytheretta adriatica								x	1	1		4		1		1	x	1	1
Cytheretta subradiosa																1	1		
Cytheroma variabilis												4							
Hemicytherura sp.									x										x
Heterocythereis voraginosa			1			1			2	2	2	1		1		1		2	
Ilyocypris sp.																x			x
Leptocythere levis			1						5			4							1
Leptocythere ramosa					x													1	
Leptocythere rara									2		1								2
Loculicytheretta pavonia		1		1					8		2	1				3	1	6	
Loxoconcha affinis			1						4		1	3	2			1	1		1
Loxoconcha nea									2										
Loxoconcha ovulata									1			3					x		
Loxoconcha rhomboidea		x		x														1	
Loxoconcha rubritincta			1						7	2	1	x		2		4	2	3	
Loxoconcha stellifera									2	1	1					3	1	3	
Mediocytherideis sp.									1										
Neocopytus cylindricus									5			2				2	3	2	
Neocytherideis fasciata									1								1	4	1
Paracytheridea sp.																x			
Pontocythere cf. *P. turbida*		2	1	2	1	x		1	11	5	2	x		4	3	6	4	15	1
Prionocypris sp.									1								x		
Procytherideis complicata									4	4	1	x	1	1		2	x	1	x
Procytherideis subspiralis											x	x							
Sagmatocythere napoliana													1						
Semicytherura inversa												2							
Semicytherura sp.												x							
Tenedocyhere prava												2	x						
Urocythereis cf. *U. britannica*	x	x	2	1		1	1	2	11	5	1	4	1	2	1	3	4	13	x
Urocythreis favosa												2				2	1		1
Xestoleberis communis		2	2	1	x	x			3	2	2	5		x	x	5	1	12	x
Xestoleberis decipiens				1		1			2			2				3	1		x
Xestoleberis dispar		x	x						x	1		1				1	1	2	1
Xestoleberis plana																			1
Total count	0	6	14	10	1	3	2	3	86	27	16	48	6	13	9	49	28	77	13

2007; Meriç et al., 2008; Perçin Paçal, 2011; Tsorou, 2011).

Among them, the most common species are *Aurila* spp., *Basslerites berchoni*, *Callistocythere* spp., *Cistacythereis* spp., *Cytheretta adriatica*, *Leptocythere* spp., *Loculicytheretta pavonia*, *Loxoconcha* spp., *Neocopytus cylindricus*, *Neocytherideis fasciata*, *Pontocythere* cf. *P. turbida*, *Procytherideis* spp., *Semicytherura* spp., and *Urocythereis*, and *Xestoleberis* spp.; a reduced number of *Cyprideis torosa*, *Loxoconcha nea*, *L. stellifera*, and *Aurila voraginosa* were recovered.

4.7. Pollen analysis

The preliminary results of pollen analysis on 6 samples from 7.20 to 8.00 m are presented in a summary diagram including pollen and NPP percentages of selected taxa and number of *Pinus* stomata per gram of sediment (Figure 5).

The pollen record of core ELA6 is characterised by percentages of arboreal pollen (AP) ranging from 45% to 60%. These are mostly represented by *Pinus* (up to 26%), accompanied by significant frequencies of evergreen trees and shrubs, such as *Olea* (15%), *Phillyrea* (9%), *Quercus coccifera* type (8%), and Ericaceae (4%). Among deciduous trees, only *Alnus*, *Fraxinus*, and *Quercus* exceed 1% in most of the analysed levels. Conifers such as *Juniperus*, *Cedrus*, and *Abies* are even less frequent. The nonarboreal pollen percentages (NAP 40%–55%) are mainly composed of Poaceae (11%), Brassicaceae (10%), Cichorioideae (9%), Chenopodiaceae (9%), and Asteroideae (5%). The *Sarcopoterium* type is abundant especially in the lower half of the record (up to 6%). Hygrophilous herbs include Cyperaceae/Juncaceae and scattered finds of *Typha* and Lythraceae pollen, whereas pollen from freshwater aquatics is completely absent. Several woody and herbaceous anthropogenic indicators (e.g., *Vitis*, *Juglans*, cereals) are also recorded. Within the NPPs the increase in *Glomus*, in the upper half of the zone, and the record of foraminiferal linings and cysts of dinoflagellates deserve a mention, as well as the presence of *Pinus* stomata (50–3500 per gram of sediment). The analysed pollen and stomata of *Pinus* probably belong to the local *Pinus brutia* (the Calabrian pine or red pine) (Yüceol et al., 2009). *Pinus* wood microfragments were also observed, but not counted. The total pollen concentration is generally low, varying between 1000 and 10,000 grains/g.

5. Discussion

5.1. Facies interpretation

The interdisciplinary study performed in the ELA6 core suggests some preliminary palaeoenvironmental considerations.

The geophysical investigation carried out along a transect located very close to the core-station ELA6 confirms the presence of the calcareous bedrock that gradually rises in the northern basin from north to south,

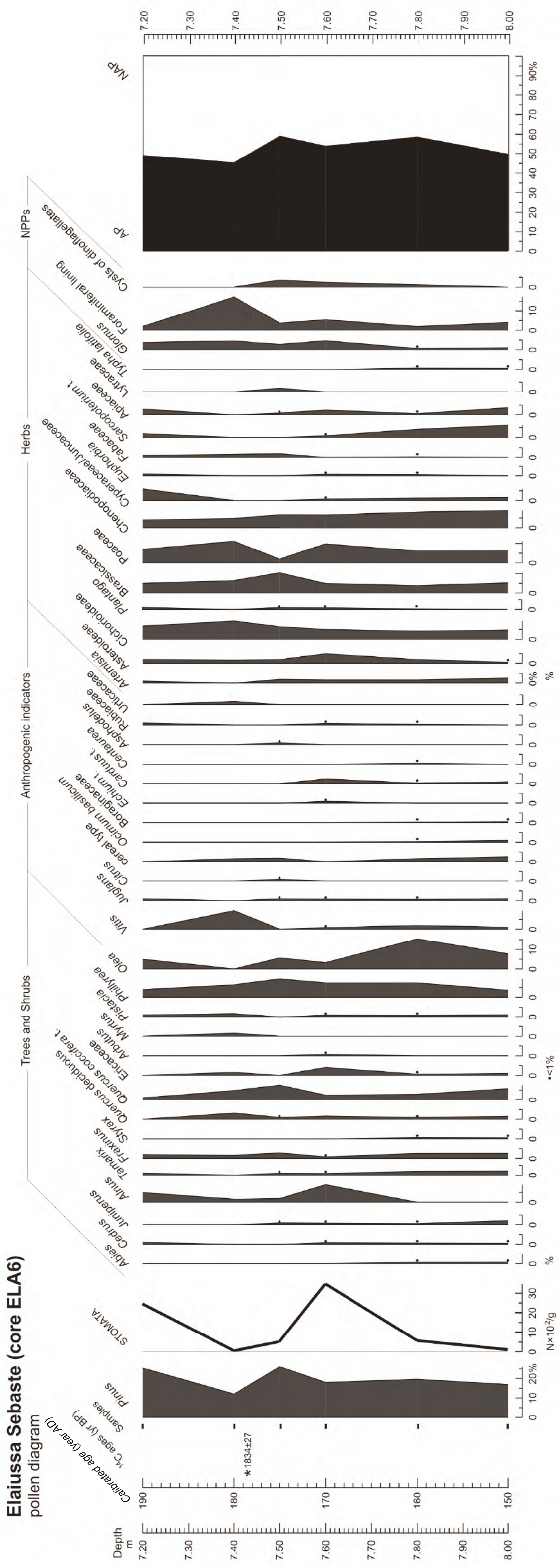

Figure 5. Pollen percentage diagram of selected taxa from ELA6 core, including the concentrations of *Pinus* stomata.

starting from an average depth of 16 m up to the surface in the archaeological site where it forms small reliefs.

Core ELA6 is mostly constituted by a succession of sand to silty sand. A coarsening-up sequence at the core base is followed by the abrupt change from coarse sands to finer sediments at about 9.5 m and the overlying fining-up sequence until 4.3 m. The transition to the upward coarsening-up sequence probably indicates the terminal burial of the harbour area.

These sediments overlying the calcareous bedrock date from about the 2nd century BC to the 6th century AD, as inferred by radiocarbon dating (Table 1). Considering the thickness of these deposits in relation to the above-mentioned timespan, the average sedimentation rate is variable from 1.85 to 1.96 cm/year in the mid-lower and mid-upper sequence, respectively (Figure 6).

Biotic data include foraminifer, mollusc, and ostracod assemblages. Most of the species found are currently living in the Mediterranean basin. The ecological information provided by the different taxa are reported in succession.

Foraminifers are the main contributors of the benthic communities. They mostly consist of species living in a range from brackish to shallow marine settings. In this study, analysing selected species (among them, *Ammonia beccarii*, *A. parkinsoniana*, *Elphidium pulvereum*, and miliolids such as *Adelosina* spp., *Cycloforina* spp., *Miliolinella subrotunda*, *Peneroplis pertusus*, *P. planatus*, *Quinqueloculina* spp., *Sinoloculina* spp., *Siphonaperta* spp., and *Triloculina* spp.), it is possible to define a shallow marine vegetate setting. In fact, these species are present with medium percentages of about 70% (from 27.7% to 80.24%, at 9.46 m and 5.97 m, respectively) that are typical of shallow marine settings rather than brackish water environments. This occurs with more evidence in the interval of 7.85–7.12 m where an increase of *Ammonia tepida* together with other brackish water species has been recorded (from 15.64%, 7.12 m to 32.52%, 7.43 m) (Figure 4). These species are typically considered as euryhaline in Mediterranean and extra-Mediterranean areas (Jorissen, 1987; Albani and Serandrei Barbero, 1990; Sgarrella and Moncharmont Zei, 1993; Debenay et al., 2000; Melis and Violanti, 2006; Melis and Covelli, 2013). *Ammonia beccarii* and *A. parkinsoniana*, characterised by stronger and ornamented tests, indicate the increasing hydrodynamics at the base and, above all, toward the top of the core.

The foraminifer assemblages record four phases in the environmental evolution, from bottom to top (Figures 3 and 4):

1) From 13 to ~8.0 m in core depth, the assemblages are relatively well diversified and characterised by species that normally occur in shallow marine environments. The noteworthy occurrences of phytophilous species, such as *Peneroplis planatus*, *P. pertusus*, and *Sorites orbiculus*, characterise this interval, indicating that this environment was well lighted and populated by algae and marine phanerogams. Higher values of diversity, with respect to other studied samples, indicate the stability of the palaeoenvironmental conditions. Along this interval, two levels denoting a degradation of the environmental conditions were recorded at a depth of 9.46 and 8.40 m, respectively, where an increase of *Ammonia parkinsoniana* is in evidence.

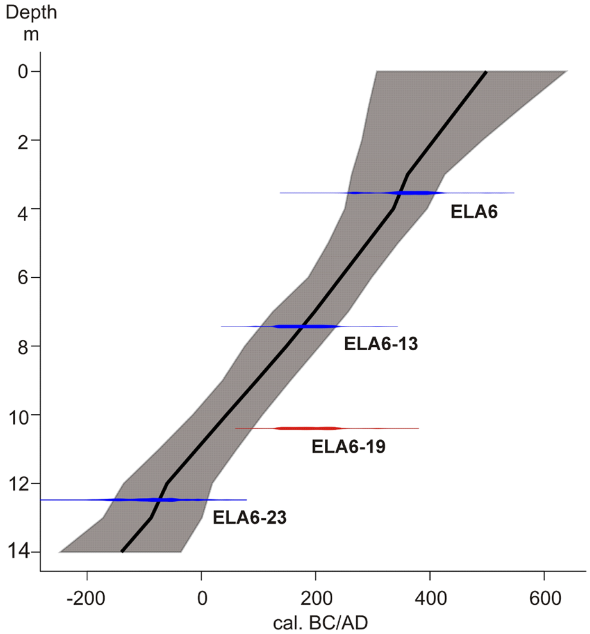

Figure 6. Age–depth model based on linear interpolation of best point calibration age estimates from ^{14}C dates, obtained using the Clam 2.2 software (Blaauw, 2010). The grey envelope shows the final 95% confidence intervals based on 1000 iterations. The ages of bottom and top core have been extrapolated by the program.

2) From ~8.0 to ~7.0 m in core depth, the assemblage is characterised by an increase of brackish water taxa, such as *Ammonia tepida*, *Haynesina germanica*, *H. depressula*, and *Cycloforina schlumbergeri*. The diversity remains high, testifying to the duration of the stable conditions.

3) From ~7.0 to ~4.5 m in core depth, the assemblage records a condition similar to that recorded at the base of the core (phase 1).

4) From ~4.5 m to the top of the core we noted a slight deterioration of the environmental conditions characterised by a shallow marine less-vegetated bottom and by a relative increase in hydrodynamism, as evidenced by the increasing occurrence of *Ammonia beccarii* and *A. parkinsoniana*.

Molluscan assemblages are generally dominated by a few species. In the samples better diversified (>3 species), the molluscs *Alvania lineata*, *Bittium reticulatum*, and those included in the *Pusillina* group attain a dominance value that ranges from ~60% (samples at 9.46 m, 10.90 m, 12.48 m, and 12.94 m) up to >80% (samples at 7.12–7.85 m, 9.20 m, 9.70 m, 11.40 m, and 12.48 m). Also present is *Loripes lacteus*, a species indicative of the Biocoenosis of the Superficial Muddy Sands in Sheltered Areas (SVMC). These taxa are associated with other species indicative either of the AP and HP biocoenoses (*Cerithium vulgatum*, *Smaragdia viridis*, *Tricolia pullus*, *Turbona cimex*, and *Venericardia antiquata*), or of other biocoenoses and/or communities consistent with the previous ones: these latter are the Biocoenosis of the Fine Well Sorted Sands (SFBC), represented by *Chamelea gallina*, *Mangelia attenuata*, and *Tellina pulchella*, and the Heterogeneous Community (PE) represented by the bivalve *Parvicardium exiguum*. The Biocoenosis of the Euryhaline and Euritherm Lagoons (LEE) is recorded in only one sample (at 7.85 m), represented by the gastropod *Hinia reticulata*.

As a whole, the molluscan assemblages record four phases in the environmental evolution of the northern port basin (Figure 3), from bottom to top:

1) From 13 to ~9.5 m in core depth, the assemblages are relatively well diversified, dominated by taxa related to the AP and HP biocoenoses: among these, *A. lineata*, *B. reticulatum*, and the *Pusillina* group are the best represented, attaining a cumulative dominance value of at least 60% in the samples included in this core section. They are accompanied by other species usually living in the leaf stratum of the phanerogams, such as *Cerithium vulgatum* and *Smaragdia viridis*, exclusively recorded in this core section, and *Tricolia pullus*, *Turbonacimex*, and *Venericardia antiquata* (Basso et al., 2008). These data suggest a shallow marine environment characterised by a well-oxygenated sandy bottom, covered by an extensive vegetation.

2) From ~9.5 to ~8.5 m, the molluscan assemblages are still dominated by taxa indicative of a vegetated seafloor and associated with these are *Chamelea gallina* and *Mangelia attenuata*, taxa related to the SFBC biocoenosis. The most remarkable aspect of the assemblages in this core section, however, is the progressive decrease in the number of both species and specimens to the extent that only *Bittium reticulatum* is recorded with 2 specimens at 8.40 m. This evolution points to a progressive degradation of the environmental conditions in the timespan corresponding to this core section sedimentation.

3) From ~8.0 m to ~7.0 m, the assemblages again include a relatively large number of species, still dominated by the group *A. lineata*, *B. reticulatum*, and *Pusillina*. In this core section *Parvicardium exiguum* is also recorded, a species denoting an instability of the environment (PE community) probably due to a finer sediment input in the port basin. These data indicate the restoration of a marine, still vegetated bottom composed of a sandy silt sediment and characterised by temporarily brackish conditions, as testified by the presence of *Hinia reticulata* at 7.85 m.

4) From ~7.0 m to the core top, the marine environment is still evidenced by the presence of *Bittium reticulatum* and *Pusillina* group species. However, the diversity of the assemblages rapidly decreases and the state of the preservation of the shell material becomes progressively very poor. This suggests a relatively rapid phase of environmental degradation associated with an increased energy level and shallower depths (shore face setting) that lasted until the port basin was completely filled.

The ostracod fauna can be subdivided into 3 ecological groups indicative of shallow marine (SM), brackish water (BW), and fresh water (FW) environments. The autochthonous species belong to the SM and BW groups that are predominant and scarce in all the assemblages, respectively. In this case, the SM group generally includes species tolerant of fresh water influence. Moreover, most species, and particularly *Xestoleberis* spp., indicate vegetated substrates. Only one species (*Cytherella vulgata*) can be considered eurybathic.

The SM group consists of an abundant number of species. Among the SM taxa, several species (*Neocytherideis fasciata*, *Procytherideis* spp., etc.) characterise shallow coastal settings in the proximity of fresh water influence and/or high energy sea floors (*Cytheretta adriatica*, *Pontocythere* cf. *turbida*, *Urocythereis* spp.) as reported by Montenegro et al. (1998).

The BW group is constituted by a reduced number of species (*Cyprideis torosa*, *Loxoconcha nea*, *L. stellifera*, *Aurila voraginosa*, etc.) that are commonly signalled in paralic Mediterranean settings (Montenegro and Pugliese, 1996; Ruiz et al., 2000; Arbulla et al., 2001) and sometimes in shallow marine settings fed by submarine fresh water springs (Masoli, 1967–1968; Arbulla et al., 2000).

The FW group is mostly composed of specimens of young instars. The most common specimens belong to Candonidae. The near-exclusive presence of young instars suggests that they may be considered displaced and thus indicative of fresh water influence.

Thus, the predominant SM taxa highlight a shallow marine scenario characterised by a fresh water influence, due to the constant presence of a very shallow aquifer, as demonstrated by the presence of rare autochthonous BW species in the assemblages and sporadic displaced FW specimens.

The ostracod assemblages give evidence of the following phases of the evolution (Figure 3):

1) From 13 to ~9.5 m, the core deposits yield the ostracod groups FW, BW, and SM. The assemblage presents good specific diversity and consists of predominant marine species (group SM) together with subordinate brackish

water taxa (group BW). Displaced fresh water forms are present. They highlight a shallow marine vegetated environment affected by the influence of fresh water. The richest fauna appears at 11.40 m (where the SM and BW groups reach more than 91% and almost 9%, respectively. The level at 10.90 m presents rare fragments of valves, recording an episode of high bottom energy.

2) From ~9.5 to ~8.5 m, the core deposits present a barren level overlaid by others characterised by a very scarce ostracod fauna characterised, where present, by SM species. This phase represents an episode of degraded conditions of the substrate.

3) From ~8.5 m to 6.0 m, the core deposits contain the ostracod groups FW, BW, and SM. The assemblage presents good specific diversity and consists of SM species, together with subordinate brackish water taxa. Displaced fresh water forms are present. Level 7.85 m represents an episode of very rich specific diversity mainly characterised by more than 90% of SM species, including 34% of *Xestoleberis* spp. and 10 % of the BW group. Moreover, this level represents an episode of fine deposition. In general, the ostracod fauna denotes a shallow marine vegetated environment affected by the influence of fresh water.

4) From 6.0 to the core top, the deposits yield the ostracod groups FW, BW, and SM. The very scarce specific diversity and number of specimens give evidence of a possible phase of higher hydrodynamism of the shallow marine environment affected by the influence of fresh water.

5.2. Vegetational landscape and human impact

According to the age–depth model (Figure 6), the pollen diagram from core ELA6 records ca. 40 years of vegetation history near Elaiussa Sebaste and its surrounding area, during the interval from 150 to 190 AD. As profiled by the pollen record of ELA6, at that time the landscape was dominated by semiopen vegetation with woody conenoses characterised by *Pinus* and evergreen shrubs, such as *Olea*, *Phillyrea*, and *Quercus coccifera*, which are still commonly found in the region (Everest, 2013). Atalay and Efe (2008) indicate for the Mediterranean region of Turkey the coexistence of two main vegetation formations: 1) the *Pinus brutia* forest, and 2) the *maquis* and *garrigue* vegetation, whose leading species are *Quercus coccifera*, *Phillyrea latifolia*, and *Olea europea* var. *sylvestris* among others. *Pinus brutia* forest represents the natural potential vegetation of the Mediterranean region, while the maquis and garrigue vegetation grows where red pine forest has been completely or partly cleared. Thus, the pollen assemblages of ELA6 clearly reflect an admixture of these two types of vegetation, suggesting a semiopen landscape shaped by the pressure of the human activities. The development of herbaceous vegetation typical of open environments, characterised by Brassicaceae, Poaceae, and Cichorioideae, was also favoured. Among the herbs, the record of the *Sarcopoterium* type is consistent with the abundance of *Sarcopoterium spinosum* in the region (Everest, 2013). This thorny bush dominates large stretches of the eastern Mediterranean region where the maquis has failed to regenerate due to the long-term effects of anthropogenic pressure (Zohary, 1962). Its record at Elaiussa provides further evidence of human-induced vegetation disturbance and degradation, as also reported in other pollen sites of the eastern Mediterranean Basin in historical times (e.g., Baruch, 1990; Jahns, 2003).

Between 150 and 190 AD, the main pollen indicators of land use point to cereal and *Vitis* cultivation. *Olea* can be partly attributed to local exploitation, although it also grows in natural maquis vegetation. The local cultivation and trade of *Olea* is confirmed by archaeological evidence in situ (Equini Schneider, 1999; Efe et al., 2011; Ferrazzoli, 2013). The name “Elaiussa” itself derives from olive. The increase in *Vitis* concomitant with the decrease in *Olea* in the upper part of the record suggests an enhancement in *Vitis* production that may have affected both natural vegetation and soil preservation, as suggested by both the decrease in the *Sarcopoterium* type, consistent with the conversion of uncultivated degraded land to vineyards, and the parallel increase in hyphae of *Glomus*, an arbuscular mycorrhizal fungus pointing to soil erosion and downwash (Kolaczek et al., 2012), possibly related to the intensification of land exploitation.

As to the modest record of *Juglans* pollen, it may indicate both local cultivated plants and regional pollen rain. At that time walnuts were distributed in many areas of eastern and western Anatolia, mostly as cultivated trees (e.g., Wick et al., 2003; Müllenhoff et al., 2004; Aradhya et al., 2007; Kaniewski et al., 2007; Bakker et al., 2012). The scattered presence of other anthropogenic indicators, such as Rubiaceae, *Echium*, *Carduus* type, *Centaurea*, and *Asphodelus*, concur in depicting an environment disturbed by humans.

The features of the regional vegetation is reflected in both the records of many broadleaved deciduous trees such as *Fraxinus*, *Alnus*, *Quercus*, and *Styrax*, and by the conifers *Cedrus* and *Abies*. These taxa still live in Mersin Province not far from Elaiussa (Yüceol et al., 2009; Everest, 2013).

The contemporary presence of Chenopodiaceae, foraminiferal linings, and dinoflagellate cysts, as in other Mediterranean coastal pollen records in saline environments (Bellotti et al., 2011; Di Rita and Melis, 2013), supports the micropalaeontological evidence of a brackish/marine aquatic environment.

5.3. Palaeoenvironmental interpretation

The biotic data indicate that the sediments of core ELA6 record a palaeoenvironmental evolution of shallow marine settings, mostly vegetated, and often influenced by fresh water. This general framework persists from the 2nd century BC to the 6th century AD. Nevertheless, this investigation highlights some variations along the core. These environmental fluctuations are clearly recorded by the changes of both the abiotic characters (texture and organic C content) and the different biodiversity of the foraminifer, ostracod, and mollusc assemblages. According to the method currently used in the description of the Neogene to Recent Mediterranean palaeoenvironments (Pugliese and Stanley, 1991; Bernasconi and Robba, 1993; Bernasconi et al., 2006, 2007), high and low species richness recorded in the examined samples is interpreted as indications of favourable and degraded environmental conditions, respectively.

Starting from the bottom, at the core interval from 13.0 to 9.6 m (approximately the 2nd century BC to 50 AD), the biotic data indicate a shallow marine vegetate environment with moderate hydrodynamism, good oxygenation (low organic C content), and well-diversified benthic life (Figures 3 and 4; Tables 3 and 4). The coarsening-up sequence along this interval could be comparable to the base of the Ancient Harbour Parasequence (AHP) described by Marriner and Morhange (2006a, 2007). According to these authors, this facies might record the transition from Pre-Harbour to Proto-Harbour conditions. Although no archaeological evidence can highlight this transition, this phase may correspond to the first important moments in the life of the city, attributable to the late Hellenistic to early Roman Imperial period, when the harbour was most certainly in use, even if not yet completely settled (Equini, 1999).

At the depth interval from 9.6 to 8.0 m, corresponding to about the 2nd century AD, a progressive decrease in diversity is recorded for the three faunal groups. In particular, the disappearance of the ostracods at the base of this core section seems to forecast the incipient benthic crisis. This critical condition could be related to a decrease in water circulation as also indicated by the sediment texture: an abrupt change from coarse sands to finer sediments at about 9.5 m could suggest the transition from natural to artificial conditions with the development of a somewhat more protected environment (Harbour Foundation Surface, HFS), sensu Marriner and Morhange (2006a, 2007).

The overlying interval, comprised between 8.0 and 7.2 m and dated at about 150–200 AD, records a new increase in diversity: for the first time, brackish water species are detected in all groups, particularly among the foraminifers, pointing toward a less saline condition in an otherwise shallow marine, vegetated setting. In addition, the mollusc *Parvicardium exiguum* indicates environmental instability (PE community), likely due to the change in the sediment inputs. In this respect, this interval, included into a fining-up sequence, is characterised by the highest percentage of organic matter content (organic C: >3.0%) of continental origin (C_{org}/N_{tot}: >10) suggesting that the port basin, in addition to the fine inorganic sediments, was receiving a relatively strong contribution from the surrounding emerged areas.

In this interval, the pollen record provides a snapshot of the cultural landscape surrounding Elaiussa Sebaste. The pollen indicators of human activity suggest both intense local agricultural practices, mainly olive, grapevine, and cereal cultivation, and the exploitation of natural plant resources. We speculate that the recorded decrease of water salinity conditions may be related to the input of fresh water used for agricultural practices documented by archaeological and pollen evidence.

Indeed, the archaeological data testify to the remarkable extension of urban development during this chronological interval. The presence of several production installations with presses and collection basins and a notable increase in the local production of amphorae are clear indicators of how the city was able to produce agricultural products, above all wine and olive oil, in such surplus quantities as to allow for considerable export (Equini Schneider, 2007; Ferrazzoli, 2013). In this period, the port basin, although efficient as a trade location, was affected by strong human influence, which contributed to environmental instability. These conditions could represent the Ancient Harbour Facies (AHF) evidenced by Marriner and Morhange (2006a, 2007).

Above this core interval, from 7.0 m upward, the molluscan and ostracod assemblages show a progressive decrease in species richness, while the foraminifers show more episodic phases of low diversity (Figure 3). However, already from the core depth of 4.0 m (from about 350 AD) up to 2 m, the faunistic data point toward conditions that were definitely unsuitable for benthic life, likely due to an increase in the hydrodynamism of the environment associated with an aeolian input. This is supported either by the presence of very few shoreface taxa (among them the foraminifer *Ammonia parkinsoniana*) and by the coarsening-upward trend recorded by the sediment texture. This likely records the abandonment of the harbour (Harbour Abandonment Facies, HAF, sensu Marriner and Morhange, 2006a, 2007) and the consequent silting of the basin, possibly accelerated by the absence of its maintenance, in response to an economic and political crisis that occurred in the 4th century AD. In addition, tectonic movements could have played a role in the harbour decline: in fact, during the Early Byzantine Tectonic Paroxysm (EBTP), an uplift event occurred in relation to a devastating earthquake that affected the entire Levantine region at the end of the 4th century AD

(Pirazzoli et al., 1996; Pararas-Carayannis, 2011). This event may have been one of the causes responsible for the definitive decline of the harbour. If we estimate an average sedimentation rate of <2 cm/year, we can easily predict a rapid natural burial of the basin, in this case even accelerated by the absence of dredging action inside the port. The archaeological evidence seems to confirm the partial silting up of the southern sector of the northern harbour. Nevertheless, there is evidence of flourishing trade activities at Elaiussa Sebaste from the late 4th century to the 7th century, mainly related to the production of wine and to its export all over the Mediterranean through the Late Roman 1 amphorae manufactured in loco (Ferrazzoli and Ricci, 2007, 2008, 2010).

The 2-m core top is devoid of fauna; here the sediments record paedogenesis and present-day anthropic activity, thus not providing further information regarding the environmental evolution.

In conclusion, the multidisciplinary study of the core ELA6 allowed the reconstruction of a detailed environmental evolution of the northern port basin at Elaiussa Sebaste. The timespan evidences changes that encompass the port life from its dawn to its complete abandonment and testify to the transition from natural to human phases of impact. Since the time they first settled, Romans likely exploited the port for both trading and fishing activities, but initially without altering the natural environment. A strong human impact is recorded in conjunction with the monumental and agricultural development of Elaiussa Sebaste that occurred in the first half of the 2nd century AD. Thus, to maintain conditions favourable to exploitation, the settlers should also have dredged the port, as was the case in other Mediterranean harbours (Marriner and Morhange, 2006b). However, core ELA6 does not show any sediment failure that could indicate such an activity. Instead, our data suggest the beginning of a slow decline of the port by a progressive silting up of the basin. This could be the result of the conjunction of economic/political problems that induced the locals to give up the maintenance of the port facility, or it could be the result of natural factors such as tectonic uplift, which induced a strong input of coarse sediment into the basin. The evidence of thriving trade until the 7th century AD at Elaiussa Sebaste could suggest that the activities were directed to another location, possibly the southern port basin.

More information is needed to refine the environmental reconstruction. The study of the remaining cores combined with the ongoing data from geophysics and geochemistry are needed to draw conclusions regarding the broader environmental picture; this is the first step in obtaining the correlation between geological and archaeological information and reconstructing the history of Elaiussa Sebaste from its early development up to the decline of its harbours.

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