

Mediterranean eustatic and climatic variations vs the Phoenician-Punic settlement/abandonment phases

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Keywords: geoarcheology, sea level changes, coastal historic sites

Abstract – This paper focuses on the eustatic and climatic variations that occurred in the Mediterranean during the Phoenician-Punic period (13th-2nd century BC) and their impact on the spread and the settlement and economic development of the two civilizations. Through a multidisciplinary approach, the geographical-settlement contexts, as well as the archaeological and climatic ones, were surveyed and analyzed, paying particular attention to changes in sea level, geomorphological conditions and trade routes. The research was developed through the search for published archaeological and historical sources, including paleoclimatic, archaeobotanical and archaeozoological data.

The published data relating to the Phoenician and Punic sites were tabulated, highlighting their period of foundation, crisis and disappearance, trying to highlight the correlations between settlements, climate and human activity. The aim was therefore to understand and reconstruct the climatic/settlement phases, contributing to a deeper understanding of the historical and natural dynamics of the Mediterranean in ancient times.

I. INTRODUCTION

The Mediterranean, defined by Georges Gras as "an enclosed space, at the center of the world" [1], has represented a crucial crossroads of economic, political, and cultural exchanges for centuries. Connected to the Atlantic only by the Strait of Gibraltar, it was the edge of the known world until the 15th century, when new ocean routes diminished its central role [2]. Despite this, the Mediterranean has preserved the memory of the civilizations that crossed it, including the Phoenicians and Punic, seafaring peoples who explored and colonized numerous coasts, contributing to the formation of a cultural and symbolic vision of the sea. Starting from this premise, this paper aims to analyze the relationship between these civilizations and the Mediterranean, divided

into two parts. The first reconstructs the history and material culture of the Phoenician-Punic period, with particular attention to ports, landing places, routes, amphorae, and fishponds, to understand their economic and commercial organization. The second part focuses on the evolution of the coastal landscape between the 13th century B.C. and 146 BC, linked to climatic and morphological variations (proxy data, eustatic variations) and their impact on the Phoenician-Punic settlement and abandonment phases. The study follows a geoarchaeological approach to reconstruct the paleoenvironment and analyze the adaptation strategies implemented by the Phoenicians and Punic. The objective is to understand how the coastal landscape influenced their settlement, agricultural, and economic choices, contributing to a broader reflection on the protection of the Mediterranean heritage [1].

II. MATERIALS AND METHODOLOGY

The research is based on extensive bibliographical consultation through scientific and academic sources (Scopus, Google Scholar, ResearchGate, Academia.edu, OPAC SBN) and specialized libraries (e.g., BIASA). The bibliographic data allowed us to map and georeference the settlement sites during the period under consideration and then correlate their historical events with paleoclimatic and eustatic data. Specifically, an interdisciplinary approach is adopted, integrating historical, archaeological, and environmental sources. The materials analyzed included paleoclimatic data (isotope curves obtained from speleothems, marine and glacial cores), pollen diagrams obtained from cores in strategic areas, and archaeobotanical and archaeozoological studies.

III. HISTORICAL AND CHRONOLOGICAL CONTEXTS

Phoenicia was an ancient region located along the narrow coastal strip of present-day Lebanon, characterized by an extremely varied terrain: the sea on one side and the mountains (Lebanon and Anti-Lebanon) on the other. Despite its small size, it featured great environmental diversity, with dense cedar forests in the mountainous

areas and fertile plains suitable for agriculture. Cedar wood, in particular, became a highly sought-after luxury commodity, especially in Egypt. The Phoenicians, likely originating from the Canaanites, developed from the 13th century BC and organized their territory into coastal city-states such as Byblos, Sidon, and Tyre, equipped with natural ports and connected to the hinterland by valleys such as the Beqaa [3]. The difficulty of expanding inland pushed the Phoenicians towards the sea, initiating significant maritime and commercial activity. They exploited the Mediterranean currents and winds to chart complex but effective routes that took them to the Atlantic coasts of the Iberian Peninsula and Morocco. Their expansion, between the 8th and 7th centuries BC, was favored by the fall of the Mycenaean and Assyrian pressure. The Phoenicians excelled in navigation and commercial organization, founding colonies such as Carthage. The main sea routes ran from Tyre to Cadiz, following the northern coast (Cyprus, Rhodes, Sicily, Sardinia), and for the return journey they often preferred the southern coast (North Africa). They navigated during the day, but also at night, orienting themselves by the stars, such as the so-called "Phoenician Star." Phoenician history conventionally begins in 1200 BC and ends in 330 BC with the arrival of Alexander the Great and the Hellenization of the territory. However, the difficulty in precisely defining the geographical and chronological boundaries of this civilization reflects their dynamic identity and the primarily mercantile and maritime nature of their culture [4]. Their diffusion occurred initially through the opening of trade routes along the coasts of the eastern Mediterranean, passing through Cyprus, Syria, and Egypt. Subsequently, between the 10th and 8th centuries BC, they founded numerous colonies in the central and western Mediterranean. Among the most important colonies were Utica and Carthage in North Africa, Motya in Sicily, Nora and Tharros in Sardinia, and Gadir (modern-day Cadiz) in the Iberian Peninsula. These foundations were not territorial conquests, but emporia and trading posts designed to facilitate the exchange of local and oriental goods.

Carthage, founded by the Phoenicians of Tyre around 814 BC, became the main center of the Punic civilization, the direct heir of the Phoenician civilization [5]. The Punic (i.e., the Western Phoenicians) developed a powerful thalassocracy, a maritime dominion, extending control over shipping routes, the major Mediterranean islands, and vast coastal areas. Carthage became one of the most important powers in the western Mediterranean, entering into conflict with Rome in the famous Punic Wars. The Phoenician-Punic diffusion had a lasting impact: they contributed to the diffusion of the phonetic alphabet, naval techniques, and a trade network connecting East and West. Their cultural and commercial influence was such that many coastal cities of the Mediterranean bore traces of their presence for centuries. With the fall of Carthage to

the Romans in 146 BC, the political career of the Punic ended, but the Phoenician legacy remained alive in the Mediterranean heritage [6].

IV. EUSTATIC AND CLIMATIC VARIATIONS BETWEEN XII SEC. B.C. AND III SEC. B.C.

In the Mediterranean archaeological context, chronological sequences vary depending on the area, particularly between the Near East, Anatolia, and the Syro-Palestinian regions, where the Phoenicians developed. Paleoclimatic curves derived from natural indicators (climate proxies) such as ice, sediments, trees, corals, stalagmites, and pollen are used to reconstruct past climates. The main investigation techniques include ice and sediment cores, dendrochronology, palynology, paleobotany, isotopic analysis, and the study of corals and speleothems [7-11]. The data obtained can cover very long periods, with varying temporal resolutions. The Holocene, which began approximately 11,700 years ago, is characterized by different climatic phases (Preboreal, Boreal, Atlantic, Subboreal, and Subatlantic), with the Mediterranean being an area sensitive to environmental changes, given its location between the arid African climate and the humid European climate [12]. This region, thanks to the wealth of historical and archaeological sources, is ideal for studying the relationship between climate and civilization. Climate analysis is addressed on a regional scale to then arrive at a general synthesis.

The period examined spans from the Late Bronze Age (13th century BC) to the Roman Imperial Age, a period characterized by climate warming. Data from the Mediterranean Sea showed different climate patterns: cooling in the Aegean, warming in the Strait of Sicily, and stable conditions in other areas. Significant climatic events are recorded around 2913 BC and 2040 BC, corresponding to important historical changes. Between 1800 and 1100 BC, a warm period coincided with cultural transformations such as the collapse of Mycenaean centers, due to increasing aridity. A cooling period around 800 BC accompanied the transition to the Iron Age. In the Alboran Sea, between the Mediterranean and the Atlantic, sedimentary data highlight correlations between climate variations and Phoenician and Punic events, such as the founding and abandonment of sites [13]. The same holds true for the Balearic Sea and the Strait of Sicily, where microfossil and pollen analyses were compared with data from Lake Monticchio and Greenland ice cores. The observed variations show alternating warm and cold phases, such as the "Iron Age cold period," the Roman climatic optimum, the Late Antiquity deterioration, and the subsequent Medieval optimum. The Monticchio lakes, in southern Italy, offer detailed palynological data confirming the link between vegetation and climate: herbaceous species in arid eras (such as the Homeric period) and an increase in trees in warm-humid periods

(such as the Roman period). Finally, comparing multiple climate archives from the last 20,000 years (marine sediments, ice, pollen, isotopes), a strong coherence emerges between climate oscillations and major historical events [14]. Climate change, therefore, has profoundly influenced the development, expansion and decline of Mediterranean civilizations, including the Phoenician and Punic ones [13].

The phenomenon of eustasy, introduced by Austrian geologist Edward Suess in 1888, can be defined as an indicator of global sea level variations caused by changes in the mass or volume of the oceans. During glacial periods, the accumulation of ice on land caused sea levels to drop, while in interglacial periods, such as the current one, the melting of ice sheets and the thermal expansion of water caused them to rise. Originally, these variations were considered uniform and global, but today we know that they are also influenced by local factors, such as isostatic and tectonic movements, which cause deformations of the Earth's crust and vertical displacements of the surface, making sea level changes a relative and non-homogeneous phenomenon. Sea level fluctuations are due to a combination of factors: melting ice (glacio-eustasy), the redistribution of surface and groundwater (hydro-eustasy), temperature and salinity variations that alter the density and therefore the volume of water (thermosteric and halosteric changes), as well as tectonic and sedimentary processes that modify the shape and capacity of ocean basins (tectono-eustasy and sediment-eustasy) [15]. While some of these factors are climate-related, others are geological in nature. Eustatic curves, reconstructed through stratigraphic and isotopic analyses, highlight significant sea level fluctuations over the last 200,000 years. Around 150,000 years ago, the sea level underwent a significant decline, followed by a slow rise. During the Holocene, starting approximately 4,000–3,000 years ago, sea levels approached current levels. During the Phoenician era, sea levels were still lower than today, with a progressive rise during the Punic era. A prime example is found in the Strait of Messina, where, during the last glaciation, sea levels were approximately 72 meters lower, with a subsequent rise also modulated by regional tectonic uplift estimated at approximately 2 mm/year. The reconstruction of these variations is based on natural indicators, such as marine and terrestrial sediments, fossils, corals, aquifers, and coastal vegetation, and on anthropogenic indicators, including port structures, salt pans, fish tanks, and submerged artifacts, as well as historical sources. These elements allow us to date sea level variations with good precision and understand how human communities have responded to environmental changes.

In the Mediterranean, a geologically active basin, the interaction between climatic dynamics and tectonic movements has profoundly affected coastal morphology. Italy, like many other regions of the basin, represents a

paradigmatic example of this complexity, where geological, archaeological, and paleoclimatic data are integrated to reconstruct landscape evolution. This type of investigation is fundamental to understanding the adaptation of ancient civilizations, such as the Phoenician-Punic, to changes in their natural environment [16-19]. In the following project, the Phoenician and Punic foundation sites were located on specific paleoclimatic curves; subsequently, the sites were located based on the chronology of their disappearance.

The chosen diagram was extrapolated from the article by [13], in which paleoclimatic trends were extrapolated in different areas of the Mediterranean through the analysis of the ratio between Magnesium and Calcium obtained from foraminiferal shells: the results allowed to obtain the average of past temperatures and the corresponding anomaly (Figs. 1-2).

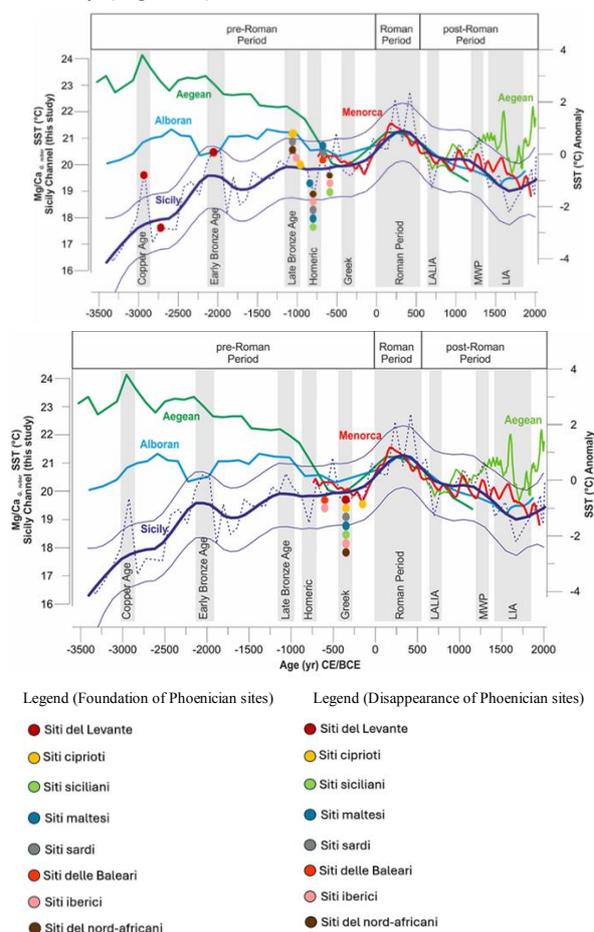


Figure 1 – Picture on: paleoclimatic curves show that most Phoenician settlements (sites) were founded during periods when the climate was relatively warmer. Picture below: paleoclimatic curves show that Phoenician settlements, starting in the 6th century BC, underwent a period of crisis and decline; some of them disappeared, particularly along the Iberian and Balearic coasts.

The same procedure has been followed for the Punic foundation sites, and similarly about the date of abandonment and disappearance of some sites.

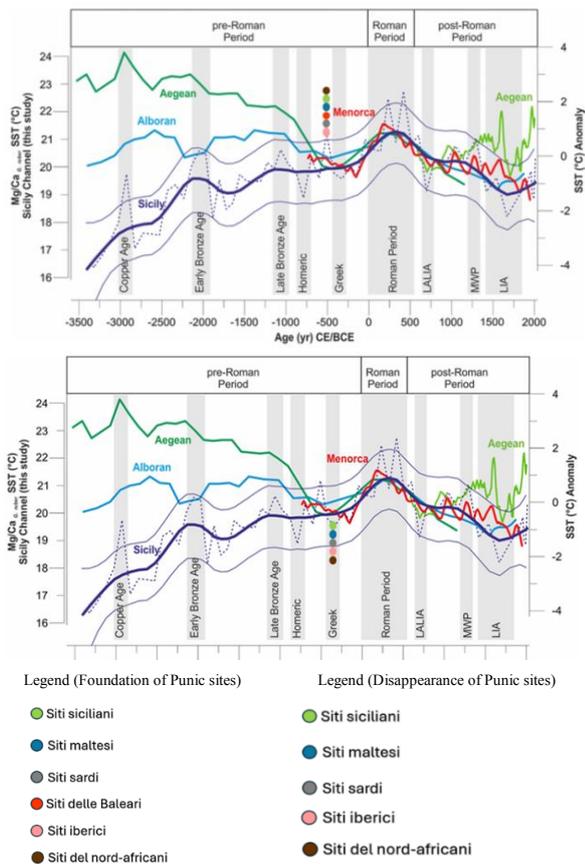


Figure 2 – Picture on: The paleoclimatic curves show that the foundation of the Punic settlements (sites) is chronologically placed in a warm period, specifically between the 7th and shortly before the 6th century BC. Picture below: the paleoclimatic curves indicate that between the 4th and 3rd centuries BC the Punic settlements underwent a period of serious climatic crisis, characterised by a cold phase and then a hot one, the latter leading to a severe drought.

V. DISCUSSION AND FINAL REMARKS

The research addresses a complex topic, focusing on the interaction between humans and the environment in the Phoenician and Punic contexts of the Mediterranean, through an interdisciplinary perspective that combined archaeological, paleoclimatic, and paleoenvironmental data. The research, conducted with a deductive-inductive approach and at both macro- and micro-regional scales, highlights how climate and environmental changes

profoundly impacted the settlement, economic, and demographic dynamics of past civilizations.

The analysis of climate proxies relating to temperature, precipitation, and sea level, combined with archaeological data, reveals a complex picture of climate fluctuations between the 13th century BC and the 2nd century BC, which led to phases of development, crisis, and transformation for Phoenician and Punic societies. Warm, dry periods, such as that between 1200 and 1000 BC, coincided with the Bronze Age crisis and the decline of settlements, while colder, wetter phases, such as that between 1000 and 800 BC, led to a cultural decline known as the "Hellenic Middle Ages." Beginning in the 8th century BC, a new, warmer and moderately humid climatic phase favored the great era of Phoenician and Greek colonization, with the spread of viticulture, olive growing, and new settlement and trade techniques.

The cyclical alternation of warm and cold phases, often accompanied by seismic and volcanic events, or sea level variations, directly influenced the development trajectories of coastal civilizations. In particular, the phenomenon of transgressive eustasy, the rise in sea level, had ambivalent effects: on the one hand, it expanded navigation possibilities, fertilized coastal lands, and favored the creation of new harbors; on the other, it generated erosion, silting, and the abandonment of port sites. Civilizations that were able to adapt, through technological and infrastructural innovations (such as the transition from wells to cisterns), were able to endure and prosper; others, such as the settlement of Sa Caleta or the Tartessian civilization, failed to overcome environmental crises, leading to collapse or irreversible transformations. Current research has also highlighted a correlation between volcanic and seismic phenomena and climate change: the most powerful volcanic eruptions lead to the accumulation of gases such as nitrogen, water vapor, and carbon dioxide in the atmosphere in such large quantities that they reduce atmospheric transparency. This phenomenon leads to reduced penetration of sunlight and, consequently, a cooling of the Earth's surface. For this reason, the maximum reduction in solar radiation occurs approximately 3-4 months after the eruption, when the effects of the acid clouds merge with those of the dust blanket [20].

The contribution of this research lies in having demonstrated how the environment is not just a passive backdrop to human history, but also an active and sometimes decisive agent.

Climate conditions, sea level variations, natural resources, and water management profoundly influenced the political, economic, and social structure of Phoenician and Punic communities.

A prime example is the transition, between the 5th and 3rd centuries BC, from a water system based on wells to one centered on cisterns, a tangible sign of technological adaptation to changing environmental conditions. Finally,

the comparison with the Roman Warm Period (3rd century BC–4th century AD), also known as the Roman Climatic Optimum, highlights the difference between past natural cycles and current climate change (Tab. 1): while in the past, the temperature increase occurred slowly and naturally, today we are experiencing rapid, anthropogenic warming, with much more drastic and difficult-to-manage consequences. This comparison reinforces the idea that studying ancient civilizations and their relationship with the environment can offer fundamental insights for understanding current and future climate challenges.

Chronology	Climate	Economy	Settlements	Eustatism
1200–1100 B.C.	Warm – arid	Economic crisis	Contraction and destruction of settlements	Marine transgression
1100–800 B.C.	Cold – humid	Economic crisis – cultural regression	Disappearance of settlements	Marine regression
750 B.C. – end of 7th c. B.C.	Cold – humid	Spread of olive, vine, and silk cultivation	Colonization with the foundation of new Phoenician settlements	Marine transgression
600 B.C. – 400 B.C.	Cold – humid	Economic crisis	Disappearance of Phoenician settlements	Marine regression
400 B.C. – 200 B.C.	Warm – dry	Drought – water crisis	Punic settlements	Marine transgression
100 B.C. – onwards	Warm – humid	Economic development	New Roman settlements	Marine transgression

Table 1 – Synthesis of the chronological historical phases and climate, economy and development of settlements and eustasy from 1200 BC to the Roman era.

The data collected in the project revealed how the close correlation between climate and human civilization is so strong that it determines the periods that mark the development of societies, or, better said, those periods in which human civilization achieves a state of collective welfare.

Among the different climatic phases identified in the project (Tab. 2), which have recurred cyclically throughout human history, it is clear that the "hot-humid" phase allows human civilizations to reach their peak development. In particular, if we consider other phases, such as the hot-arid and cold-humid phases, we note a retention of settlements, with their abandonment and disappearance, and a stagnation of trade. In the hot-arid phases, such as the one that touched the lands of the Fertile Crescent in 1200 BC, high temperatures caused the sea level to rise, which in turn enabled the development of trade, but the scarcity of rainfall affected the yield of crops. Drought created an imbalance between resources and population density. These imbalances resulted in conflict and famine. The invasions of the Sea Peoples would represent a key link between eustasy, which facilitated sea migration, and the movement of peoples in search of new lands to cultivate a response to the environmental stress caused by drought. Conversely, during the cold and humid period, despite abundant rainfall, the frigid climate does not allow for

large harvests. Furthermore, water stagnation, with recurrent flooding of the river networks, must be considered. Low temperatures lead to a drop in sea level, making navigation extremely difficult: the retreat of the coastline and the emergence of sandbanks and sandbanks lead to a decline in trade, detrimental to coastal settlements that benefit from maritime trade.

The compromised trade routes lead to the abandonment of coastal sites, de facto changing the Mediterranean coastal landscape.

Through this framework, we proceeded to summarise the salient points typical of the climatic and eustatic phases identified in the project and their respective effects on the actions of human societies (Tab. 2).

HOT AND ARID PHASE	COLD AND HUMID PHASE	HOT AND HUMID PHASE
<ul style="list-style-type: none"> •Sea level rise •Favorable conditions for navigation •Construction of barriers to contain sea advancement •Low rainfall •Change in water resource management •Famines •Invasions (Sea Peoples) •Destruction •Period: Final Bronze Age 	<ul style="list-style-type: none"> •Sea level drop •Unfavorable conditions for navigation •Seafloor reduction •Shoals and sandbanks •Coastline retreat •Disruption of trade routes •Impact on river ports •Poor crop yields, difficulties in livestock farming, soil erosion, flooding •Periods: Dark Age and 6th–5th centuries B.C. 	<ul style="list-style-type: none"> •Sea level rise •Favorable conditions for navigation •Founding of new colonies •Increase in trade •Increase in agricultural yield •Population growth •Construction of palisades (by the Punics) or dams and piers (by the Romans) •Abundant summer rainfall •Increased water availability •Periods: Phoenician colonization and expansion, Roman climatic optimum

Table 2 - Historical and environmental conditions in different climatic phases.

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