Chapter 14
Paleo-Hazards in the Coastal Mediterranean: A Geoarchaeological Approach

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Human societies in coastal zones are arguably the populations most prone to the danger of geological hazards and the need to devise strategies to live with them. Not only do settlers in coastal zones confront, the major geological problems of earthquake and volcanic eruption as do inland societies, but any such hazards are compounded by the situation of life at the interface between land and sea. Tsunamis are an obvious link between classical geological hazards and the ocean, but slower connections are also encountered, for example sea-level rise associated with the wasting away of the Pleistocene ice sheets. Slow, neotectonic changes along coasts are also significant, and starting in the Neolithic, human activities become a notable forcing factor in this zone.

In fact, the human dimension is a two way street. Pioneer settlements from the Neolithic onwards are clearly constrained by their environments. After initial colonization of the habitat, the environment is in turn manipulated by the human inhabitants, who are now recognized as a geological force in their own right. Seldom are the human manipulations without significant problems, so that humanity itself has become a geological hazard.

Geoarchaeology has long focused on paleonvironmental reconstructions and landscape evolution (Rapp and Hill 1998; Goldberg and Macphail 2005). Recent research progress in the Mediterranean has furthered the understanding of paleohazards in the coastal areas (Marriner and Morhange 2007). In this chapter, we draw on current topical examples to focus on four types of coastal hazard: slow postglacial sea-level rise, rapid sea-level rise, coastal deformation linked to base-level sediment inputs, and human impacts.

14.1 Slow Postglacial Sea-Level Rise in the Coastal Mediterranean

Since 18,000 year BP a sea-level rise of about 120 m has drowned significant areas of Paleolithic archaeology beneath the sea (Fig. 14.1; Masters and Flemming 1983). Until recent times, human societies in coastal regions were totally at the mercy of sea-level rise. Only late in history, essentially beginning with the Roman era, did people acquire the engineering sophistication to do something about it.

Southern France provides good evidence of the effect of sea-level rise on human settlement in late prehistory. Cosquer, for example, is a partially drowned Paleolithic cave near Marseille (Fig. 14.2). The cave has an entrance 37 m below present sea level, and was partially submerged around 7000 year BP during the marine transgression of the continental shelf (Fig. 14.3; Sartoretto et al. 1995). The preserved horse paintings in it demonstrate that the present sea level is at its highest point since the postglacial period in a so-called tectonically stable setting. Many coastal Paleolithic sites may therefore have been drowned offshore, waiting the investigations of underwater archaeologists. The sea-level change was too slow to constitute a hazard in the true meaning of the word, but, in any case, no technology was yet available to protect against the inexorable rise of the sea.

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See Plate 14a in the Color Plate Section; also available at: extras.springer.com

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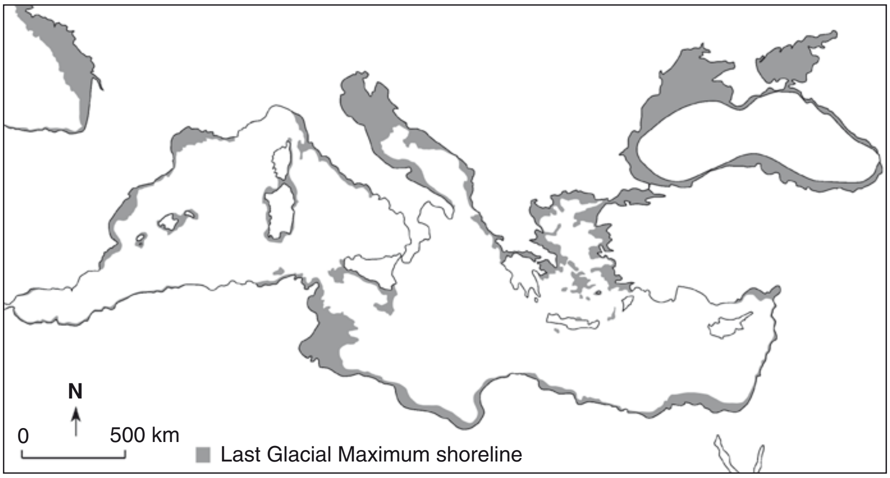

Fig. 14.1 Trangression of the Mediterranean coastal shelf since the Last Glacial Maximum

Since ca. 6000 year BP, sea-level changes have been characterized by a pronounced deceleration linked to the end of glacio-eustatic forcing. After this period, local adjustments are for the most part attributable to glacio-isostatic factors, and in the case of the Mediterranean coast, relative sea-level changes of less than 10 m are observed (Fairbanks 1989; Bard et al. 1996). Within this context, Mediterranean environments provide excellent paleobathymetric archives due to a precise biological zonation of marine species living just above or below mean sea level, and given the density of archaeological coastal remains such as harbors and drowned urban areas (Blackman 1982a, b; Franco 1996). A methodology refined by Laborel and Laborel-Deguen (1994) has been successfully applied to numerous excavations including the ancient harbor of Marseille (Pirazzoli and Thommeret 1973; Morhange et al. 2001) and Pozzuoli (Morhange et al. 2006a). Such data, fundamental to understanding the vertical distribution of coastal remains, were traditionally derived from the geological record (note the exception of Lyell's (1830) observations on the bored columns of the Roman market of Puteoli (Pozzuoli), and the intensive fieldwork of Negris (1904) in coastal

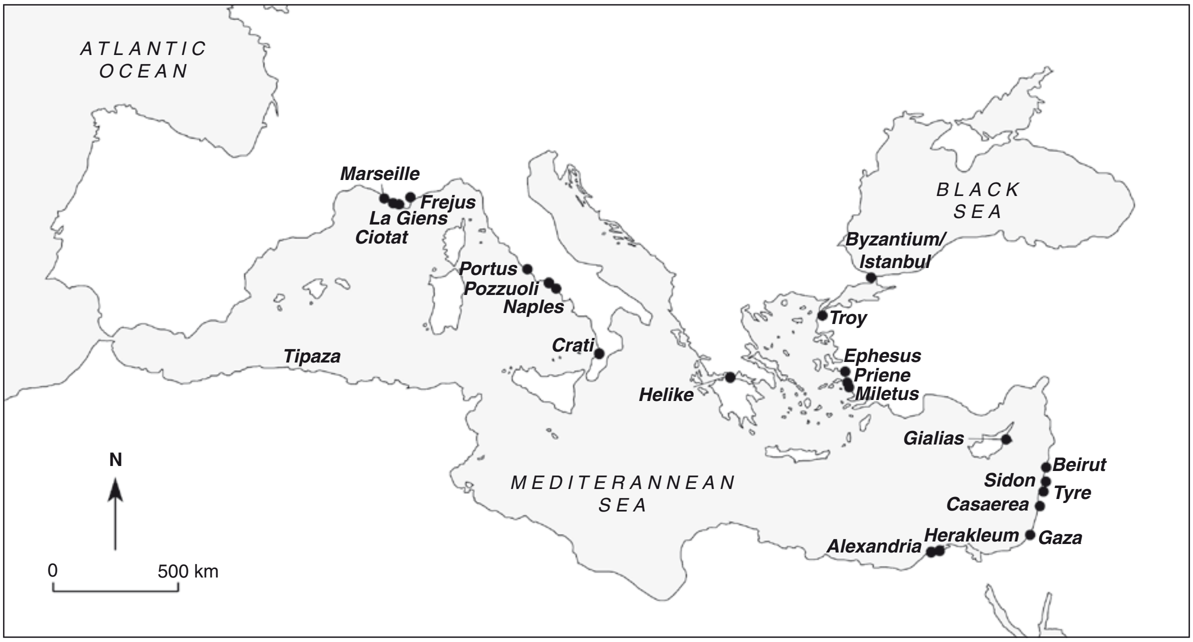

Fig. 14.2 Location of sites discussed in the text

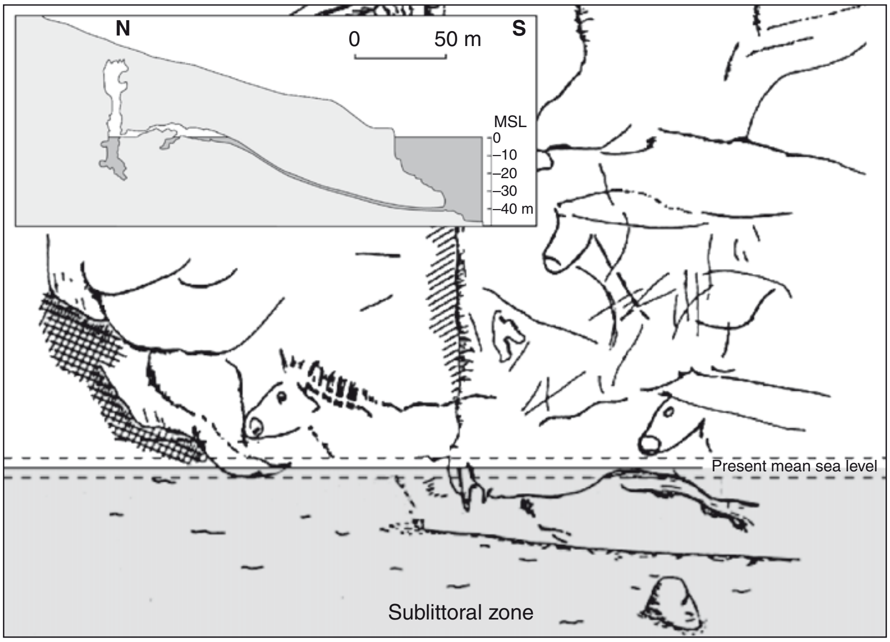

Fig. 14.3 Partial submersion of Paleolithic rock paintings in Cosquer cave, southern France. This example demonstrates that, in tectonically stable areas, no sea level higher than present is attested since the Last Glacial Maximum 18,000 years ago. (From Morhange et al. 2001)

Greece. Where precise vertical relationships can be established between archaeological structures and biological indices it has been possible to accurately reconstruct relative sea-level trends since antiquity at a number of Mediterranean sites (Pirazzoli 1976, 1979–1980, 1980, 1987a, b, 1988). Three groups of structures have traditionally been used: emerged vestiges (dwellings, stock houses, walls, mooring-stones), partially emerged structures (quays, slipways, channels), and submerged structures (shipwrecks) (Blackman 1973a, b; Flemming 1978; Flemming 1979–1980; Flemming and Webb 1986; van Andel 1989; Stanley 1999; Blackman 2003). Unfortunately, the bathymetric imprecision linked to these data is often significant, around 50 cm in most cases. Indeed, the envelope of imprecision can frequently be as important as the absolute sea-level change since antiquity.

Since the 1970s, shortfalls have been overcome using biological fossil remains attached on interface harbor structures (quays and jetties). By transposing the techniques developed on rocky coasts (Pirazzoli 1988; Stiros et al. 1992; Laborel and Laborel-Deguen 1994; Stiros and Pirazzoli 2008) to the context of ancient harbors, precise sea-level datasets have become a good source of primary data (Devillers et al. 2007). The strength of such results lies in the bathymetric precision of biological zonation with the chronological accuracy of well-dated archaeological remains. For example, the biological zoning of certain species (such as the upper limit of *Balanus* spp., *Lithophaga lithophaga*, *Vermetus triqueter*, *Chama griphoides* populations) is linked to mean biological sea level (Péres 1982). By measuring the upper altimetric difference between fossil and contemporary populations low vertical error margins of ±5 cm can be obtained (Laborel and Laborel-Deguen 1994).

Recent geoarchaeological research undertaken in the Roman harbor of Forum Julii (lower Argens valley, Frejus, southern France), demonstrates that sea-level rise of less than 50 cm has occurred during the past 2000 years. Devillers et al. (2007) have dated the upper limit of fixed *Vermetus triqueter* populations at −33 cm under the 0 N.G.F. ('Nivellement Général de la France', French 0 datum; Fig. 14.4). Two different samples yielded respective ages of 2420 ± 30 year BP (300 BC–10 AD) and 2345 ± 30 year BP (160 BC–80 AD). These radiometric datings are supported by ceramics attributed to 30–20 BC and 20–30 AD. The findings fit well with other sites from the region including Marseille (Morhange et al. 2001) and La Ciotat and Giens (Fig. 14.5; Laborel et al. 1994) characterized by a relative sea-level change of ~50 cm during the past 2000 years. It is regrettable that such a multidisciplinary approach is not more widely applied to harbor contexts. In other words, over the last 2000 years, sea-level rise has averaged less than 1 mm/year—hardly a hazard to the human population. Of course it could be said that higher sea levels meant that

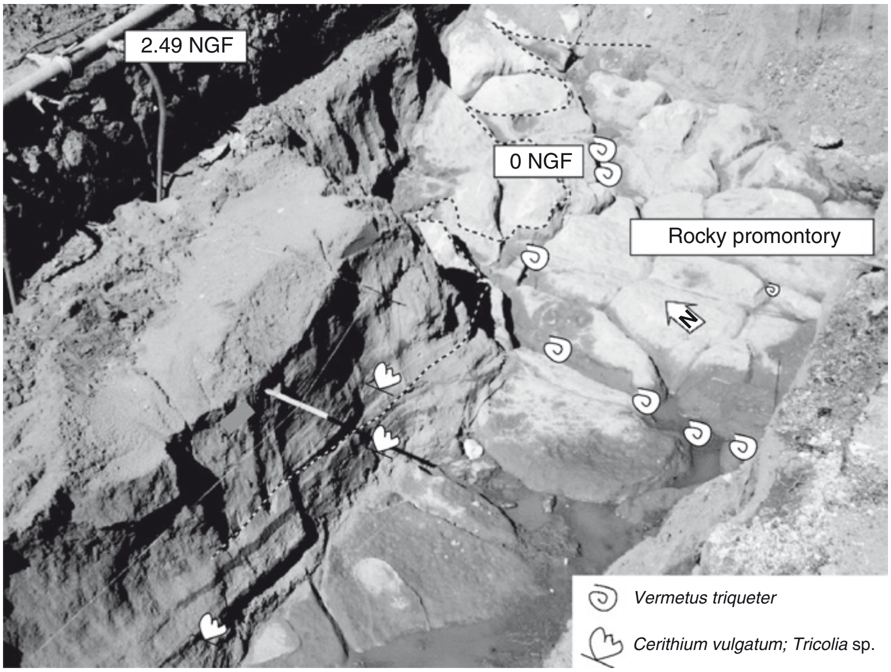

Fig. 14.4 Biological sea-level indicators showing the position of Roman sea level in Frejus' ancient harbor, southern France (after Devillers et al. 2007). The dotted line denotes the NGF ('Nivellement Général de la France' or French national 0 datum)

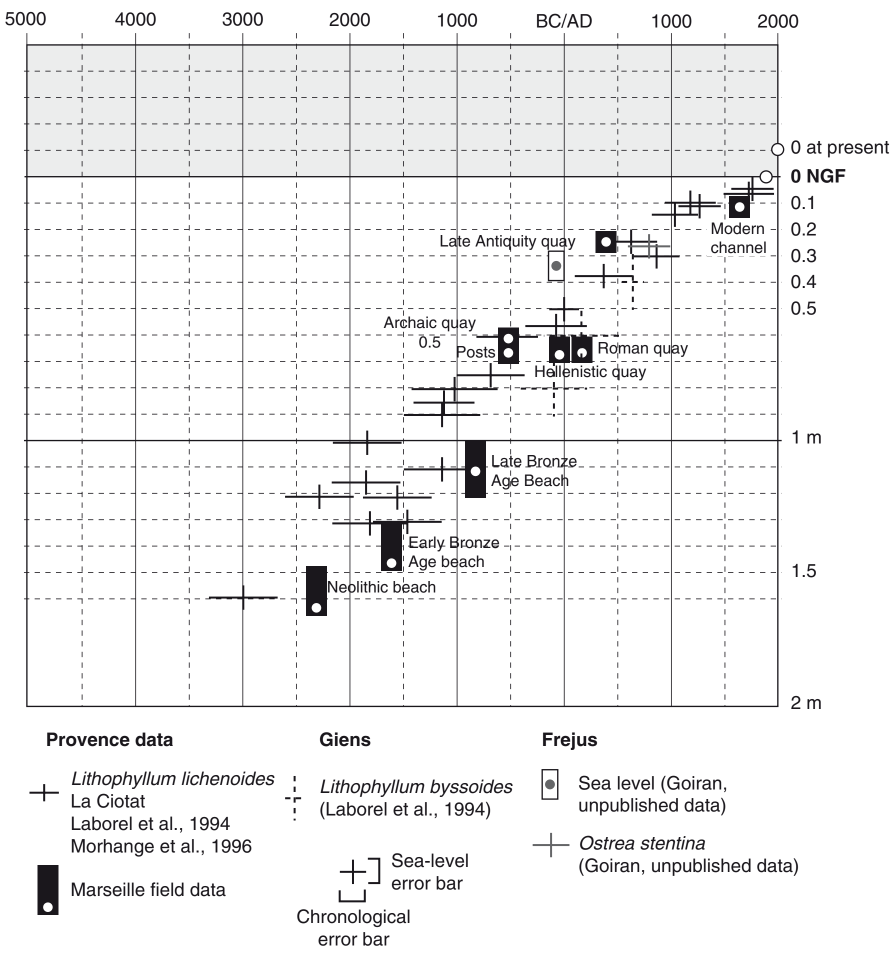

Fig. 14.5 Sea-level changes along the Provence coast since 3000 BC (modified from Morhange et al. 2001; Devillers et al. 2007)

the risk of inundation during storms, or from tsunami in tectonically unstable areas, would be increased, but the short term hazard of rapid sea-level rise in such cases is hardly to be laid at the door of deglaciation.

A consequence of moderate sea-level rise after 6000 years BP was the gradual infilling of base-level depocenters such as lagoons, river mouths, and marshlands. During the Bronze Age, for example, the Levantine coastline was characterized by an indented morphology, where lagoons and estuaries were exploited as natural harbors. Limited accommodation space and high clastic inputs from local sediment sources and the Nile River gradually infilled this indented morphology to yield a linear coastline. Bronze Age sites gradually became isolated from the sea and human populations, unable to offset the rapid rates of sedimentation, were displaced to new locations on the rapidly prograding coasts.

14.2 Rapid Sea-Level Rise and Paleohazards

Effects of rapid sea-level rise may be illustrated by two well-dated examples from Helike in Greece, and Alexandria in Egypt.

The southwestern coast of the Gulf of Corinth, Greece, lies in a region of rapid tectonic uplift and extension. In 373 BC, the city of Helike and its harbor, built on a Gilbert-type fan delta, were destroyed by an earthquake and submerged (Kiskyras 1988; Soter and Katsonopoulou 1998). Using borehole datings, Soter (1998) estimates that the Helike delta subsided by at least 3 m during the event. The opposition between gradual regional uplift and local co-seismic subsidence apparently resulted in a relatively small absolute displacement of the delta during the Holocene.

In a similar vein, the late Roman harbor of Alexandria is submerged about 6 m below present sea level (Goiran 2001; Stanley and Bernasconi 2006). To the west of the city, at ancient Menouthis and Herakleum, this offset is even more pronounced at ~8 m relative to present (Stanley et al. 2001, 2004). The mechanisms responsible for the collapse of the western margin of the Nile delta are at present unclear; scholars have attributed sediment failure to different factors including, fault tectonics, sediment compaction, offshore diapirism and slope instability due to Messinian salt outcrops.

Research has also highlighted the role of instantaneous relative sea-level changes causing harbor and settlement damage during severe storm and tsunami events. For example, major excavation works in the Byzantine port of Theodosius (Yenikapi, Istanbul) has elucidated a scenario of catastrophic seaport destruction during the sixth century AD (Periniçek, personal communication). The sedimentary sequence studied at Yenikapı represents a high-energy sequence attributed to the earthquake of 553 AD and its associated tsunami (Fig. 14.6). Harbor destruction is related to a rapid sea-level oscillation linked to exogenous forcing agents. Other well-dated tsunami sequences are known from the Levantine coasts (Morhange et al. 2006b). For example, Reinhardt et al. (2006) have analyzed high-energy facies in the offshore zone of Caesarea Maritima. They ascribe coarse biofacies to the destruction of Caesarea seawall during the fifth century AD.

In the western Mediterranean, recent work has also focused on catastrophic mega-block deposition on the Algerian coast of Tipaza, a region prone to large earthquakes. Several former tsunamis are inferred to have detached large boulders from the nearshore zone and deposited them inland (Maouche et al. 2009). The boulders, which weigh up to 200 tons, are scattered along some 150 km of coastline, isolated or in clusters, from the sub-littoral to supra-littoral zones. Radiocarbon datings of attached bio-indicators have been used to constrain two tsunamis events on the Algerian coastline between 400 and 600 AD and approximately 1700 AD.

A review of the literature written during the past 30 years shows a shift away from the drowning of

Fig. 14.6 Tsunami depositional layer at Yenikapi (Istanbul) dated to the sixth century AD. (Photo: D. Perincek)

ancient cities (Frost 1963; Flemming 1971) to a more modern paradigm of rapid sediment accretion driving coastal progradation and the landlocking of ancient coastal cities and their infrastructures (such as harbors). In the case of rapid coastal progradation, sites were invariably dislocated seawards. This is particularly true of settlements located in rias, the best examples deriving from the Ionian coast of Turkey (Brückner 1997; Brückner et al. 2002). These examples will be addressed in more detail below in Sect. 14.3. Geographical inertia means that earthquake and tsunami impacted settlements were, in most cases, rebuilt (for example Beirut). The discovery of hydraulic concrete during the early Roman period marked a watershed in coastal engineering. Natural roadsteads were no longer a prerequisite for seaport construction and completely artificial harbor basins could be built on high-energy coastlines, an enterprise which was difficult during the Bronze and Iron ages.

14.3 Hypersedimentation and Coastal Deformation

14.3.1 Delta Scale

Since 6000 year BP, Mediterranean coasts attest to exceptional coastal progradation linked to a deceleration of global glacio-eustasy at all spatial scales (Stanley and Warne 1994). This phenomenon is the rule and not the exception, and explains significant coastal changes to which ancient societies had to constantly adapt. The Bronze Age harbor of Gaza, for example, is currently landlocked due to sediment inputs from the Nile that have been reworked by the eastern Mediterranean gyre. This sweeps westward across the prodelta area before being deviated north towards the Levantine coast (Morhange et al. 2005). In a wave-dominated situation, sedimentary infilling has led to a change in the littoral geomorphology from an indented rocky coastline to a rectilinear coast comprising clastic sediments of predominantly fluvial origin. The effect on the pattern of human settlement has been a gradual dislocation of ancient settlements to keep pace with coastal progradation.

Recent research in the lower Argens (Frejus) has elucidated a coastal progradation of the shoreline by about 10 km during the last 6000 years (Dubar 2003, 2004; Excoffon and Devillers 2006; Devillers et al. 2007). In a similar vein, the Pedheios-Gialias ria (Cyprus) has undergone some 20 km of coastal progradation since the Neolithic. Ancient harbor paleogeography in this vast paleobay attests to the gradual seaward displacement of settlements in order to keep pace with the rapid sedimentation and dislocation of the shoreline (Devillers 2008). Hypersedimentation of coastal areas, therefore, clearly engendered problems of access to the sea and hence the long-term viability of settlements.

All coastal valley centers of deposition have been affected by this dynamic. Many good examples are known from the Ionian coast of Turkey, an area where human–environment interactions have a long history of research (Kraft et al. 1977, 1980; Brückner 1997; Brückner et al. 2002, 2005; Kraft et al. 2003, 2007). The watersheds of Miletus, Troy, Priene, and Ephesus correspond to narrow paleorias, or transgressed grabens, with very limited accommodation space. Recent research at Ephesus provides a good illustration of harbor displacement, or 'race to the sea', linked to rapid shoreline progradation. The ancient first artificial harbor, near Artemision, silted up as early as the sixth century BC, during a period of rapid deltaic growth. A second harbor was subsequently built to the west in the fifth century BC, before relocation of the landlocked city at the end of the third century BC.

Work by Stanley and Bernasconi (2009) the Crati River delta in Italy has focused on coastal progradation and the evolution of three ancient Greco-Roman sites. Sybaris, Thuri, and Copia were successively built up on the delta coast, between the early eighth and first centuries BC. Stanley used sediment cores to reconstruct the gradual seaward growth of the delta front and the respective isolation of each of the sites from the sea.

14.3.2 Harbor Basin Scale

In recent years, a number of studies have shown ancient harbors to be rich time-series of human-environment interactions since the Bronze Age (Reinhardt et al. 1998; Reinhardt and Raban 1999; Morhange 2000; Goiran and Morhange 2003; Kraft et al. 2003; Marriner et al. 2008). Sediment base-level accumulation in ports is the terminal transport pathway for fine-grained sediments in the coastal zone. The main problem of harbor maintenance was rapid silting up. To maintain a sufficient draught depth, ancient societies adapted techniques to evacuate sediment tracts deposited inside these artificial traps (Marriner and Morhange 2006a). Understanding how sediment accumulation rates have varied in space and time has helped to shed light on regional sediment transport conveyors, depocenters and anthropogenic impacts. Societies have had a significant role to play in coastal sedimentation, where ports act like artificial sinks accumulating thick sequences of fine-grained sediments over many millennia.

A common speculation is that primitive harbor dredging began during the Bronze Age along the Nile, Euphrates, Tigris, and Indus rivers (Fabre 2004/2005). For the Roman period, Vitruvius gives a few brief accounts of dredging, although direct archaeological evidence has traditionally remained elusive (Hesnard 2004a, b). Recent examples from Marseille (Morhange et al. 2003), Naples (Giampaola et al. 2004), Sidon (Marriner et al. 2006), and Tyre (Marriner et al. 2008) show evidence for extensive coastal dredging from the late fourth century BC onwards.

These recent case studies allow three questions to be resolved.

14.3.2.1 Why Dredge?

Two variables can be used to explain the long-term viability of ancient harbors: sea-level changes, and sediment supply and its role in modifying the draught depth. Since relative sea-level changes have been quite modest on stable Mediterranean coasts during the past 6000 years (within 2–3 m of present) this variable is of minor importance in explaining coastal deformation (Laborel et al. 1994; Lambeck and Purcell 2005). On centennial timescales, continued silting induced a concomitant thinning of the water column. On short timescales de-silting infrastructure, such as sluice gates, vaulted moles, and channels partially attenuated the problem but in the medium term these measures appear to have been relatively ineffective (Blackman 1982a, b). In light of this, repeated dredging was the only means of maintaining a viable draught depth and ensuring long-term harbor viability.

14.3.2.2 Where and When?

Marseille Archaeological excavations at Marseille have uncovered around 8000 m² of the buried port. Litho- and bio-stratigraphic studies elucidate a long history of human impacts stretching back to the late Neolithic period (Morhange et al. 2003). Rapid shoreline progradation is recorded following the foundation of the colony in 600 BC. During the first century BC, after over 500 years of Phocean rule, the demise and fall of the Greek city is translated by wide-reaching changes in the spatial organization of the harbor area. Although dredging phases are recorded from the third century BC onwards, the most extensive enterprises were undertaken during the first century AD, at which time huge tracts of Greek sediment were extracted down to a hard oyster-shell midden layer (Fig. 14.7). Notwithstanding the creation of artificial accommodation space the

Fig. 14.7 Example of a cut-and-fill talus at Marseille, as depicted by the dotted line, resulting from Roman dredging activity. The cohesive nature of the harbor sediments (>90% silts) has allowed these feature to be well-preserved in the stratigraphic record

seaport rapidly infilled and necessitated regular intervention. Repeated dredging phases are evidenced up to late Roman times, after which time the basin margins were completely silted up.

Naples In Naples, recent excavations at the Piazza Municipo show the absence of pre-fourth century BC layers due to extensive dredging between the fourth and second centuries BC (Giampaola et al. 2004). Unprecedented traces 165–180 cm wide and 30–50 cm deep attest to powerful dredging technology that scoured the volcanic tufa substratum, completely reshaping the harbor bottom.

Dateable archaeological artefacts contained within the deposits allow the decipherment of a very detailed time series of sediment fluxes with much greater temporal resolution than traditional radiometric methods. Investigated stratigraphic sections were dated to the third century BC and the beginning of the sixth century AD. Calculated fluxes are concurrent with intercentennial variability throughout this period. Rapid settling velocities of 17–20 mm/year are recorded during the second century BC and the first and fifth centuries AD. Low sedimentation fluxes of 0–5 mm/year are evidenced during the first century BC, and the late second and early fifth centuries AD. The most rapid rates are consistent with data from Archaic Marseille (20 mm/year; Morhange 1994), Roman Alexandria (15 mm/year; Goiran 2001) and Roman and Byzantine Tyre (10 mm/year; Marriner et al. 2008).

Phoenicia At Sidon and Tyre, unique chronostratigraphic patterns from over 40 radiocarbon dates have yielded strong evidence in support of the dredging findings from other sites (Marriner and Morhange 2006a). Naturally accreting marine bottoms are observed between approximately 6000 BC and 1500 BC, with a pronounced sediment hiatus spanning the Middle Bronze and Iron ages. Rapid rates of sediment accretion and persistent age-depth inversions are evidenced from the third century BC onwards, inconsistent with a natural sedimentary system. Chronostratigraphic patterns from the natural coastlines of the cities do not show similar patterns, discarding the hypothesis of radiocarbon discrepancies at the two sites.

The Romans and Byzantines significantly refashioned their seaports, notably removing great tracts of Bronze Age and Iron Age sediments. This has created a stratigraphic paradox of archive-less Phoenician harbors.

14.3.2.3 How?

The discussed data assert that Roman and Byzantine dredging was a well-organized management technique, not as crude as previously speculated. Bed shear stress in cohesive harbor clays is considerable, and powerful vessels are inferred from the depth of scour marks and the volume of sediment removed. Dredging boats, dating from the first and second centuries AD, have been unearthed and studied at Marseille (Pomey 1995; Pomey and Rieth 2005). The vessels are characterized by an open central well that is inferred to have accommodated the dredging arm. Jules Verne 3's reconstructed vessel length is about 16 m and the central well measures 255 cm long by 50 cm wide. Although the exact nature and mechanics of the dredging arms are not known, dredging taluses some 30–50 cm deep have been fossilised in the stratigraphic record.

It is only during the Romano–Byzantine period that deltaic areas could be transformed into artificial harbor environments. The basin of Portus, on the Tiber delta, is the archetype of such coastal management (Keay et al. 2005). Ancient harbors on rocky coasts were generally not subject to such intense rates of sedimentation. For example, both Marseille and Istanbul are not located in proximity to large fluvial systems; this explains why the ancient port basins are still in use today, more than 2500 years after their foundation.

14.4 Human Impacts

Relationships between human societies and environments have long been considered in quasi-independence of each other rather than as a co-evolution where both are complimentary. Recent work demonstrates that coastal sediments can be used to reconstruct the history of humans and their interactions with the environment since prehistory. The presence of human societies is manifested by a number of proxies.

a. Granulometric impacts: the construction of harborworks is recorded in the stratigraphic record by a unique fine-grained sedimentary facies. This lithoclastic signature facilitates a delimitation of the ancient basin topography. For example, Alexandria's

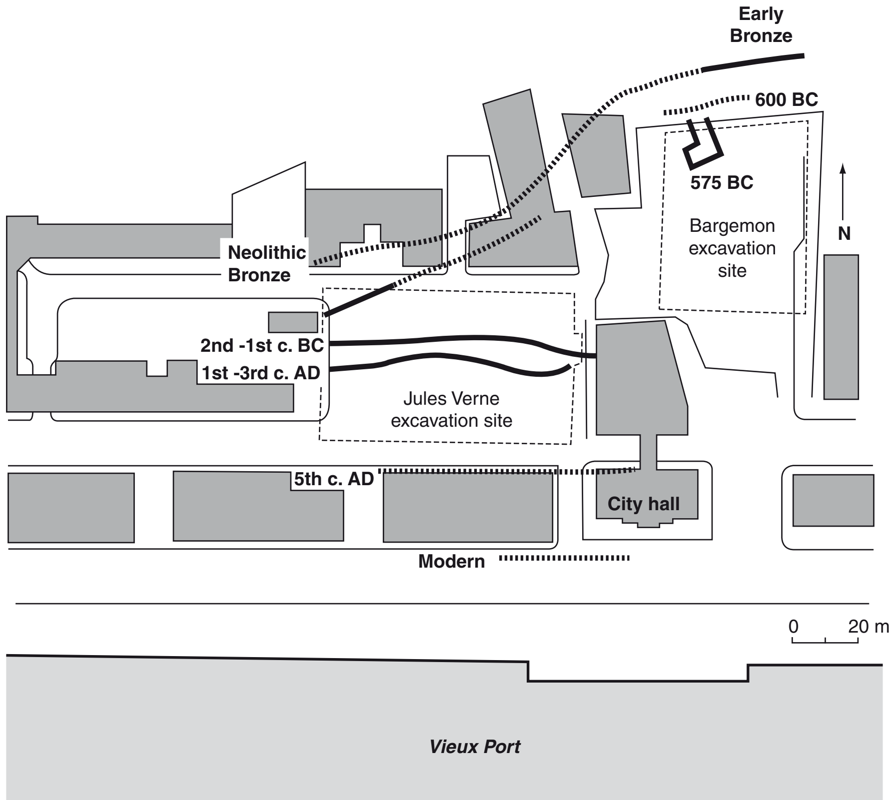

Fig. 14.8 Coastal changes in the ancient harbor of Marseille since the Neolithic period (from Morhange et al. 2001). The full and dashed black lines denote the various shoreline positions for the prehistoric and historic periods. A gradual straightening of the coastline is noted as the harbor basin infilled with fine-grained sediments

eastern harbor is characterized by very fine-grained particles, mainly silt. This harbor facies contrasts with the pre-harbor sedimentary environment, which includes coarse sand and gravels in association with open sea marine assemblages (Goiran 2001). After the collapse of the eastern bay by 6 m during late Antiquity, a transition to open sea facies is observed (post-harbor facies; Marriner and Morhange 2006b).

b. Morphological impacts: the rapid aggradation of harbor bottoms leads to accelerated coastline progradation. For example, progradation of Marseille's northern harbor coastline since the Neolithic is characterized by a progressive regularisation of the littoral geomorphology (Fig. 14.8).
c. Biological pollution: modification in faunal assemblages reworks local anthropogenic inputs such as increases in turbidity and use of the basin as a waste depocenter over many thousands of years.
d. Geochemical impacts: lead has proved to be a powerful tool in recognizing ancient industrial activities (Hong et al. 1994; Renberg et al. 1994; Nriagu 1998; Shotyk et al. 1998; Grattan et al. 2007). Within this context, ancient harbors have been demonstrated to be particularly rich archives of paleopollution. At Alexandria in Egypt, for example, lead isotope analyses have been used to elucidate the pre-Hellenistic occupation of the site (Véron et al. 2006), calling into question the Alexandria 'ex nihilo' hypothesis. The Greco-Roman apogee of the city is attested by lead pollution levels twice as high as those measured in contemporary ports and estuaries. Similar patterns have also been reconstructed in harbor sediments from Marseille (Le Roux et al. 2005), Sidon (Le Roux et al. 2002, 2003) and Tyre.

14.5 Conclusion

Coastal archaeological contexts in the Mediterranean comprise excellent sedimentary archives, yielding insights into the magnitude and direction of anthropogenically forced coastal changes during the Holocene (Marriner and Morhange 2007). In addition to reconstructing the paleoenvironmental evolution of ancient sites, it is important to move beyond the site scale of investigation to compare and contrast the now rich geoarchaeological data from around the Mediterranean and to formulate a working type stratigraphy of ancient harbors. Traditional disciplinary studies have been shown to be largely inadequate when considered in isolation and, through the above examples, we have demonstrated that a geoarchaeological approach is particularly useful in areas of data paucity. An informed earth-science approach can aid in answering three questions imperative to the better understanding of the maritime archaeological record.

a. Where? We have demonstrated that diagnostic litho- and bio-stratigraphies, consistent with geological hazards and human-modified coastal environments, are clearly recorded in the geological record.
b. When? The transition from natural to anthropogenic environments can be dated using either radiometric or ceramic dating techniques.
c. How? How did ancient hazards and local populations impact upon coastal zones.

Recent examples have demonstrated that coastal sites, and particularly ancient harbors, are also appropriate for the analysis of archaeological data at three scales.

a. Basin scale: An informed geoarchaeological approach can yield insights into the harbor basin topography, its functioning, spatial organization, and coeval infrastructure through time.
b. Urban scale: Information pertaining to the site occupation history, notably using geochemistry and geophysics, is made possible due to high rates of sedimentation through time.
c. Regional scale: Typological data can be derived on how these individual maritime sites evolved on a regional scale. It has also been demonstrated that harbor basins are important in better understanding the source to sink sedimentary conveyor and the impact of natural hazards on coastal populations.

Nowadays, most large-scale coastal archaeological projects seek to apply a multi-disciplinary approach at different temporal and spatial scales. Since 1985, harbor archaeology and geoscience workshops have furnished important scientific arenas for multidisciplinary discussion and debate, and attest to a clear growth in this domain as a focal point of research interest.

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