

Ancient Tyre and its harbours: 5000 years of human-environment interactions

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Abstract

The exact location and evolution of Tyre's ancient harbour areas have been matters of scholarly conjecture since the 16th century. Here, we use geoscience techniques to precisely relocate the ancient northern harbour, the city's principal transport hub during antiquity, and reconstruct its geomorphological evolution (Marriner, N., Morhange, C., Boudagher-Fadel, M., Bourcier, M., Carbonel, P., 2005. Geoarchaeology of Tyre's ancient northern harbour, Phoenicia. *Journal of Archaeological Science* 32, 1302–1327.). While a natural anchorage is inferred during the Bronze Age, we expound the increasing weight of anthropogenic forcings from the Iron Age onwards, culminating in a technological apogee during the Byzantine period (Hohlfelder, R.L., 1997. Building harbours in the early Byzantine era: the persistence of Roman technology. *Byzantinische Forschungen Internationale Zeitschrift für Byzantinistik* 24, 367–389.). Using coastal stratigraphy and underwater archaeological data (El Amouri, M., El Helou, M., Marquet, M., Noureddine, I., Seco Alvarez, M., 2005. Mission d'expertise archéologique du port sud de Tyr, sud Liban: résultats préliminaires. *Bulletin d'Archéologie et d'Architecture Libanaises, Hors-Série* 2, 91–110; Frost, H., Recent observations on the submerged harbour works at Tyre. *Bulletin du Musée de Beyrouth* 24, 103–111; Noureddine, I., Helou, M., 2005. Underwater archaeological survey in the northern harbour at Tyre. *Bulletin d'Archéologie et d'Architecture Libanaises, Hors-Série* 2, 111–128) we demonstrate that Poidebard's (1939. *Un grand port disparu, Tyr. Recherches aériennes et sous-marines, 1934–1936*, Librairie Orientaliste Paul Geuthner, Paris) Egyptian harbour is in reality a drowned quarter of the ancient city. Informed hypotheses are proposed for a possible second anchorage at Tyre, and it is demonstrated that presently drowned portions of the sandstone ridge served as outer harbours during the Bronze and Iron Ages. Stratigraphic data in the vicinity of Tell Mashuk, Chawakir and Rachidiye are also presented and discussed.

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1. Introduction

Tyre was founded during the third millennium BC on an easily defendable offshore island (Bikai, 1979; Katzenstein, 1997; Marriner et al., 2007). This sea bastion was particularly attractive to early societies as it possessed a number of natural low-energy basins that could be exploited as anchorage

havens, with little or no need for human artificialisation (Marriner and Morhange, 2005, 2006a,b; Marriner et al., 2005). In spite of its former maritime glory, however, the evolution of this important Phoenician city–state has remained largely enigmatic. Erroneously, much of the present literature continues to cite the pioneering 1930s work of Poidebard (1939). Although Frost (1971) questioned some of her predecessor's interpretations, notably regarding Tyre's southern harbour, many of these have failed to filter down to the wider archaeological literature (Briquel-Chatonnet and Gubel, 1999; Holst and Harb, 2006; Katzenstein, 1997; Markoe, 2002; Moscati, 1997; Strong, 2002). In the southern Levant,

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the Bronze and Iron Age harbours of Israel have been the object of significant scientific endeavours since the early 1980s (Raban, 1981, 1984, 1985a–c, 1988, 1995a). Geopolitical frictions meant that similar data from the Lebanon had been missing, important in not only understanding the archaeological evolution of the whole Syro-Canaanite coast (Marcus, 2002a,b, in press; Wachsmann, 1998), but also the geomorphological and geological responses of the Levantine seaboard since 6000 BP (Morhange et al., 2006; Raban, 1987a; Sanlaville, 1977; Sanlaville et al., 1997; Stanley, 2002).

This paper looks to better comprehend 5000 years of human–environment interactions at Tyre through the application of geoscience techniques developed and refined during the past 15 years (Goiran and Morhange, 2003; Marriner and Morhange, 2007; Morhange, 2001). Since the publication of two earlier papers on Tyre's northern harbour (Marriner et al., 2005, 2006a), our understanding of the location and evolution of Tyre's ancient palaeoenvironments has advanced significantly. Here, we comprehensively review previous work and present extensive new geoscience data to reconstruct the palaeoenvironmental history of this important site during the Holocene.

Tyre bears witness to significant coastal modifications since 6000 BP. These are attributed to three complementary dynamics: (1) important coastal artificialisation during the Hellenistic period, with the construction of Alexander the Great's causeway (Katzenstein, 1997; Marriner et al., 2007); (2) the location of the site at the distal margin of the Litani delta, the Lebanon's largest fluvial system and a major source of sediment at the Holocene timescale (Abd-el-Al, 1948; Marriner, 2007; Soffer, 1994); and (3) rapid relative sea-level changes, attributed to a tectonic subsidence of the Tyrian horst by ~ 3 m since late Roman times (Morhange et al., 2006).

Ancient texts and iconographic evidence suggest that four harbour complexes existed in the Tyre area during antiquity: (1) a northern seaport looking towards Sidon, Beirut and Byblos (referred to as the Sidonian harbour during the siege of Tyre by Alexander the Great: Arrian, *An.* II, 16, 7–27, 7; Diodorus of Sicily, XVII, 40, 2–47, 6; Quinte-Curce, IV, 2–4; Plutarch, *Alex.* XXIV–XXV and Strabo, XVI, 2, 23); (2) a southern anchorage facing Egypt; (3) a number of outer harbours, taking advantage of the exposed sandstone ridges at this time (Achilles Tattius, II, 17, 3); and (4) a fourth continental complex, located around Tell Mashuk and Tell Chawakir, which served as a transport hub for the inhabitants of Palaeo-Tyre during the Bronze Age. In this paper, we combine coastal geomorphology and the multidisciplinary study of sediment archives to precisely reconstruct where, when and how Tyre's ancient harbour complexes evolved during the Holocene.

2. In search of Tyre's northern harbour: geoarchaeological context

Tyre's northern harbour has been a source of archaeological speculation since the 16th century when a number of religious pilgrims visited the Phoenician coast *en route* to the Holy Land shrines (Arvieux, 1735; Le Besson et al., 1660; Maundrell,

1703; Pococke, 1745; Stochovede, 1650; Van Cotvyck, 1620; Villamontde, 1596). Although the use of this northern cove as the ancient city's main seaport has never been questioned, for many early erudites its shallow basin appeared enigmatic with Tyre's former maritime glory (Shaw, 1743). Indeed Volney (1791), for the English translation see Volney (1792), noted that the "harbour, dug by the hand of man" was silted up to such an extent that children could walk across it without wetting their upper body.

While 16th–18th century travellers contented themselves with landscape descriptions and nostalgic reveries of the city's former grandeur, the scientific ascendancy of the 19th century ushered in more robust ideologies on history and archaeological inquiry (Marriner and Morhange, 2007). It was at this time that a number of scholars intuitively drew the link between harbour silting and coastal progradation to hypothesise that great tracts of the ancient northern port lay beneath the medieval and modern centres (Bertou, 1843; Kenrick, 1855; Poullain de Bossay, 1861, 1863; Rawlinson, 1889; Renan, 1864; see Fig. 1). This basin, it was argued, had been protected by an ancient breakwater which protruded from the eastern tip of the harbour and was known to many of the early workers (Kenrick, 1855; Renan, 1864). Logistic difficulties meant that it was not until the 1930s, under the auspices of Poidebard (1939), that precise archaeological surveying of this mole was undertaken. Despite very recent diving prospections (Nouredine and Helou, 2005; Descamps, personal communication; Sicre, personal communication) the exact age of the structure remains ambiguous, and in reality very little is known about this basin, the city's most important transport hub.

Given the dearth of data in this northern area, we drilled a series of cores around the edges of the present basin (Fig. 2) with an aim to accurately reconstruct: (1) the harbour's ancient dimensions and topography; (2) its stages of evolution since the Holocene marine transgression; and (3) attempt to link discrete stratigraphic signatures with changes in harbour infrastructure.

3. Methods

The Holocene paleoenvironments have been reconstructed using a series of 25 stratigraphic cores. All cores have been GPS levelled and altitudinally benchmarked relative to present MSL. Interpretations are based upon high-resolution litho- and biostratigraphical studies of the sedimentary cores as described in Marriner and Morhange (2007). Radiocarbon and archaeological dates provide a chronological framework for the landforms and sedimentary bodies observed.

4. Results and discussion

4.1. Where was the ancient northern harbour?

The geoarchaeological data indicate that the heart of Tyre's ancient seaport is presently buried beneath the medieval and modern city centres (Fig. 3). These centres lie upon ~ 8 –10 m of medium to low-energy coastal sediments which began

Poulain de Bossay (1861, 1863)

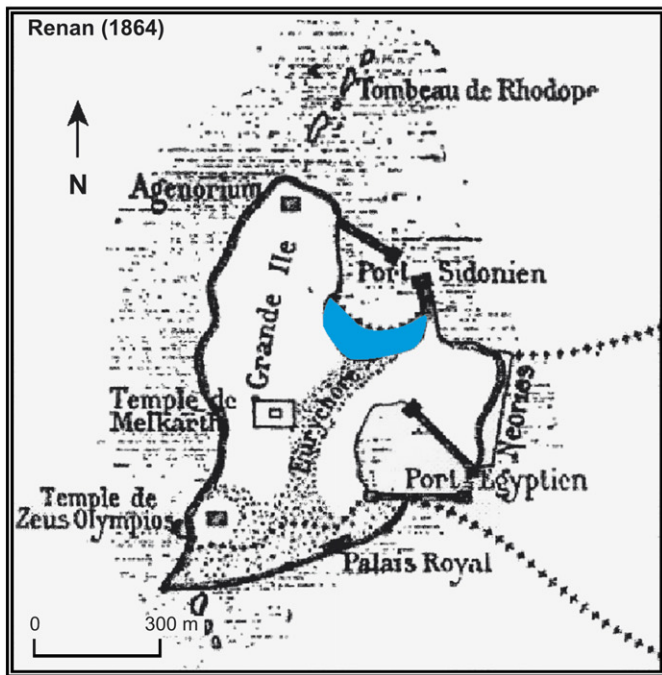
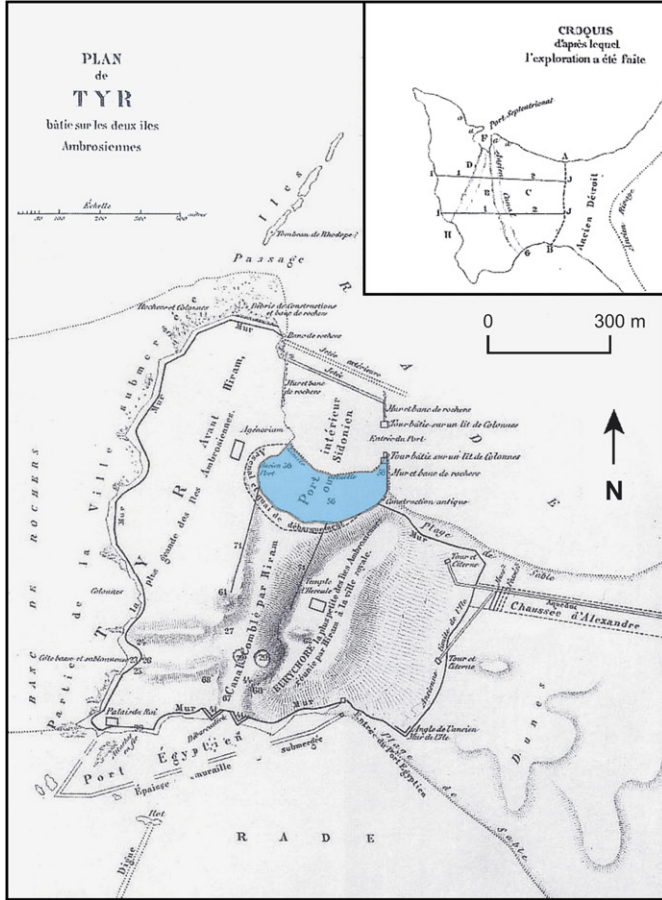


Fig. 1. Proposed reconstructions of Tyre's silted northern harbour by Poulain de Bossay (1861, 1863) and Renan (1864).

accreting between 8000 and 6000 BP. The findings confirm earlier interpretations made by Kenrick (1855), Poulain de Bossay, (1861, 1863) and Renan (1864) who, during the 19th century, were the first to suggest that silting up had significantly diminished the size of the former basin. By coupling a study of the bedrock and urban topography with the landward position of Holocene coastal strata, we have reconstructed an ancient harbour approximately twice as large as present (Marriner et al., 2005, 2006a). Coastal progradation of 100–150 m has occurred since the Byzantine period, encroaching on the sea to landlock the heart of the ancient seaport. We discuss these stratigraphic data in more detail in Section 4.2.

Core TVI, drilled just east of the harbour's south–north trending mole, is void of diagnostic harbour facies affirming that the hub was not more extensive in this direction (Figs. 4–6).

Description: unit B is characterised by a medium to coarse-grained shelly-sands deposit, dominated by molluscan taxa indicative of a low-energy beach environment, including *Bittium reticulatum* (subtidal sands and hard substrate assemblage), *Tricolia tenuis*, *Rissoa dolium*, *Rissoa lineolata* (subtidal sands assemblage), *Nassarius lousi*, *Nassarius pygmaeus*, *Nassarius mutabilis* and *Donax semistriatus* (upper clean-sand assemblage). In unit A, a net transition to fine-grained sands (~90%) is attested to after ~1700 cal. BP. Modal grain values of between 0.2 and 0.4 μm , allied with medium sorting indices, concur a low-energy beach environment. These sedimentological data are consistent with a fall in water competence linked to the construction or reinforcement of the south-eastern harbour mole. The molluscan fauna is dominated by sand-loving taxa including the subtidal sands assemblage (*R. lineolata*, *T. tenuis*, *Smaragdia viridis*, *Bulla striata*), the upper clean-sand assemblage (*N. pygmaeus*, *D. semistriatus*) and the upper muddy-sand assemblage in sheltered areas (*Cerithium vulgatum*). The top of unit B is dated to modern times. Both units B and A comprise marine lagoonal (*Loxiconcha* spp. and *Xestoleberis aurantia*) and coastal (*Aurila convexa*) ostracod species.

Interpretation: a priori the eastern mole has been continuously adapted and reinforced from antiquity through to present, as is commonplace with ancient seaport infrastructure.

The submerged northern breakwater, which protrudes seawards from the extreme eastern tip of the island, closes the basin. This structure lies ~40 m north of the present mole. First mentioned in the literature by Bertou (1843), it has manifestly been known to local fishermen and sailors for much longer. The structure was not precisely surveyed until the work of Poidebard (1939) during the 1930s. Since then, two surveys of note have been undertaken by Noureddine and Helou (2005) and Descamps et al. (Descamps, personal communication). These studies have elucidated an 80 m long breakwater, with a constant width of 12.7 m. The mole comprises two parallel walls made-up of 40/50 × 50/60 × 190 cm ramleh headers, and whose surfaces presently lie ~2 m below MSL (Descamps, personal communication). Excavations by Descamps et al. have put into evidence five assises constituting a 3.1 m

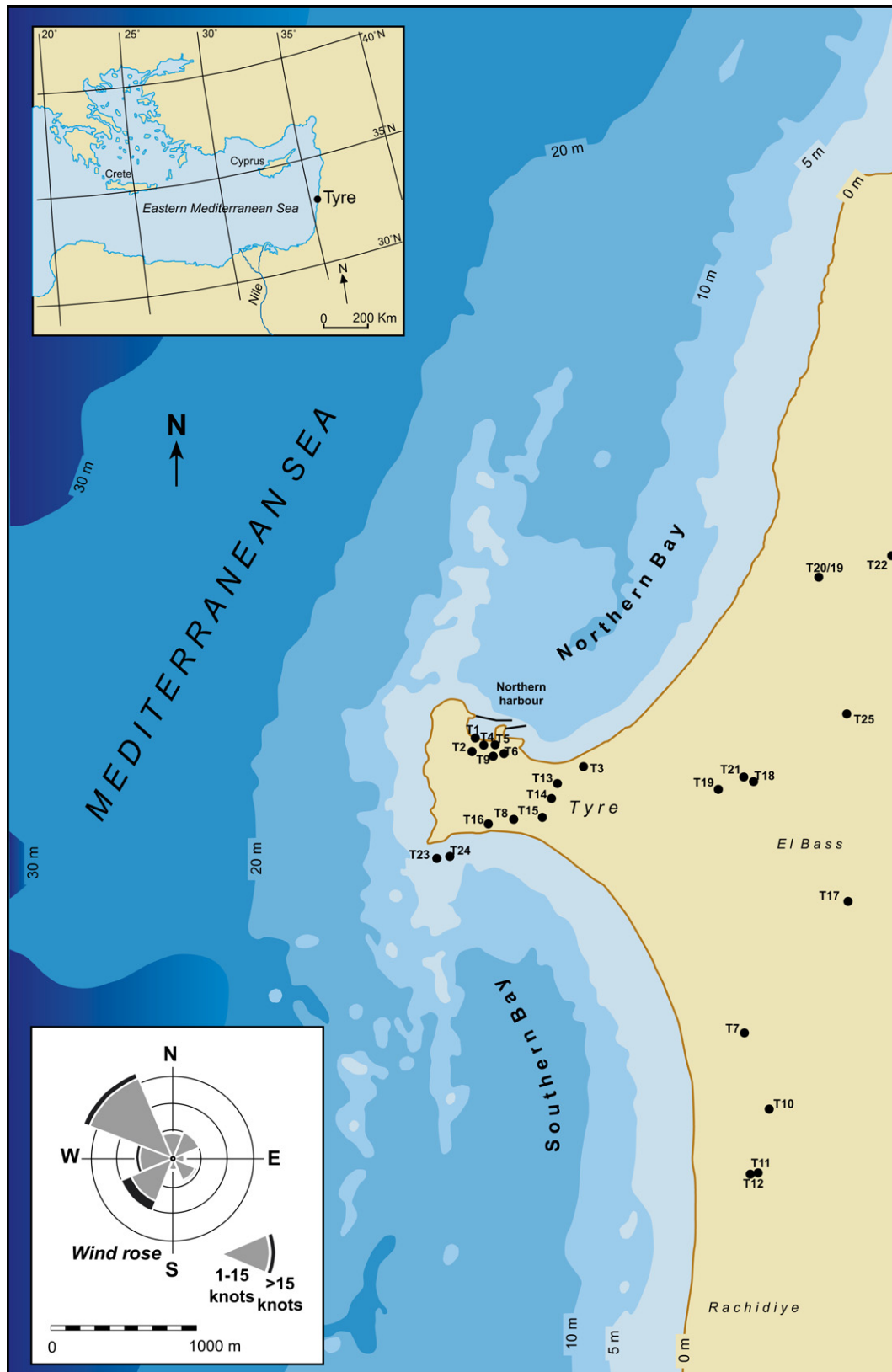


Fig. 2. Tyre's coastal bathymetry at present and location of core sites (denoted by black dots).

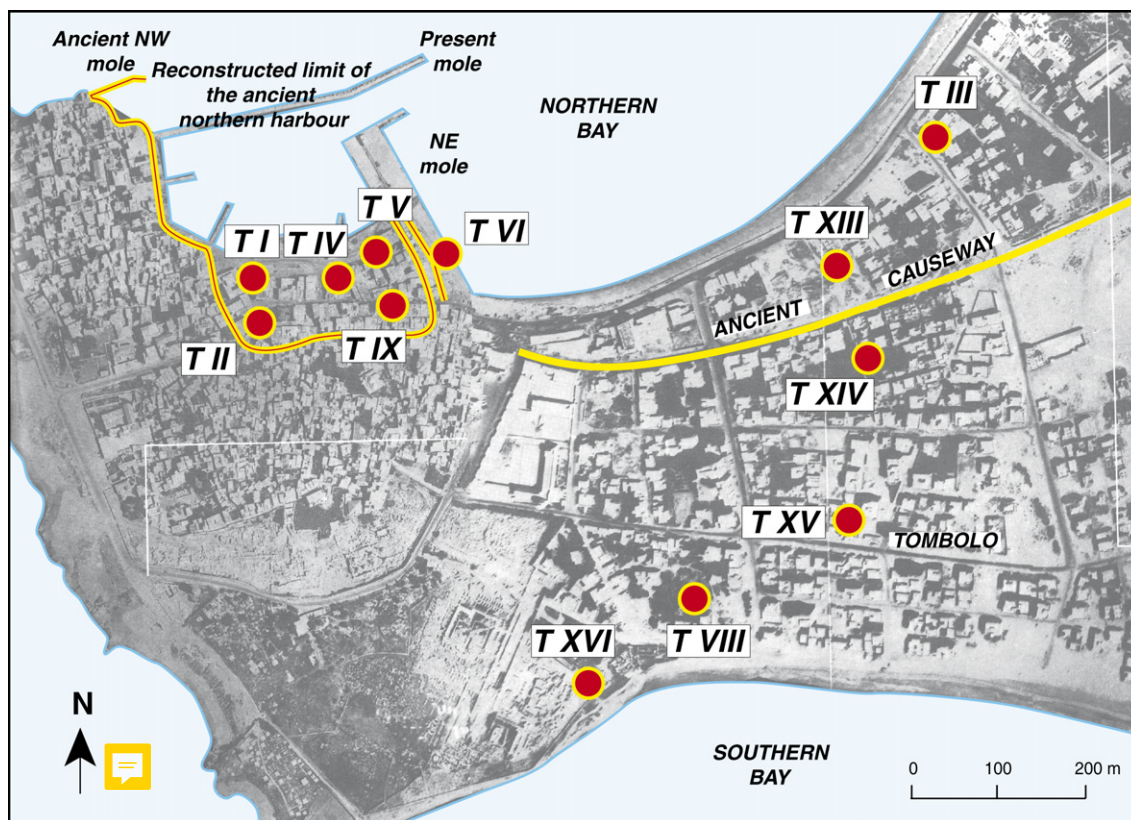


Fig. 3. Reconstructed limits of Tyre's ancient northern harbour. Silting up since antiquity has led to a 100–150 m progradation of the cove's coastline, isolating the heart of the ancient seaport beneath the medieval and modern centres.

high wall. On the basis of ceramics and engravings on the stone blocks, Descamps has attributed the mole to the Hellenistic or Roman periods.

4.2. When and how did the northern seaport evolve?

Coastal stratigraphy and high-resolution laboratory analyses allow us to elucidate six phases in the evolution of this semi-sheltered cove. Here we report its palaeogeographical history since the flooding of the cove during the Holocene marine transgression, and attempt to interpret the stratigraphic data with reference to the archaeological record. We demonstrate that harbour history can be clearly chronicled by diagnostic litho- and biostratigraphies. These depocentres are also appropriate for the analysis of numerous archaeological problems and cultural processes, providing a diversity of research possibilities (Marriner and Morhange, 2007).

4.2.1. Maximum Flooding Surface and sheltered lagoon environment (~8000 to ~6000 years BP)

Description: the Holocene Maximum Flooding Surface is dated ~8000 BP, overlain by shelly silt and clay deposits that accreted in the cove until ~6000 BP. The sedimentology of this basal layer is consistent with a reworking of the underlying clay substratum, giving rise to a lithodependent unit. The facies is dominated by upper muddy-sand (*Loripes*

lacteus) and lagoonal molluscan taxa (*Parvicardium exiguum*; Figs. 7–9). High species diversity and the presence of both juvenile and adult tests are consistent with a rich biocenosis. The brackish lagoonal ostracod *Cyprideis torosa* attains relative abundance figures of >80% with intercalated peaks of *Aurila woodwardii*, *A. convexa* and outer marine species (Figs. 7 and 10). Foraminifera are dominated by the brackish water species *Ammonia beccarii*.

Interpretation: the dominant litho- and biostratigraphical proxies attest to a shallow, low-energy marine embayment newly transgressed by the post-glacial sea-level rise. With relative sea-level approximately 7 ± 1 m below present, the coastal bathymetry shows the existence of a north–south trending subaerial ridge ~6 times longer than the present 1 km island (Fig. 11). This geomorphological disposition led to the creation of a very low-energy sediment depocentre, sheltered from the onshore south-westerly winds and fetch by this extensive drowned ridge. A series of proximal clastic beach ridges are inferred to have closed the marine embayment, which, the biostratigraphic data demonstrate, was breached during periods of storm and high swell.

4.2.2. Pocket beach unit and Bronze Age proto-harbour

Description: after the onset of relative sea-level stability around 6000 BP, the northern coast of Tyre remained naturally protected by the aeolianite ridge system. Fig. 11 (inset 2) depicts a tentative coastal reconstruction of Tyre island ~6000

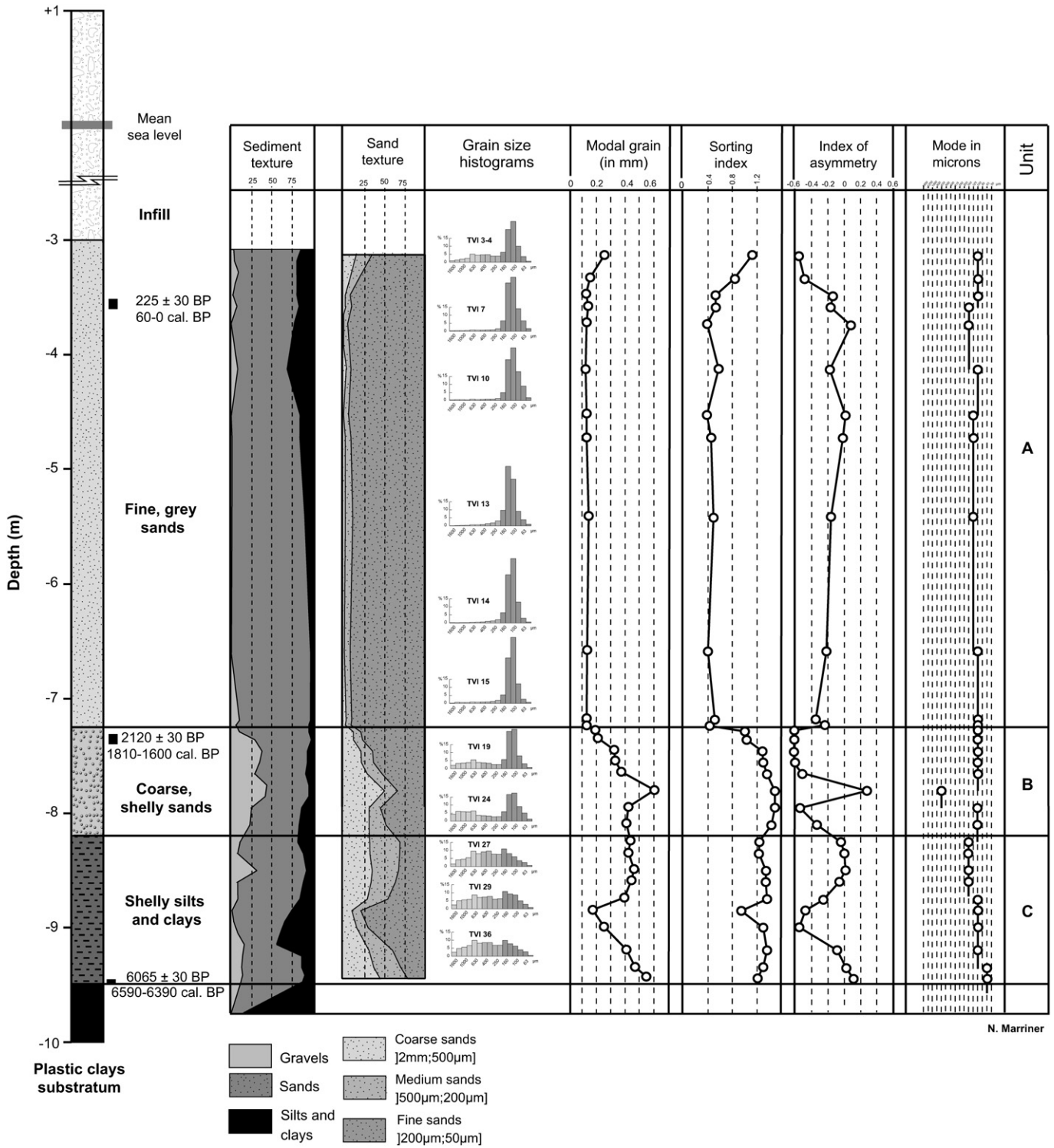


Fig. 4. Grain size analyses of core TVI.

BP, with a projected relative sea-level scenario at 5 m below present.

The molluscan fossils are consistent with a semi-sheltered environment in which both *in situ* taxa and reworked *extra situ* tests are represented. The dominant taxa include species from the hard substrate assemblage (*Cerithium rupestre*, *Fusinus pulchellus*, *Gibbula varia*) and *in situ* individuals from the

upper muddy-sand in sheltered areas assemblage (*Nassarius corniculus*, *Cerastoderma glaucum*). An increase in coastal ostracod species, notably *A. convexa*, is to the detriment of *C. torosa*. Marine lagoonal taxa *Loxoconcha rhomboidea* and *X. aurantia* attest to a relatively confined littoral environment. This unit corresponds to a semi-sheltered shoreface, which began accreting at the end of the mid-Holocene marine

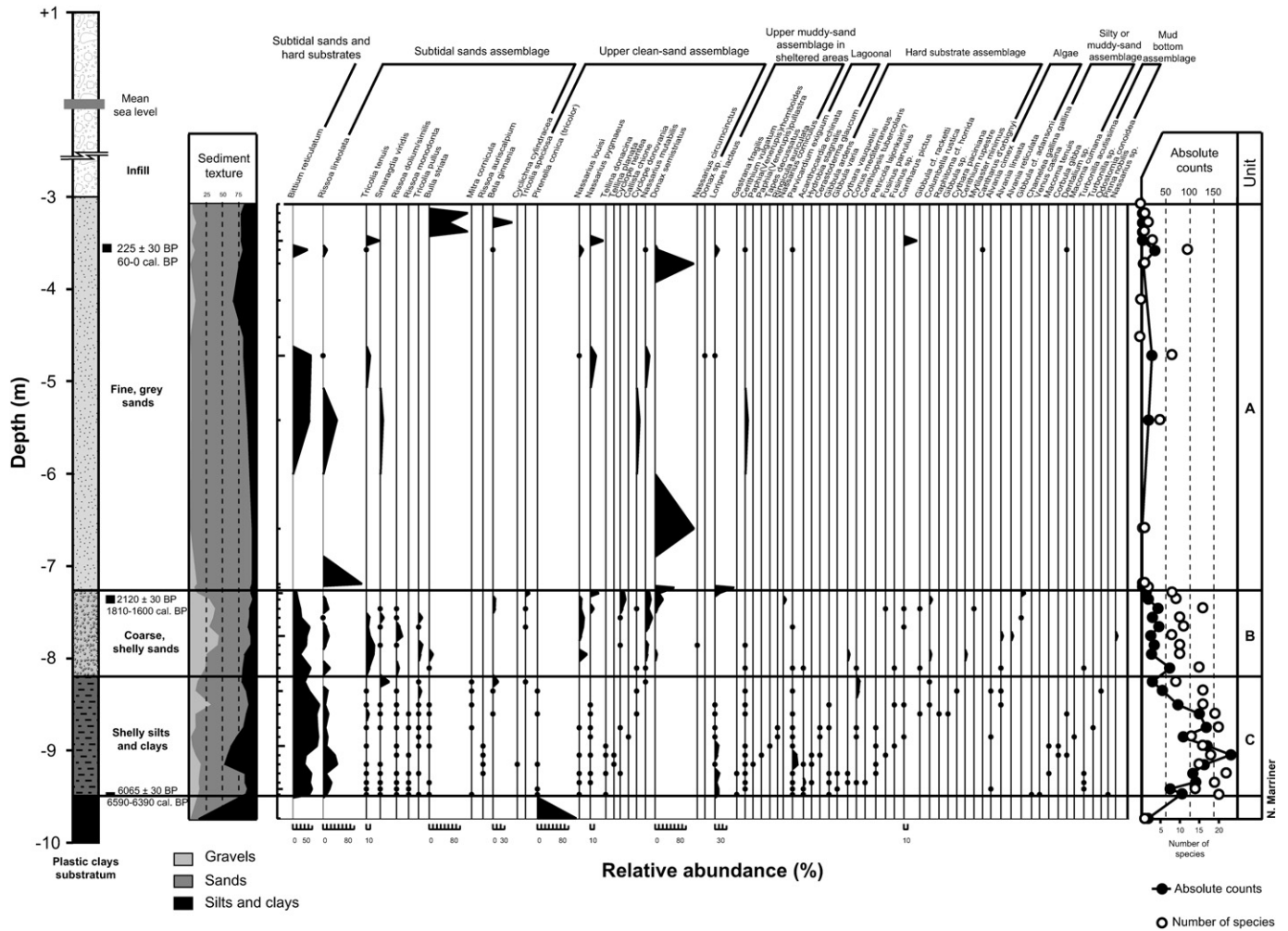


Fig. 5. Macrofauna data of core TVI.

transgression. Presence of numerous marine taxa including *Semicytherura* sp., *Bairdia* sp., *Cistacythereis* sp., *Jugosocythereis* sp., *Loculicytheretta* sp., and *Callistocythere* spp. are drifted in and corroborate communication with the open sea.

Interpretation: the biosedimentological proxies asseverate a semi-open marine cove conducive to early settlement of the island by human societies. Unequivocally, the geomorphology of the Tyrian coastline — an easily defendable offshore island shielding a number of natural low-energy anchorages — is significant in explaining the foundation of Tyre during the third millennium BC. At this time, the northern cove was used as a proto-harbour, where seafarers would have the choice of beaching their ships on the sandy shore, or leaving them at anchor in the bay, depending on the daily or seasonal weather and the direction of the wind. The use of lighters, small ferry boats used to load and unload larger vessels, was also widespread at this time (Marcus, 2002a).

The oldest documentary evidence we have for the beaching of seafaring vessels during the Bronze Age derives from Akrotiri, on the island of Thera (Casson, 1978; Giescke, 1983; Gillmer, 1975, 1978, 1985). The so-called Flotilla Fresco, dated ~1550 BC, depicts a maritime scene of small harbours

in which boats are moored or pulled up onto the beach (Casson, 1975, 1978; Dumas, 1992; Marinatos, 1971, 1974, 1976; Televantou, 1990; Wachsmann, 1998). On the basis of an architectural study of the larger processional boats in the frieze, de Cervin (1977, 1978) has proposed a hypothetical reconstruction of a ship being beached using lines attached to the stern device. In the Syro-Palestinian world, the tomb of Kenamon (14th century BC) was decorated with frescos representing Syrian vessels hauled onto the banks of the Nile. Wooden gangplanks, set against the stern of the boats, facilitated the unloading of merchandise (Carayon, 2005a; Daressy, 1895; Davies and Faulkner, 1947). It is interesting to note that boat beaching is still used to this day by Mediterranean fisherman with light, shallow-draught vessels.

During the Middle to Late Bronze Age, dynamic interaction throughout the eastern Mediterranean brought about a period of internationalism characterised by developed trade routes which interlaced the Levant, Egypt and the Aegean (Dickinson, 1994; Hankey, 1993; Ilan, 1995; Knapp, 1993; Kristiansen and Larsson, 2005; Marcus, 2002b, in press). For the societies ringing the eastern basin of the Mediterranean, contact was established primarily by the sea

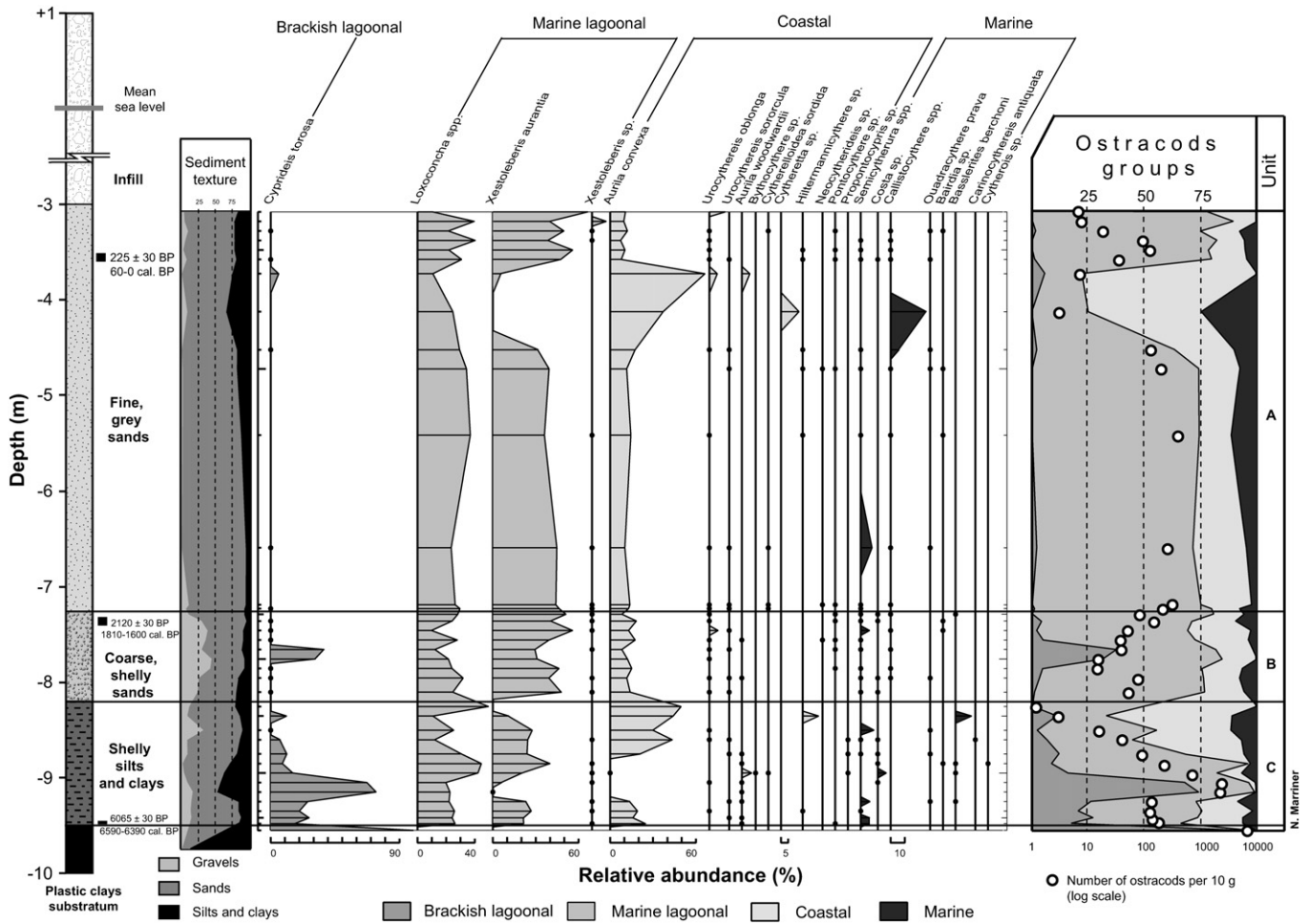


Fig. 6. Ostracod data of core TVI.

(Wachsmann, 1998). The movement of ships in this area is implied by the distribution of trade goods along its shores, and demonstrated by the discovery of numerous Bronze Age shipwrecks (Bass, 1987, 1991). At this time, Tyre and other coastal settlements along the Phoenician coast started to consolidate their positions as major emporia for trade with Cyprus, Crete, and Mycenaean Greece (Barnett, 1956; Doumet-Serhal, 2004a). Although it is widely believed that this expanding Mediterranean trade prompted coastal populations into modifying their natural anchorages, the exact timing and technology used to achieve this is open to conjecture (Raban, 1995a).

For many scholars, the ancient Near East is the cradle of coastal harbour development, logically adapted from the deltaic contexts of Mesopotamia and Egypt (Fabre, 2004/2005). From Egypt alone, iconographic depictions of ships and fluvial quaysides exist in many tomb paintings (Edgerton, 1922–1923; Haldane, 1990; Wachsmann, 1998). A great number of tombs have also yielded model boats of various descriptions, which, along with their crews, are poised to transport and provision the deceased in the afterlife (El Baz, 1988). The Cheops ship, for example, is so technically advanced that development over many thousands of years must be assumed (Casson, 1994). Indeed, primitive river transportation

probably existed on the Nile by Palaeolithic times (Fabre, 2004/2005; Hornell, 1970).

Although opinions vary on whether Egypt was a major sea-going culture (Fabre, 2004/2005; Nibbi, 1979; Säve-Söderbergh, 1946; Wachsmann, 1998), proximity to the two major Egyptian and Mesopotamian riverine cultures appears consistent with rapid diffusion and adaptation of this *savoir faire* to the Levantine seaboard; by contrast, contemporaneous Aegean harbour infrastructure was much less evolved at this time (Raban, 1991; Shaw, 1990). Even though fluvial construction techniques had to be adapted to the difficult maritime context, the quasi-absence of tides in the Mediterranean was a significant advantage in the construction of permanent harbour infrastructure. Active research along the Levantine seaboard, notably in Israel, has yielded valuable new information about shipping and harbours (Galili et al., 2002; Marcus, 2002a,b; Raban, 1984, 1985a–c, 1987a,b, 1991, 1997a,b; Raban and Holum, 1996). Although there is general agreement about the attribution of numerous moles and quays to the Romans (Raban and Holum, 1996) or even the Phoenicians (Haggai, 2006), very few can be unequivocally constrained to the Bronze Age due to the difficulties in dating rock-cut structures.

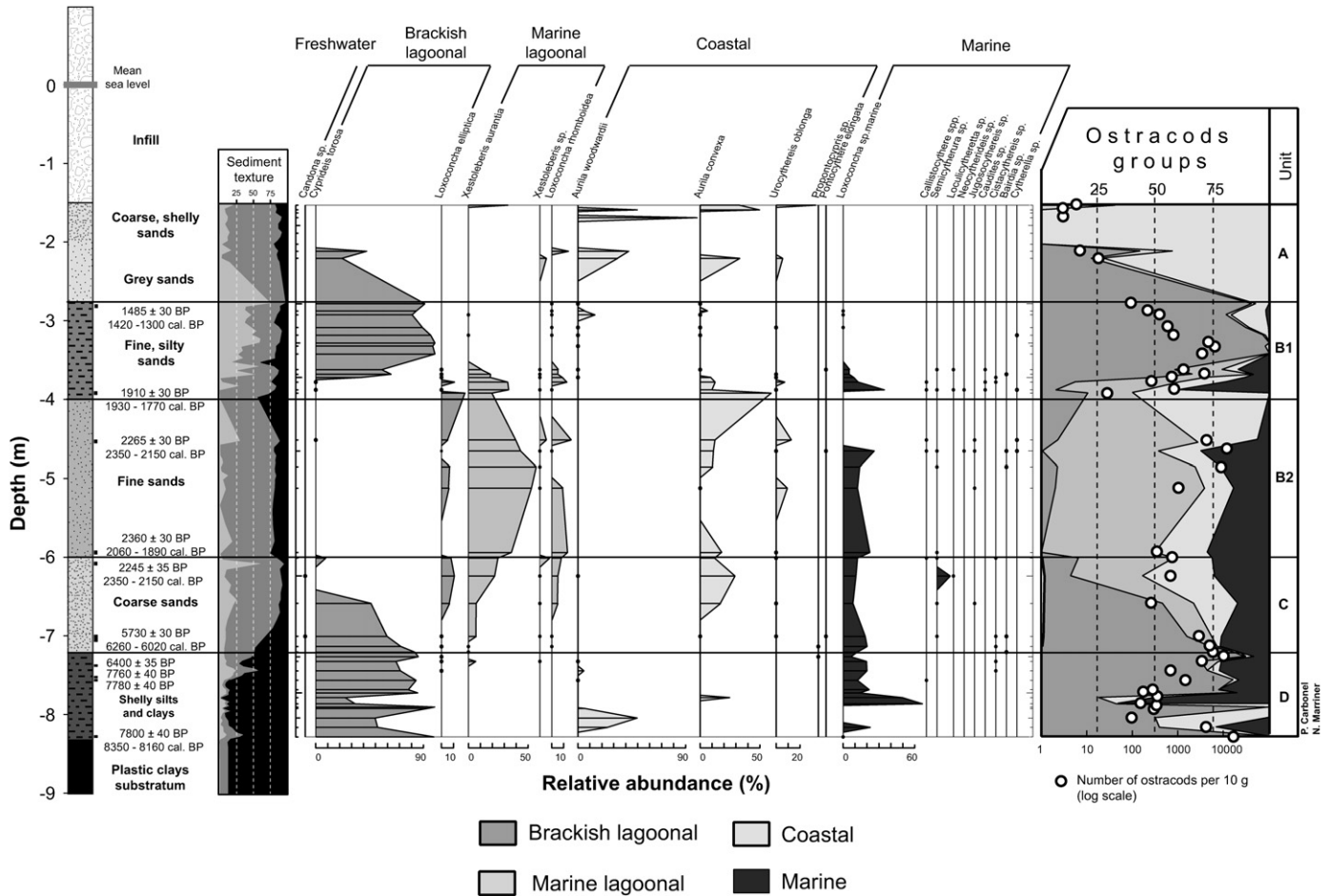


Fig. 7. Ostracod data of core TV.

A number of sites have been important in yielding tentative evidence:

- (i) For many, the most likely candidate for a constructed Bronze Age facility is the quay found at *Dor* in Israel (Kingsley, 1996; Raban, 1995b). This quay is established along a coastal lagoon to the south of the settlement. Raban (1984, 1985a, 1987b) has dated the 35 m × 11–12 m platform to the 13th/12th centuries BC, on the basis of ceramics at the foot of the structure. The masonry techniques employed are typical of early Canaanite and Phoenician societies.
- (ii) At *Yavne Yam*, Israel, recent work has brought to light a crude rubble construction measuring 100 × 50 m, inferred to have been used to improve the quality of the ancient anchorage (Galili et al., 1993; Raban, 1993). On the basis of stone anchors in the vicinity of the structure Galili et al. (1993) have attributed the structure to the Late Bronze Age, although Marcus (personal communication) concedes that it could belong to any of the periods attested to at the site (Middle Bronze Age to Late Bronze 1).
- (iii) On the northern Levantine coastline, Frost (1964, 1966) has also attributed the early harbour infrastructure at

Arados (Arwad, Syria) to the Bronze Age. Like Tyre, Arados was an insular city founded upon a partially drowned sandstone ridge, 2.5 km from the present coastline. Extensive seawalls are also present on the island (Viret, 2005). The leeward side of the island forms a natural bay separated into two basins by a semi-artificial jetty. Renan (1864) and Frost (1966) have hypothesised that the southern basin was the larger of the two, silting up with coastal sediments since antiquity.

- (iv) At *Sidon*, modification of the sandstone ridge is constrained to the Middle to Late Bronze Age (~1700–1450 cal. BC) on the basis of sedimentological evidence (Marriner et al., 2006b).
- (v) Other examples of carved seawalls are known from Tripoli, Batroun and Byblos but these have no clear chronological control and cannot be unambiguously attributed to the Bronze Age (Viret, 2004).

At Tyre, linking the coastal stratigraphy to early artificial harbourworks is difficult for two reasons: (1) the dearth of Bronze Age archaeological finds in and around the basin; and (2) the relative absence of Middle to Late Bronze Age harbour sediments, due to Roman dredging practices (Marriner and Morhange, 2006a). We expand upon this point later in the paper.

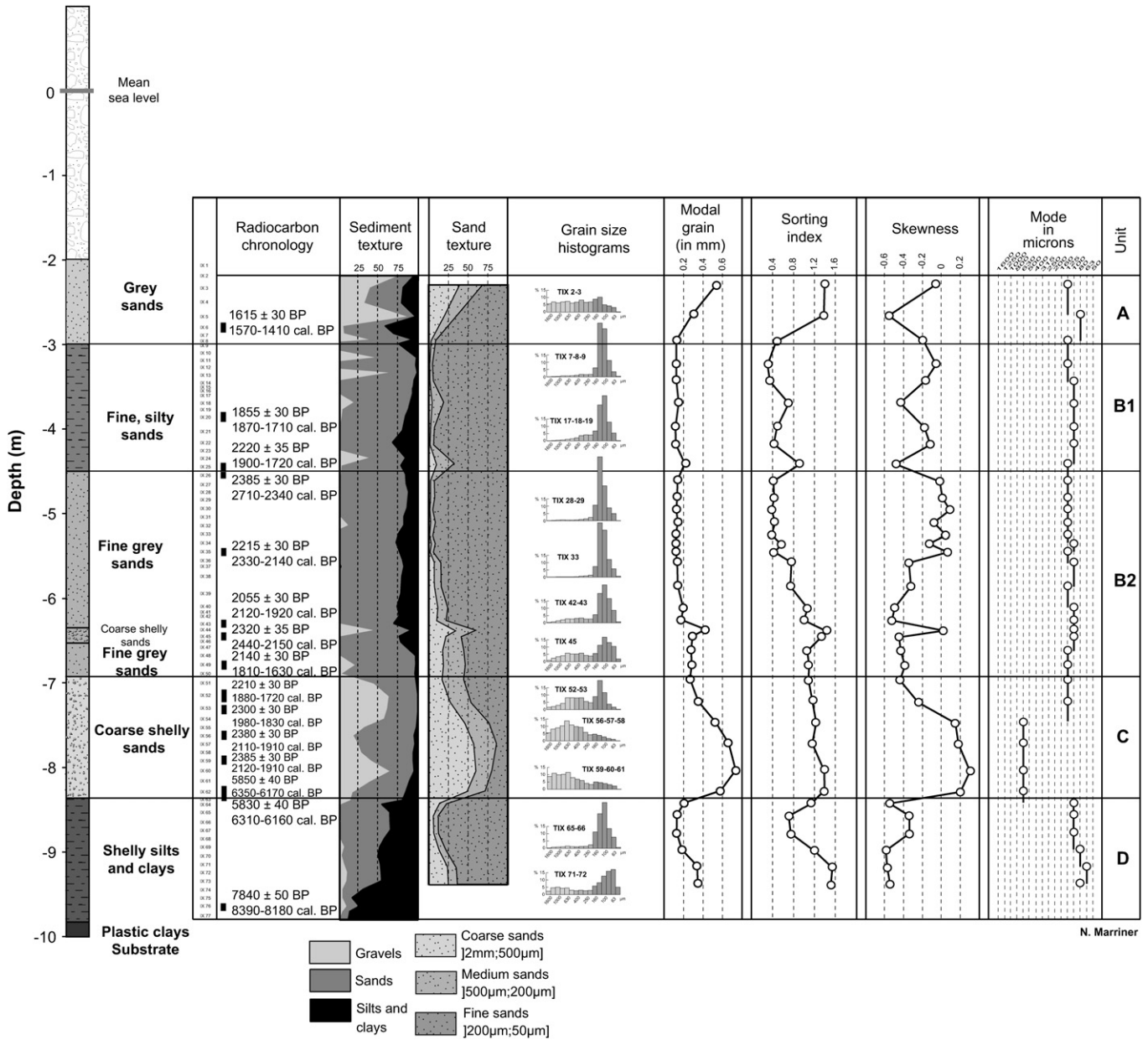


Fig. 8. Grain size analyses of core TIX.

4.2.3. Phoenician and Persian periods: archiveless harbour

Description: paradoxically, Roman dredging means that very little stratigraphic evidence exists for Tyre’s Iron Age harbours. Fine-grained clay deposits found to the south of the city, in the drowned southern quarters, have been dated to the Persian period (see below). On the basis of granulometric analyses, we hypothesise that these units are dredged Iron Age sediments from the northern harbour, deposited in this area for use in the ceramics and construction industries. The sediments are fine-grained comprising 4–10% gravels, 10–30% sands and 60–90% silts and clays, while the ostracod fauna is dominated by marine lagoonal taxa (*Loxocochna* spp. and *Xestoleberis* spp.). Although great tracts of Iron Age strata are missing from the northern harbour, these litho- and biostratigraphic data attest to a well-protected harbour

during the Persian period. This is corroborated by findings from Sidon’s northern harbour (Marriner et al., 2006b).

Interpretation: during the Late Bronze Age, Tyre consolidated its position as a key trade centre to emerge during the Iron Age as a commercial dominion with hegemony over the region’s sea lanes (Aubet, 2001). The city drew its wealth from the coastal hinterland, namely metal, ivory, glass and cedar, commodities which it subsequently traded throughout the eastern Mediterranean. It also became an important transit seaport for Egyptian and Mesopotamian goods en route to other Mediterranean destinations. At the turn of the first millennium BC, Tyre had surpassed Byblos – Phoenicia’s principal Bronze Age seaport – to become the Levant’s most eminent trade emporium (Aubet, 2001; Katzenstein, 1997). This city of merchants had large marketplaces, the most prominent of

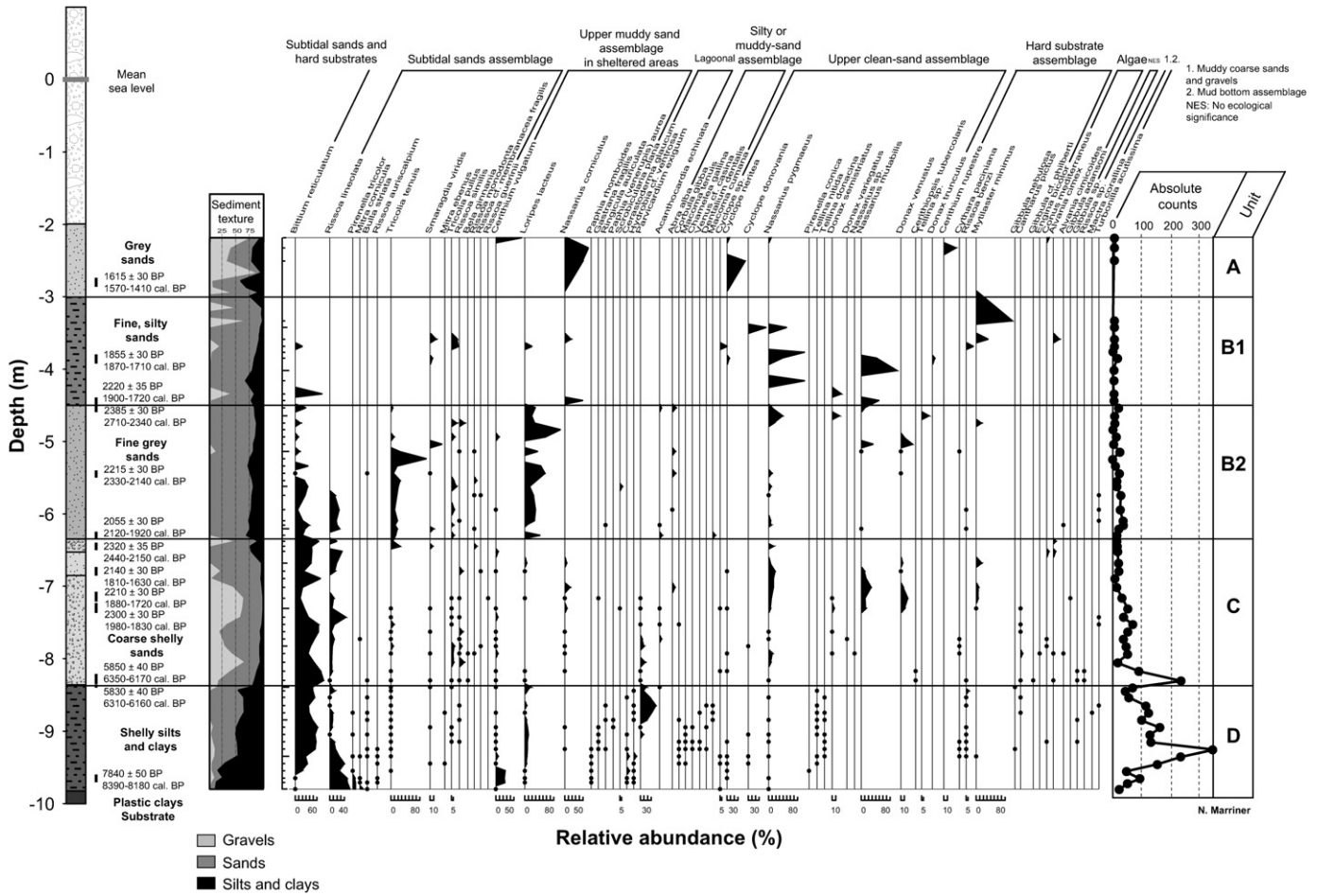


Fig. 9. Macrofauna data of core TIX.

which was centred on its northern harbour (Bunnens, 1983; Lehmann-Hartleben, 1923). Improvements in water storage also meant that the island could support much larger populations, and it has been speculated that during its golden age Tyre was the most populated city in the Levant, ahead of Jerusalem (Katzenstein, 1997).

Significant advances in naval technology have been attributed to this period (Basch, 1987; Bass, 1974; Casson, 1994; Kemp, 2001). Most importantly, the use of iron in shipbuilding, from the 13th century BC onwards, served as a major impetus to the construction of larger and stronger vessels. It is indeed the Tyrians who are attributed with the invention of the cargo-ship, also referred to as “ships of Tarshish” in the Bible (White, 2002). These new vessels, capable of sailing great distances, permitted trading outposts to be founded at various points throughout the Mediterranean basin (Aubert, 2001). Unmistakably, the development of maritime trade and rising population levels necessitated a complex port infrastructure containing installations for the overhauling of vessels, dockyards, quays and sheds in which boats could be kept. Direct evidence of this infrastructure is at present sparse and insights into Tyre’s Phoenician and later Persian ports are marred by the relative absence of Iron Age sediments.

One must look to other Levantine harbours in attempt to better understand the construction methods and infrastructure used at this time. Archetypal Phoenician moles and quays are known from Athlit (Israel) and Tabbat al-Hammam (Syria).

- (1) The harbour at Athlit is the best-preserved Phoenician seaport on the Levantine seaboard, and its remains have solicited the attentions of archaeologists looking to understand Iron Age building techniques and harbour engineering for a number of decades (Haggai, 2006; Raban, 1985b, 1997a,b). Athlit’s harbour lies north of a natural promontory; the Phoenician basin is separated into two areas:
 - (i) A southern quay and N–S pier: the southern quay comprises narrow headers, 1.2 × 0.5 × 0.5 m, and extends eastwards along the shoreline for a length of 38 m. A 10 m wide pier lies perpendicular to this quay and runs northwards 100 m into the sea. The structure was built of two walls of headers, with a mixture of ashlar and rubble fill.
 - (ii) An eastern quay and northern mole: a 43 m long quay has been constructed on a partially drowned sandstone reef and is protected by an eastward trending mole that runs from the northern extremity of the

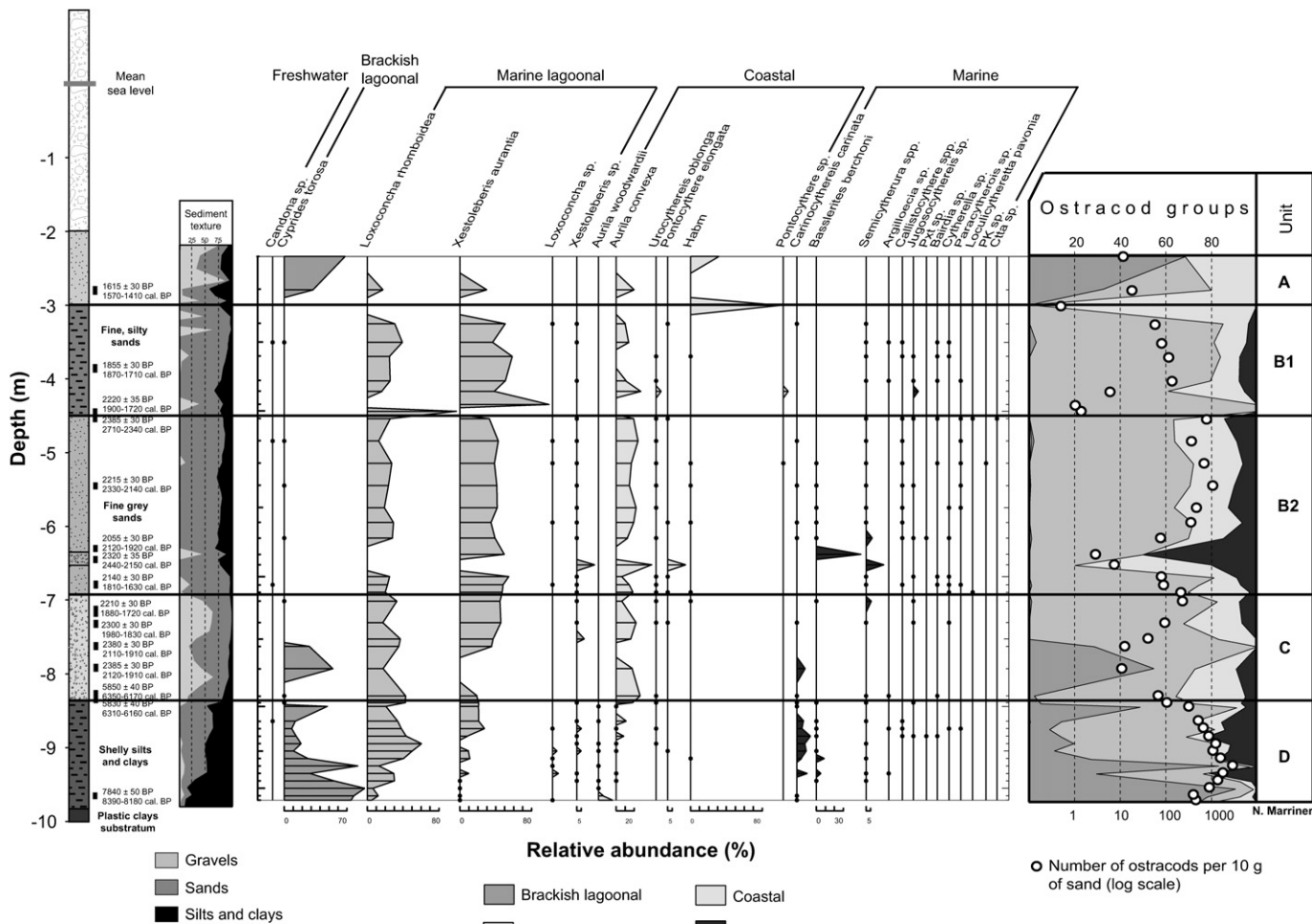


Fig. 10. Ostracod data of core TIX.

quay. This structure is identical in construction to its counterpart on the southern shore. Haggai (2006) has recently dated wooden fragments contained within these two moles, constraining the inception of the structures to the 9th to 8th centuries BC. The separation of the harbour into two mooring areas enabled a distinction between the “home quay”, for Phoenician ships to anchor, and the “free quay” or emporium for foreign ships. Cargo would have been transhipped in lighters to harbours such as Acre, Tyre and Sidon.

(2) These chronological findings support similar evidence from Tabbat al-Hammam, where a 130 m long mole has been dated to the same period (Braidwood, 1940). The mole comprises a sheltered face made of ashlar headers that almost certainly served as a harbour quay. This artificially cut quay is protected by a more elevated backing wall that faces seawards.

At Sidon, the sandstone reef which encloses the ancient northern harbour appears to have been cut to create semi-artificial docking stations on the rock itself. Such docking facilities are still clearly visible on Zire island. The quality of this

outer anchorage was improved during the Persian period, when two jetties were erected to protect a series of quay dockings. At present, however, it is unclear at what date the semi-artificial quays were fashioned (Carayon, 2003; Carayon and Viret, 2004).

Our palaeogeographical reconstructions for Iron Age Tyre put into evidence a ~3000 m long island (Fig. 11, insets 4 and 5). Archaeological finds such as amphorae and stone anchors, allied with literary evidence (e.g. Achilles Tattius, II, 27, 3), corroborate the use of these reefs as outer harbours, functioning in tandem with the city’s artificial anchorage(s) (El Amouri et al., 2005).

4.2.4. Hellenistic and Roman harbours

Description: transition from a medium-grained sand unit to fine-grained sands and silts is the most conspicuous geological evidence we have found for an artificially closed harbour at Tyre. This facies comprises a series of radiocarbon dates that cluster between ~2400 BP and ~2000 BP, consistent with the Graeco-Roman period. The sediment texture comprises 2–22% silts and clays, 59–92% sands and 2–30% gravels. Unimodal histograms well developed in the fine

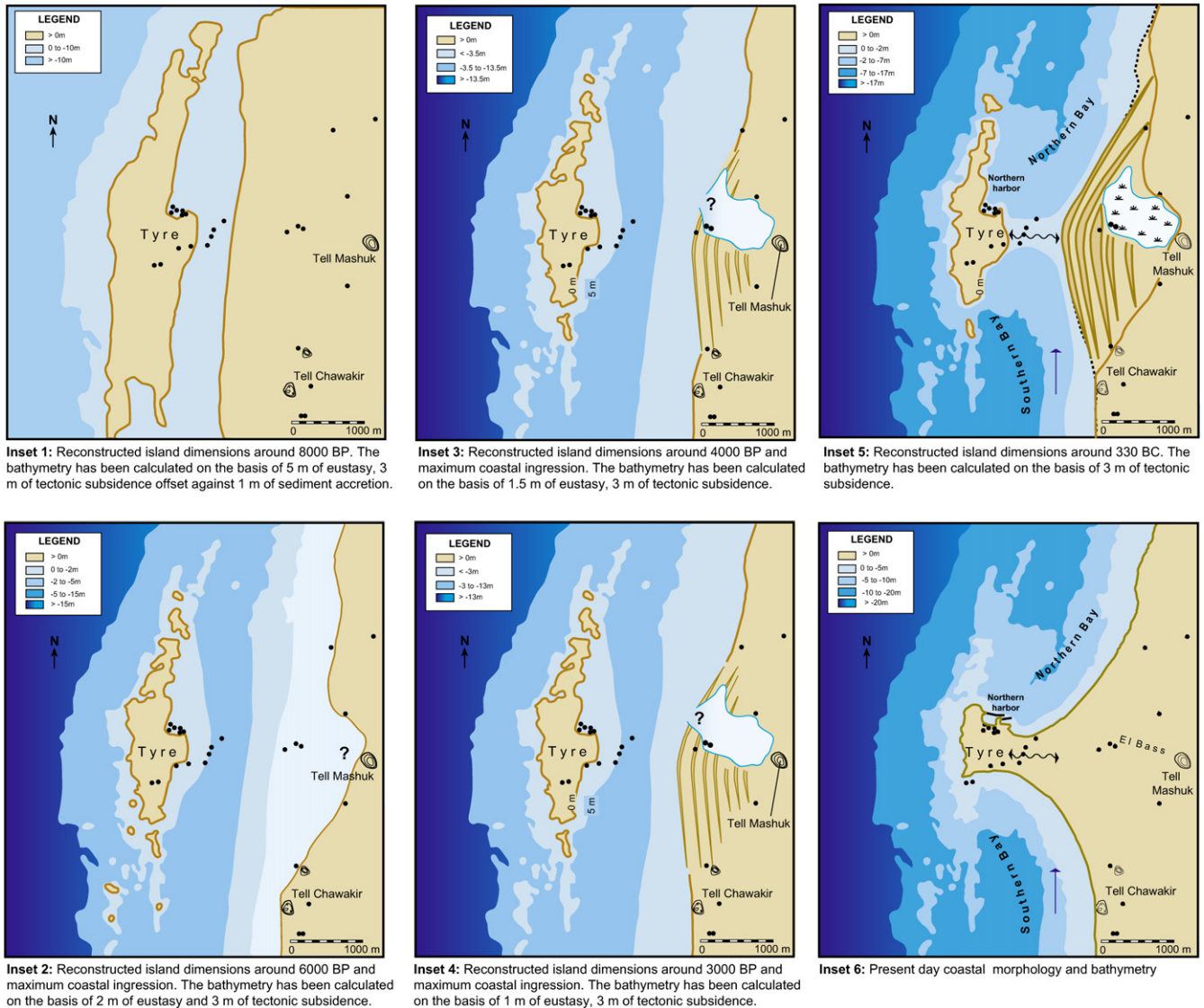


Fig. 11. Tentative coastal reconstruction of Tyre’s sandstone ridge since 8000 BP based on relative sea-level variations at the site.

sands, allied with skewness values of -0.16 to -0.52 , attest to a low-energy depositional environment (Fig. 11).

The molluscan faunas comprise taxa from diverse biocenoses (Fig. 9). Despite the increasingly sheltered nature of the environment, significant numbers of *extra situ* species continue to be represented. These are indicative of either: (1) the periodic incursion of strong marine currents; or (2) cultural inputs from boats and ships (i.e. shells caught in fishing nets etc.). *In situ* taxa are dominated by species from the upper clean-sand assemblage (*Cyclope neritea*, *S. viridis*, *N. pygmaeus*, *N. mutabilis*) and the upper muddy-sand assemblage (*Macoma cumana*, *Haminea hydatis*, *L. lacteus*).

Four diagnostic taxa dominate the ostracod fauna of this harbour facies: *Loxoconcha elliptica*, *Loxoconcha* spp., *X. aurantia* and *A. convexa*. *Loxoconcha* spp. and *X. aurantia* have oligo-mesohaline salinity ranges and prefer muddy to sandy substrates; they attest to a marine lagoonal environment (Figs. 7 and 10). In TV, presence of the brackish water species

L. elliptica is consistent with a sheltered harbour. Continued exposure to outer marine dynamics is manifested by low percentages of coastal and marine species such as *A. convexa*, *A. woodwardii*, *Cushmanidea* sp. and *Urocythereis oblonga*.

Interpretation: the northern harbour’s geological record clearly translates a number of technological advances in port engineering, which can be attributed to the Romans (Oleson, 1988). The most important of these breakthroughs was their mastery of concrete (Brandon, 1996, 1999; Fitchen, 1988; Fletcher, 1996; Garrison, 1998; Oleson et al., 2004a,b). The Romans had two distinct types of concrete mortar:

- (1) The first was made with simple lime and river sand, mixed at a ratio of three parts sand to one part lime, and was widely used in terrestrial construction (Ginouves, 1998; Lancaster, 2005). Its use in seaport contexts was more problematic as it could not harden underwater, which implied building structures on dry land or in

a previously drained area (using cofferdams, compacted clays, etc.).

- (2) The other type replaced the river sand with pozzolan, mixed at a ratio of two parts pozzolan to one part lime (Garrison, 1998; Humphrey et al., 1998, Vitruvius, II, 5). Pozzolan, or pozzolanic ash, is a siliceous and aluminous material which reacts with calcium hydroxide in the presence of water to form compounds possessing cementitious properties at ambient temperature (Malhotra and Mehta, 1996; Mehta, 1991). Its discovery was a revolution in harbour engineering, as it could set underwater. It derives its name from the Bay of Pozzuoli, where the ash is found in abundance; indeed, recent research suggests that the Pozzuoli vicinity was the primary source for Mediterranean pozzolana during Roman times (Oleson et al., 2004a).

Whereas earlier Bronze Age and Iron Age societies exploited natural roadsteads to establish anchorages, the Romans' mastery of hydraulic concrete engendered significant new construction possibilities in coastal areas (Brandon, 1999; Oleson et al., 2004a). It appears that by ~200 BC, they were using pozzolan concrete to line the harbourworks at Pozzuoli (Puteoli), which already indicates a striking degree of sophistication. The use of hydraulic concrete in Roman port construction reached its zenith during the 1st and 2nd centuries AD as bear witness the totally artificial harbours at Caesarea, Cosa and Portus (Gazda, 2001; McCann, 2002; McCann et al., 1987; Oleson and Branton, 1992; Oleson et al., 2004b; Raban and Holum, 1996; Roller, 1998). Throughout the circum Mediterranean, geoarchaeological studies of Roman harbours indicate a diagnostic silt or plastic clay unit that is consistent with the significant technological advances of the period (Giampaola et al., 2004; Goiran, 2001; Goiran and Morhange, 2003; Hesnard, 1995, 2004a,b; Marriner and Morhange, 2006a,b, 2007; Morhange, 2001).

At Tyre, there is presently very little archaeological information pertaining to the nature of the harbourworks in the northern cove. However, unlike Caesarea's outer harbour, which is exposed to the southern Levant's high-energy meteo-marine regime, Tyre was artificially protected by the partially drowned sandstone ridge. Large-scale seaport enterprises were thus not required and we speculate that preceding structures were reinforced and added to at this time. The main west–east trending breakwater shows evidence of Roman courses (Descamps, personal communication), and it seems probable that existing Iron Age port infrastructure would have been reinforced and added to at this time. The cluster of radiocarbon dates centred on the 1st century BC and 2nd century AD, suggests a major overhaul of harbour infrastructure when Tyre fell under Roman control in 64 BC.

4.2.5. Byzantine harbour

Description: the late Roman and Byzantine periods are marked by transition to a fine-grained silty sand facies. This second pronounced phase of harbour confinement is consistent with highly sophisticated port infrastructure creating a brackish lagoon type environment isolated from the sea. We observe

a sharp decline in molluscan and ostracod species diversities. *In situ* molluscan taxa include individuals from the upper clean-sand assemblage (e.g. *Pirenella conica*, *C. neritea*), the lagoonal assemblage, and the upper muddy-sand assemblage in sheltered areas (*C. vulgatum*). The brackish water ostracod *C. torosa* attains relative abundance levels >90%. Relative absence of outer marine species is a result of confinement from the open sea.

Interpretation: these litho- and biostratigraphical data all point to an infrastructural apogee during the Byzantine period, culminating in a protected hyposaline basin (Kjerfve and Magill, 1989). The Byzantines inherited from the Romans' rich legacy of engineering *savoir faire*. Many of the techniques were improved upon and consolidated during this period (Hohlfelder, 1997). Indeed, never again did such a well-protected basin exist at Tyre (Borrut, 1999–2000).

4.2.6. Semi-abandonment phase: 6th to 8th centuries AD

Description: the transition to unit A postdates the Byzantine period and is constrained to between the 6th and 8th centuries AD. The unit comprises a grey, shelly-sand unit rich in gravels (3–31%) and coarse sands (58–83%), against a mere 9–18% for the silts and clays.

C. vulgatum and *P. conica* dominate the molluscan suites, with numerous secondary species from diverse biocenoses (*Ringicula auriculata*, *N. pygmaeus*, *Gibberula miliaria*; Fig. 9). The increase in coastal ostracod taxa, such as *Urocythereis* sp. and *A. woodwardii*, is to the detriment of the formerly abundant lagoonal and marine lagoonal taxa of the Byzantine harbour (Figs. 7 and 10). This translates a re-exposure of the environment to the influence of the marine swell and currents. The tests of many of these individuals have been broken by wave action, consistent with a rise in energy dynamics due to the demise of the port. This semi-abandonment phase led to rapid coastal progradation diminishing the size of the basin by around 40%. Seaward dislocation of the land accommodated urban growth during the medieval period, at which time it became Tyre's main market centre.

Interpretation: presence of this coarse sand unit is a classic feature of semi-abandoned ports not only in the Levant but also throughout the Mediterranean (Marriner and Morhange, 2007). Explaining its presence at Tyre is complex and appears to be linked to a number of different phenomena.

- (1) *Cultural:* Byzantine control of Tyre lasted until the 7th century AD at which time a series of political crises (internal quarrels, Arab onslaught) forced the empire to shrink back to its Anatolian core (Norwich, 1993; Treadgold, 2000). By 650 AD Arab forces had conquered all of the Levant (up to Syria), Persia, and Egypt (Bonner, 2005). This epoch was marked by significant permutations in the eastern Mediterranean's trade network which directly impacted upon the area's seaports.
- (2) *Natural catastrophes:* the 4th–11th centuries AD are well-documented as being a period of tectonic and

tsunamogenic instability on the Levantine coast (Elias et al., 2007; Guidoboni et al., 1994).

4.2.7. Roman and Byzantine dredging

Until recently, ancient harbours were considered to be quasi-continuous archives of human–environment interactions spanning the late Neolithic to present (Goiran and Morhange, 2003; Morhange, 2001). During the course of our recent geoarchaeological research, this premise has come under scrutiny and indeed mounting evidence suggests that scholars must now nuance how they interpret these records. At Tyre and Sidon, persistent dating discrepancies have been evidenced throughout the fine-grained harbour units. Initially, these were problematic to interpret and evoked an unquantified reservoir effect for the coasts of southern Lebanon. In the absence of pre-1930 molluscan shells, to more precisely elucidate this local reservoir age, we performed a series of radiocarbon dates on charcoal (2215 ± 30 BP; Poz-5777) and *in situ* *L. lacteus* molluscan shells (2505 ± 30 BP; Poz-5775) from the same stratigraphic layer, TIX 35. The offset confirms findings from elsewhere in the Mediterranean (Reimer and McCormac, 2002), and indicates that radiocarbon anomalies are not responsible for the empirical chronostratigraphic patterns. These data, coupled with mounting evidence from other ancient harbours (Marseilles and Naples), suggest the Romans significantly overhauled their seaports at the turn of the Christian era, notably removing great tracts of Bronze Age and Iron Age sediments (Giampaola et al., 2004; Giampaola and Carasana, 2005; Hesnard, 2004a). This has created a stratigraphic paradox of archiveless Phoenician harbours.

Roman and Byzantine societies had a significant impact upon sedimentation patterns within Tyre's northern basin. Whilst in natural coastal systems, sediment accumulation rates and sediment supply converged towards a state of equilibrium, the influence of man in this low-energy environment brought about a number of 'anthropogenic disequilibria'. Rapid rates of sedimentation, around 10 times greater than nearby natural coastlines, are recorded at this time. For example, for the period 6000–4000 BC, sedimentation rates of 0.5–1 mm/yr are contrasted against 10 mm/yr for the period 500 BC–500 AD. The basin acted like a sediment sink, or depocentre, accumulating thick sequences of fine-grained sediments. Silting up rates of between 10 and 20 mm/yr have also been observed at Alexandria (Goiran, 2001) and Marseilles (Morhange et al., 2003). By Roman times the problem had grown so acute that it threatened the viability of Tyre's northern harbour and necessitated a clear management response. Although desilting infrastructure, such as sluice gates and channels, could have partially attenuated the problem, in the long term these were relatively ineffective (Blackman, 1982a,b). Repeated dredging remained, therefore, the only means of creating artificial accommodation space and ensuring long-term harbour viability.

In the rest of this paper, we look to elucidate new evidence for Tyre's other harbour complexes, notably the hypothesised southern basin, the city's outer harbours and the series of continental anchorages that functioned in tandem with the Tells Mashuk, Chawakir and Rachidiye.

4.3. In search of Tyre's southern harbour

Although the question of a southern seaport was not properly evoked until the 19th century (Guérin, 1880; Kenrick, 1855; Poulain de Bossay, 1861), drowned archaeological remains along the city's southern coastal fringe had long attracted the curiosity of early pilgrims and travellers. As early as the 12th century AD, Benjamin of Toledo, a traveller in Phoenicia, described the towers, palaces, squares and streets he observed drowned on the southern coast of the city. Later Maundrell (1703), briefly touches on the subject when he observes that the northern and southern "bays are, in part, defended from the ocean, each by a long ridge, resembling a mole, stretching directly out, on both sides, from the head of the island; but these ridges, whether they were walls or rocks, whether the work of art or nature, I was too far distant to discern." The idea of building a double harbour is motivated by the fact that there are two main wind and offshore wave directions at Tyre. Indeed, dual seaports are a recurrent theme in Iron Age and later period maritime façades (Lehmann-Hartleben, 1923).

4.3.1. What is the epigraphic and iconographic evidence for two harbours at Tyre?

The development of inter-state trade during the Early Iron Age almost certainly demanded an expansion of the city's docking capacities (Katzenstein, 1997). Various lines of indirect evidence exist in support of two basins on the island. (1) The first, and perhaps most interesting from a palaeogeographical standpoint, derives from an Assyrian iconographic depiction of Tyre at Balawat (near Mosul in modern Iraq [Fig. 12]). The upper register of this band shows Shalmaneser in the first full year of his reign (858 BC), receiving tribute from the Tyrians. The Phoenicians, distinguished by their pointed caps, ferry goods across from their island fortress to King Shalmaneser (?) who awaits on the mainland with a bow and arrow as symbols of the conqueror. The offshore bastion is represented by tall turreted walls with two gates leading into the city. Some scholars have interpreted these separate entrances as a symbol of the city's two ports (Barnett, 1969; Katzenstein, 1997). Other researchers have questioned this interpretation, noting that the gates are not directly linked to the sea (Bunnens, 1983). (2) The idea of double harbours on Tyre is further corroborated by an Old Testament description of Tyre as "throned above your harbours" (Ezek. 27:3; Katzenstein, 1997). Carayon (2005b) notes, however, that the Hebrew Bible does not use the term 'harbour' but rather 'access', implying either a gate or passage. In light of this, Katzenstein's interpretation of the Ezekiel text is not totally justified. (3) The first unequivocal evidence for Tyre's two seaports dates from the narrations of Alexander the Great's siege. Arrian, writing at the time of Alexander, noted that Tyre had two harbours, one a natural bay and the other artificial (Arrian II, 20, 10: "towards Sidon" and "towards Egypt"). Diodorus of Sicily (90–30 BC), uses the plural of harbour (XVII, 42, 4) when discussing the city's seaports, but does not provide any detailed information. (4) Finally, Strabo (~40–25 BC)

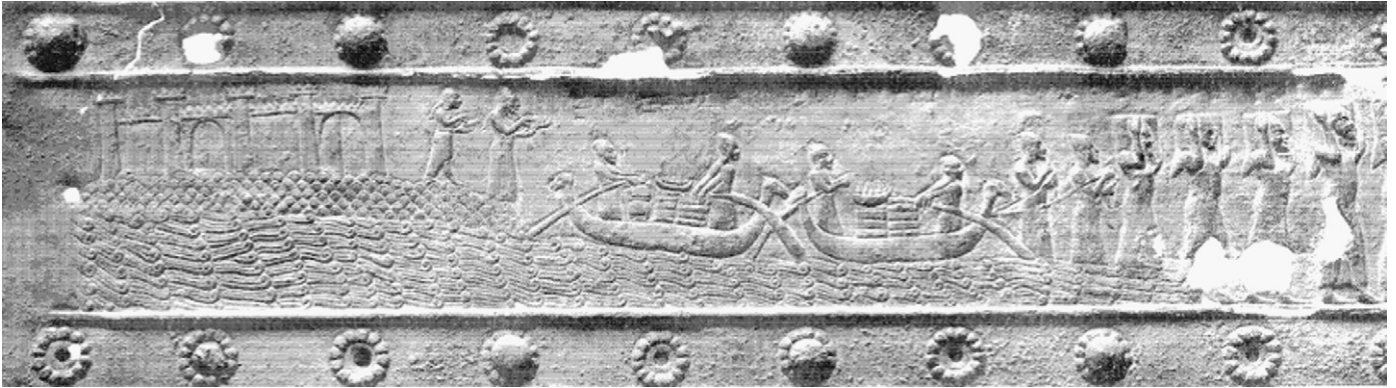


Fig. 12. Ninth century BC depiction of Tyre from the Assyrian site of Balawat in Iraq. This particular representation of the Phoenician island raises a number of interesting palaeogeographical questions: (1) there are two gates in the offshore bastion. Are these a symbol of Tyre's twin harbours? (2) Secondly, the sea is clearly rendered between the offshore fortress and the mainland. However, today Tyre comprises a peninsula, connected to the mainland by a sandy isthmus. (3) Finally, the beaching of the vessels evokes Bronze Age/Iron Age anchorage havens around Palaeotyros on the mainland (Tell Mashuk and Tell Rachidiye). Photograph: N. Marriner at the British Museum.

describes two harbours at Tyre, one a closed port (*limena kleistov*) and the other open (*aneimenon*). The text is particularly interesting, as it can be linked to the *bas-reliefs* in the Palace of Sennacherib (704–681 BC) at Nineveh. These *reliefs* are today lost but can still be studied thanks to drawings made by Layard and later collated by Barnett (1956). It has been suggested that the scene depicts the escape of Lulû, king of Tyre and Sidon. The scene is clearly located in a harbour, apparently exterior to the main city walls and accessed via a postern (Fig. 13). This idea is in keeping with Lehmann-Hartleben (1923) who defined the closed harbour (*limen kleistos*) as an *intra muros* seaport, contrasting with the *extra muros* open harbour (*limen aneimenon*). On the basis of this, it is likely that the *bas-reliefs* at Nineveh correspond to the southern harbour.

4.3.2. Poidebard's southern harbour

By the turn of the 20th century, two schools of thought were juxtaposed regarding the interpretation of these southern archaeological remains: (1) an 'ancient harbour school', with proponents such as Kenrick and De Bossay; and (2) a 'drowned city school', led notably by Renan. Significantly, technological limitations meant that neither group had strong archaeological evidence in which to ground their hypotheses.

Fascinated by the conjectures of his predecessors, Poidebard (1939) coupled aerial photography and diving surveys to investigate the underwater archaeology of Tyre's southern coastal fringe. His interest in Tyre began in 1934 when, as an officer of the French air force, he began aerially photographing the Phoenician coast. From this exceptional vantage point, Poidebard came to fully comprehend the rich archaeological potential of the city and saw scope to extrapolate the techniques he had developed working in the Syrian desert.

This southern area comprises an east–west trending basin around 700 m long by 200 m wide and runs parallel to the present island coastline (Fig. 14). The marine bottom lies ~3–4 m below present mean sea level. Today, the area is sometimes used as a fair-weather anchorage by local fishermen, but is, at least for the present, not sufficiently protected

to be considered a harbour basin *sensu stricto*. Indeed, it seems almost paradoxical that ancient societies should have built such a large harbour basin on an exposed façade of the island.

After extensive research spanning 1934–1936, Poidebard eventually diagnosed what he believed to be an artificial harbour basin enclosed by an imposing 670 m long mole. For many scholars Tyre's southern seaport had been rediscovered and, despite reanalysis by Frost (1971) during the 1960s and 1970s, archaeologists and historians continue to promulgate Poidebard's (mis)interpretations to this day (Bikai, 1979; Bikai and Bikai, 1987; Jidejian, 1996; Kassis and Tyr, 2005; Katzenstein, 1997). Building on Frost's partial reinterpretation of Poidebard's southern harbour, **new underwater research undertaken in 2002 has confirmed that this locale is in fact a drowned quarter of the ancient city (El Amouri et al., 2005)**. Poidebard's supposed Iron Age mole has yielded late Roman ceramics, implying that it is almost certainly not of Phoenician age; El Amouri et al. (2005) have hypothesised this mole to be a polder wall. The presence of urban structures, walls and drowned quarries within the basin further call into question its use as a seaport during antiquity.

4.3.3. Reinterpretation of Tyre's supposed southern harbour

To independently test these archaeological data, we drilled two short offshore cores (TXXIII and TXIV; Fig. 14) in Poidebard's supposed southern basin looking to answer a number of questions: (1) is there any sedimentological evidence for ancient harbour sediments in this area (be they Iron Age, Roman or Byzantine)? and (2) if this basin was indeed an urban quarter, would it be possible to accurately date the collapse of the island?

4.3.3.1. Polder surface (unit C). A very thin veneer (50 cm) of clastic sediments was elucidated in this southern area (Fig. 15). Unit C of cores TXXIII and TXXIV comprises **coarse-grained sands** with poor sorting indices of between 1.2 and 1.6. Five taxa dominate the ostracod suites, *L. rhomboidea*, *X. aurantia* (marine lagoonal), *A. convexa*, *A. woodwardii* and *U. oblonga* (coastal). Faunal densities are low,

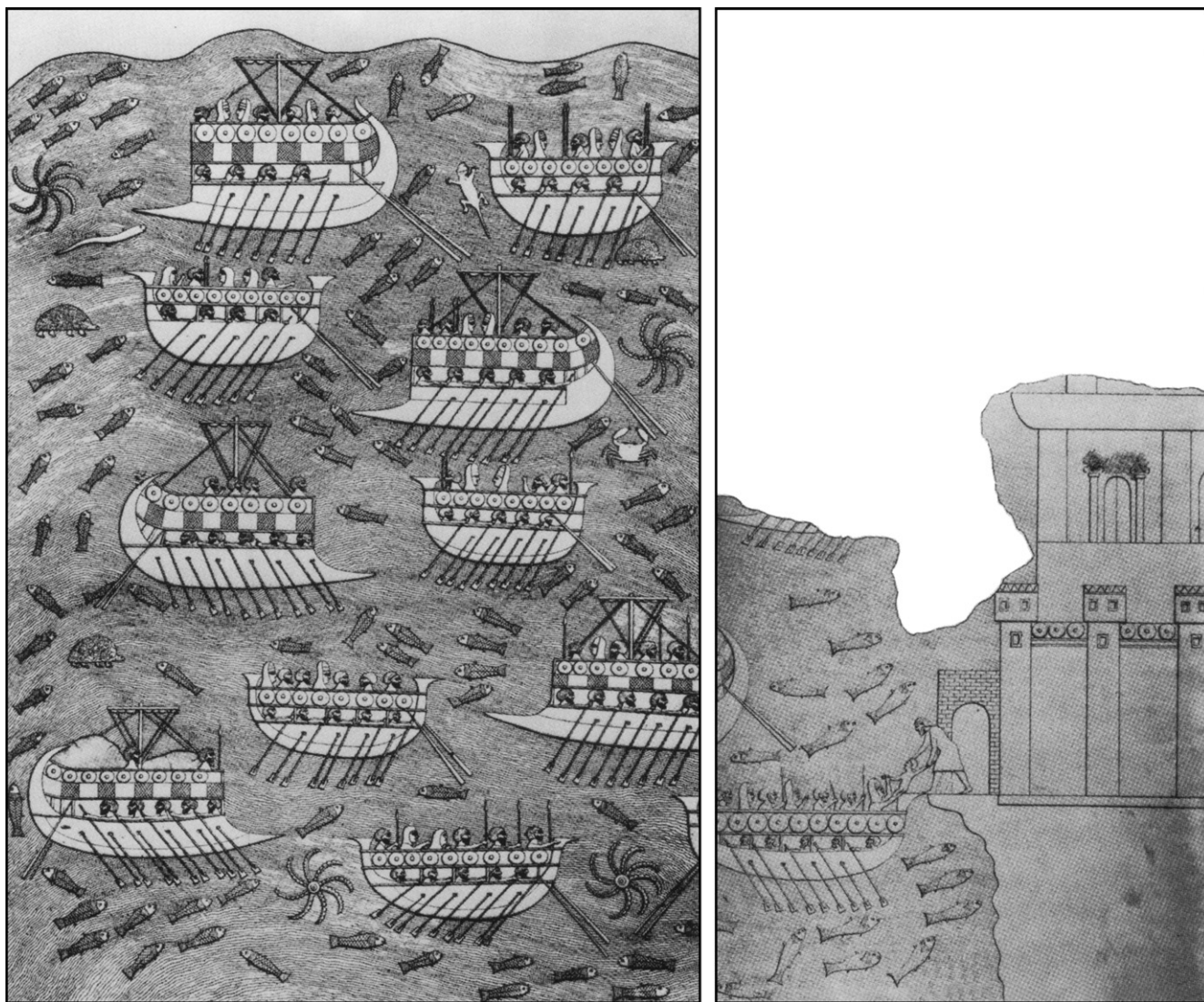


Fig. 13. Bas-reliefs from the Palace of Sennacherib (704–681 BC) at Nineveh, inferred to represent the escape of Lulī from Tyre via the southern harbour. The drawings, by Layard and collated by Barnett, are conserved at the British Museum (Jidejian, 1996).

between 20 and 40 tests per 10 g of sand (Fig. 16). Diverse ecological groups are represented by the molluscan faunas, including the subtidal sands assemblage (*Tricolia pullus*, *R. dolium*, *Mitra cornicula*), the hard substrate assemblage and the upper clean-sand assemblage (Fig. 17). These litho- and biostratigraphical data appear consistent with polder infill, whereby nearby coastal sediments were imported to raise the general level of the land. Tracts of the island have been infilled since Phoenician times, to increase the habitable area of the ancient city (Katzenstein, 1997).

4.3.3.2. *Dredged Iron Age harbour deposits (unit B)?*. The coarse-grained sand deposits of unit C are overlain by low-energy fine sands and silts. A sharp rise is observed in the silts and clays fraction to between 80% and 90% of the total sediment texture. Poorly developed histograms allied with the juxtaposition of coarse sands and fine-grained silts are typical of an ancient harbour deposit (Morhange, 2001). The gravels fraction comprises numerous rootlets, charcoal, wood fragments and

seeds analogous to deposits found in Tyre's northern harbour during the Roman and Byzantine periods. There is very little biostratigraphic variation in the ostracod faunas, and the unit is dominated by marine lagoonal and coastal taxa consistent with a semi-protected environment. The subtidal sands and hard substrate assemblages characterise the molluscs. Three analogous dates from core TXXIV constrain the chronology of this unit to the Persian period (750–400 cal. years BC). The absence of any notable bio- and chronostratigraphic variations suggests that the unit was deposited contemporaneously.

We advance two hypotheses to explain the origin of these fine-grained deposits.

- (1) Tectonic subsidence of the coastal ridge drowned this southern urban quarter during antiquity leading to the formation of a semi-protected enclave sheltered by the polder walls. New archaeological and stratigraphic data support tectonic collapse of ~3 m during antiquity. Two types of evidence exist.

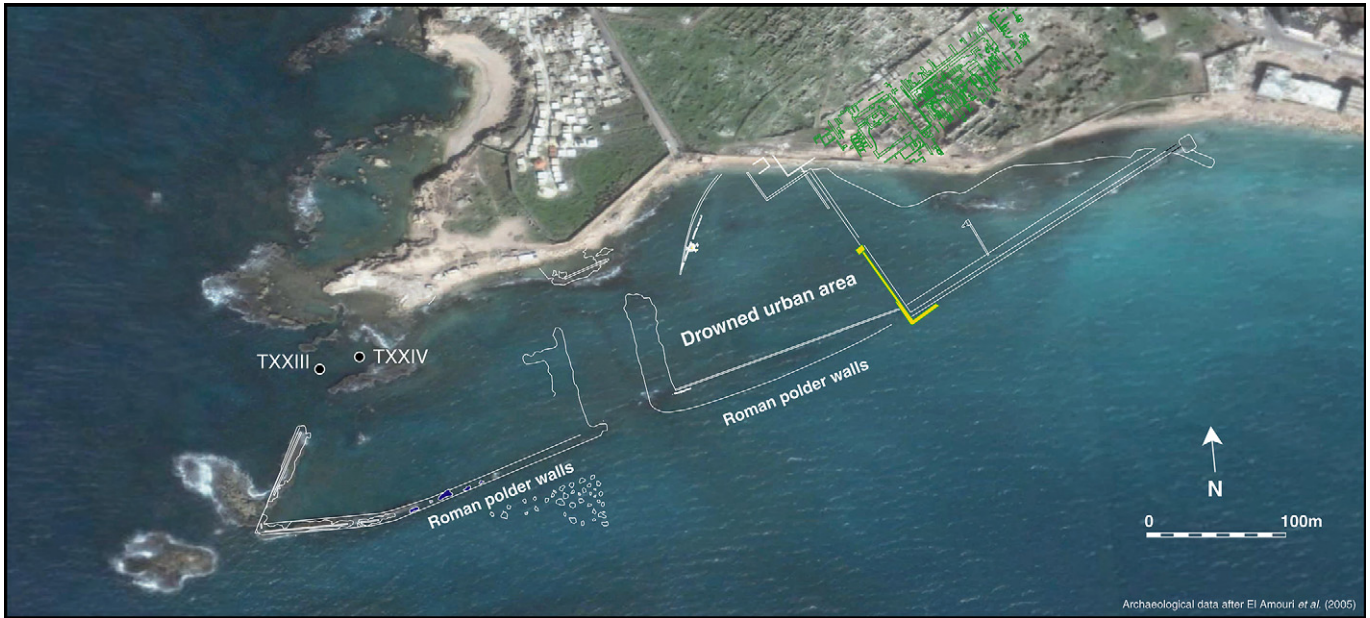


Fig. 14. Aerial photograph of Tyre's southern harbour and outlay of its drowned polder walls (archaeological data from El Amouri et al. (2005) and Poidebard (1939)). The drowned southern basin has yielded extensive archaeological material pertaining to a submerged urban quarter still active during the late Roman period (El Amouri et al., 2005). Base image: DigitalGlobe.

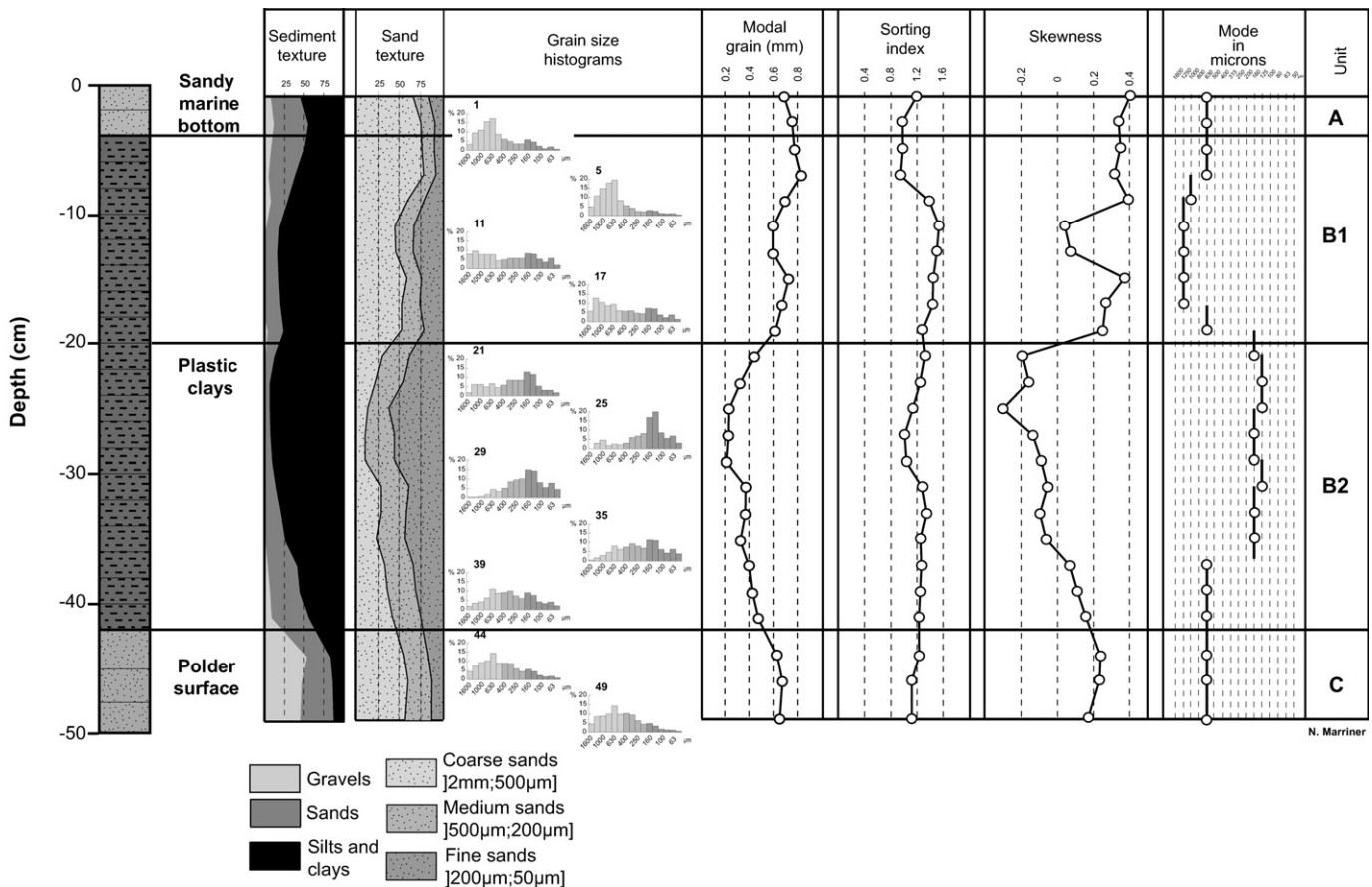


Fig. 15. Grain size analyses of core TXXIV.

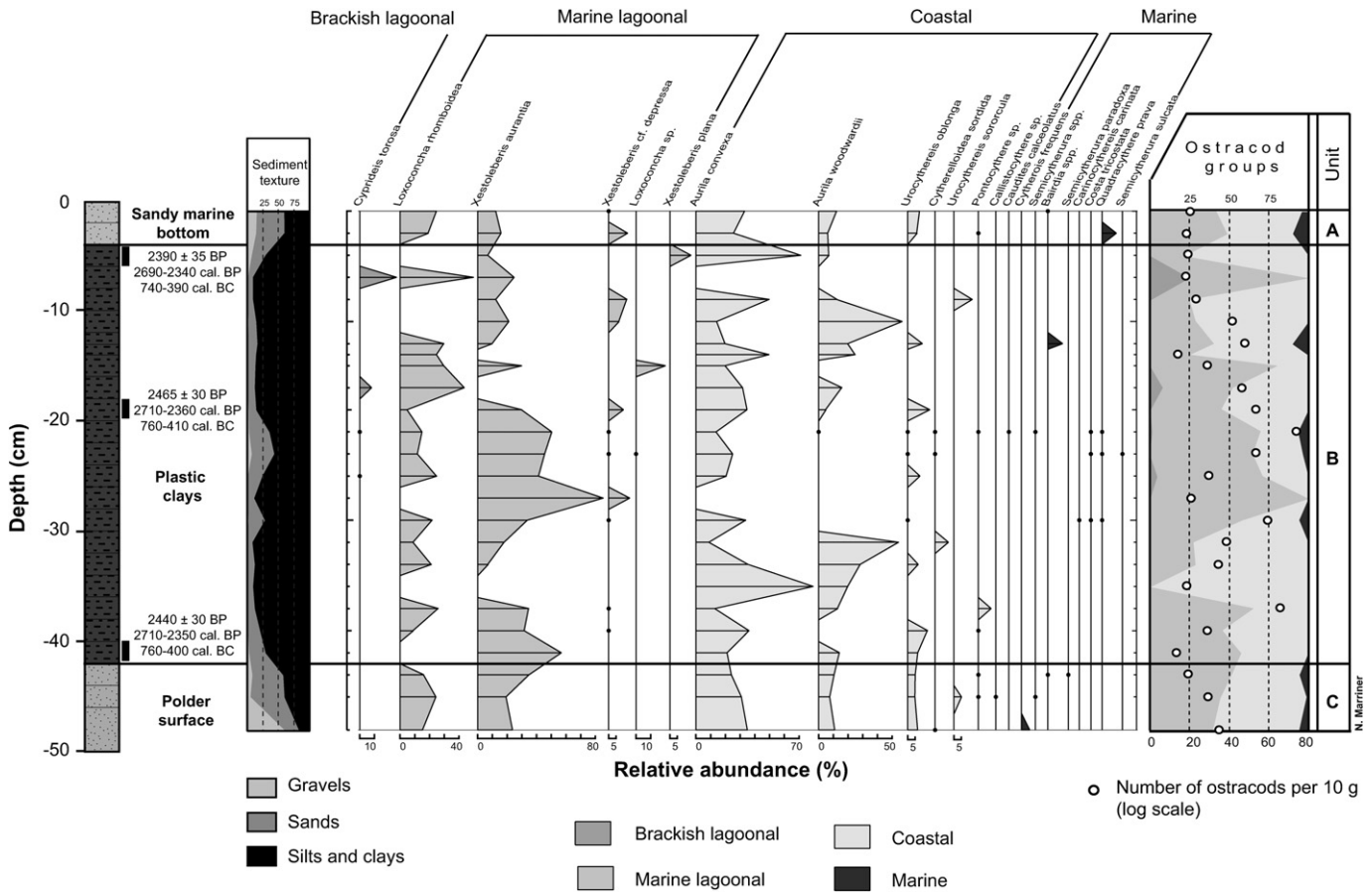


Fig. 16. Ostracod data of core TXXIV.

- (i) *Archaeological:* Tyre’s northern Roman mole is currently 2.5 m below present sea level, translating a subsidence of ~3–3.5 m (Nouredine and Helou, 2005; Descamps, personal communication). On the southern shore, walls and drowned quarries at 2.5 m below MSL have also been elucidated (El Amouri et al., 2005; Frost, 1971).
 - (ii) *Stratigraphic:* similar subsidence is translated in the city’s coastal stratigraphy, notably a ~3 m offset in sediment accommodation space and radiocarbon-dated strata between Tyre and Sidon. The archaeology suggests that this area of the ancient city was still fully functional during the Hellenistic and Roman periods (El Amouri et al., 2005), therefore contradicting evidence for island collapse during the Persian occupation. Our palaeogeographical reconstructions attest to a 2800 m (N–S) by 800 m (E–W) Hellenistic/Roman island compared to 1000 m (N–S) by 700 m (E–W) after the late Roman collapse (Fig. 11). In light of these chronological discrepancies, how can one explain the presence of marine harbour deposits on dry land?
- (2) This question leads us on to a second, more plausible hypothesis. We speculate that these deposits comprise dredged Iron Age material from the northern harbour, deposited in this area for use in the ceramic and construction

industries (Fig. 18). This hypothesis is further corroborated by the relatively localised distribution of the clay deposits and their proximity to the Greek/Roman shoreline of the period. Similar examples of clay mounds are known from a number of sites on the Phoenician coast, and the technique is still used by artisanal industries on the Nile delta (Leclant, 2005). It appears likely, therefore, that some of the dredging vessels deposited small sediment loads from the northern harbour in this area. El Amouri et al. (2005) have noted that these clay mounds are relatively localised, constituting <5% of the total basin area. Evidence from Marseilles suggests that *marie-salopes* were important in transporting dredged material (Pomey and Rieth, 2005). These vessels were designed to accommodate dredged sands and silts extracted by dredging. Once the vessel had been filled, it would either offload its deposit on land, or dump the material offshore via a specially conceived trap in the hull of the boat (Pomey, 1995; Long, personal communication).

4.3.3.3. Present marine bottom (unit A). Coarse-grained sands characterise unit A of cores TXXIII and TXXIV. This thin cap of sediment is consistent with the present marine bottom. It has not been possible to accurately date the submergence of this southern area on purely radiometric grounds. The

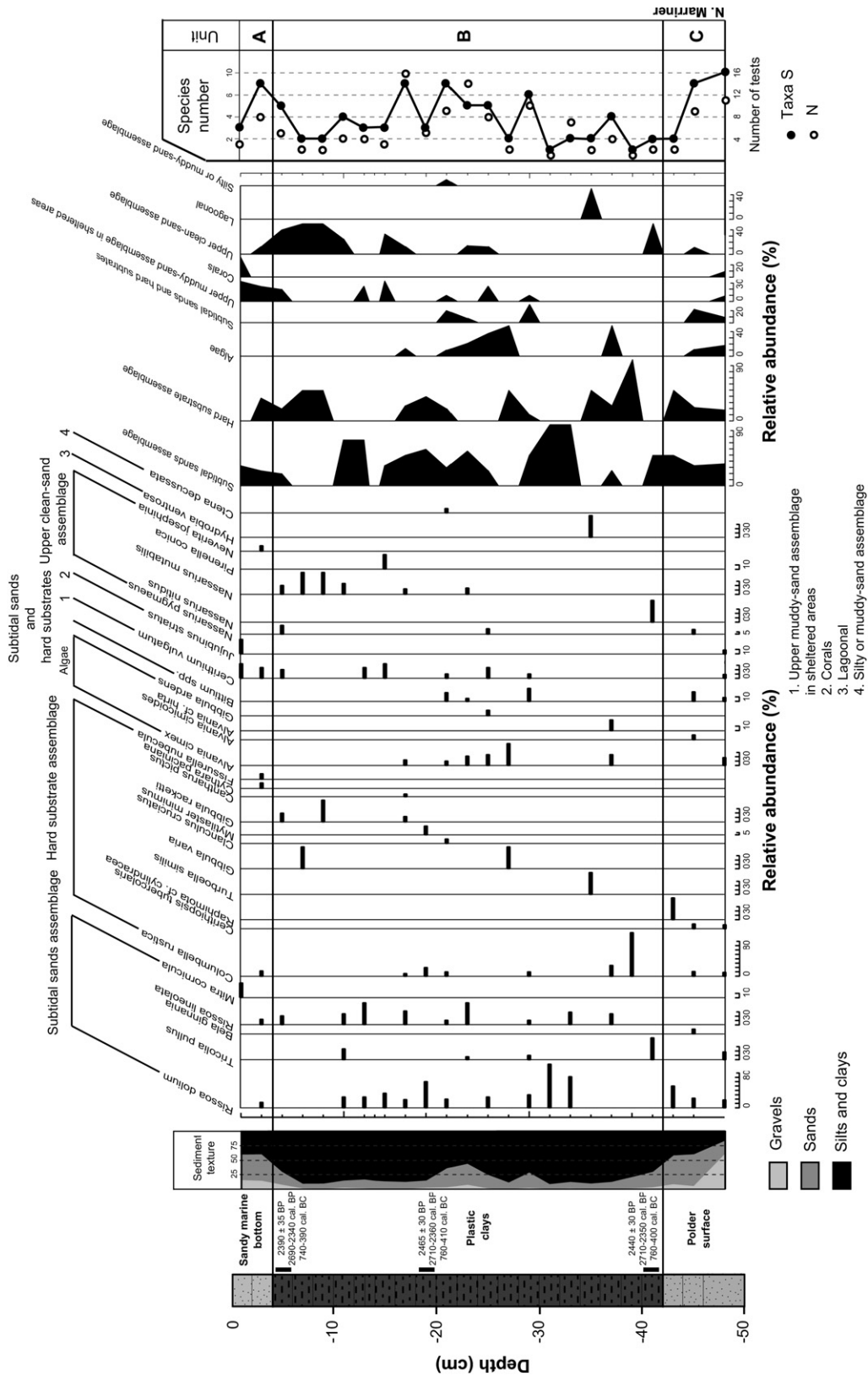


Fig. 17. Macrofauna data of core TXXIV.

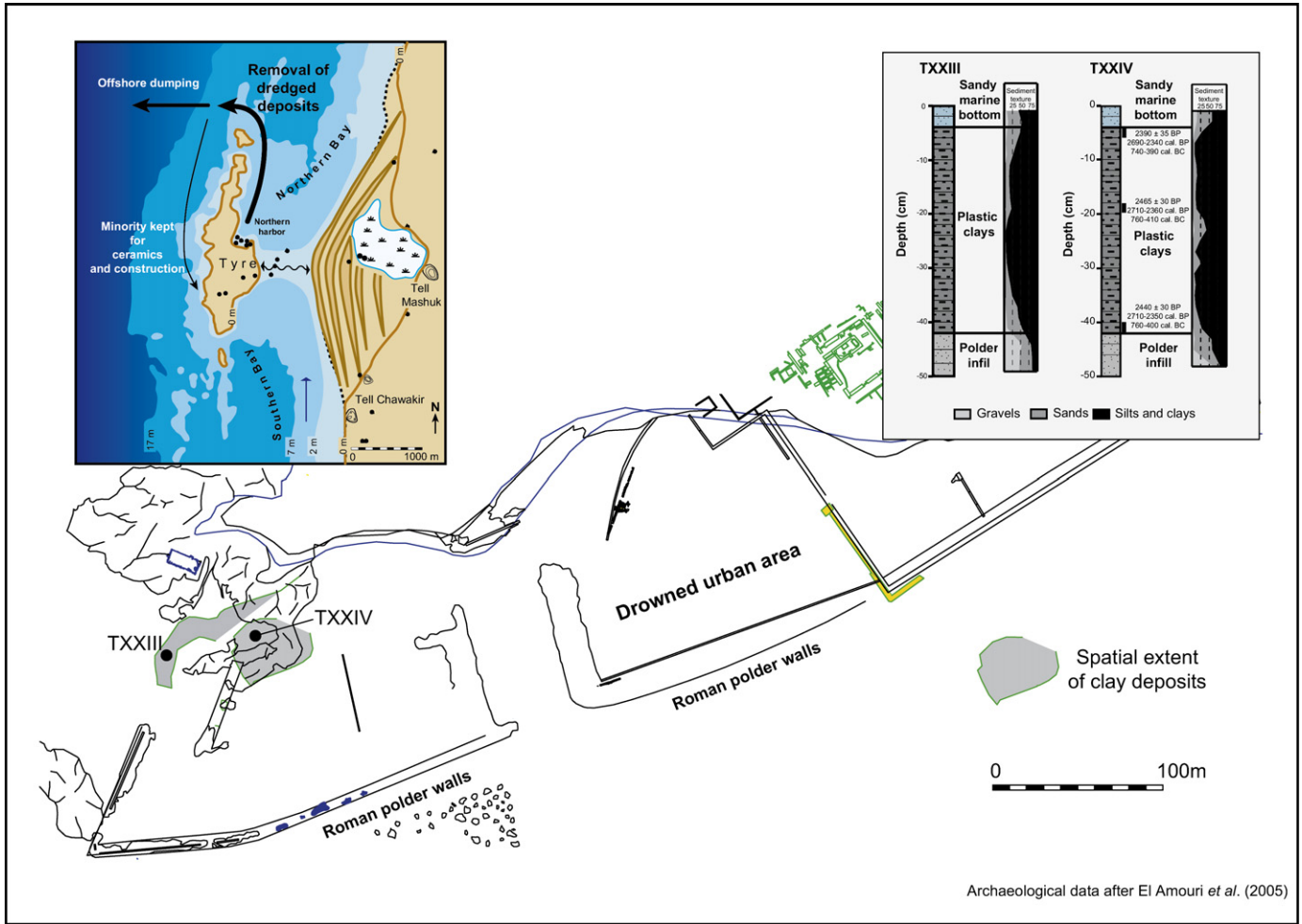


Fig. 18. Spatial extent of dredged clay deposits in Tyre's southern drowned basin (archaeological data from El Amouri et al., 2005).

archaeology, on the other hand, constrains this **tectonic collapse to the late Roman period**. As today, it is plausible that the drowned basin could have been used as a fair-weather harbour by small vessels during the Byzantine and later periods. There is no evidence to suggest, however, any elaborate sea-port infrastructure and Poidebard's initial interpretations can now be irrefutably rejected.

4.4. Where was Tyre's southern harbour?

Unlike many of his contemporaries, Renan (1864) always questioned the validity of a southern harbour on the exposed fringe of the island. Based on his knowledge and observations of the site, he conjectured that the most plausible location for a second anchorage lay on the southeastern side of the island, in an area presently covered by thick tracts of coastal sediments. To test this hypothesis we investigated the coastal stratigraphy.

Numerical models indicate that during antiquity the island of Tyre generated a large 3 km × 1.5 km wave shadow, which would have favoured a number of secondary anchorages on Tyre (Marriner et al., 2007). One of the lowest energy zones lies in the area identified by Renan as sheltering the southern harbour (see Fig. 1); this area also lies in close proximity to the city

centre. The reefs extending to the north and south of the city would have been used as offshore anchorages in the same way as Zire island at Sidon. This is corroborated by **extensive anchorage finds from around these outer reef systems** (El Amouri et al., 2005). Exploitation of such an outer harbour system would have greatly increased the docking capacity of the city.

4.4.1. What can coastal stratigraphy tell us about Tyre's southern harbour?

A number of cores was also drilled on the southeastern fringe, in an area hypothesised by Renan (1864) to have sheltered Tyre's southern harbour. This area attests to a complex stratigraphic history characterised by the accretion of natural coastal sediments juxtaposed against a series of infill phases (undertaken to raise the surface of the ancient city during the Hellenistic and Roman periods).

4.4.1.1. Renan's southeastern harbour

4.4.1.1.1. *TVIII marine transgression.* The marine transgression in core TVIII is dated 6300 ± 40 BP (6880–6650 cal. BP). The unit comprises fine-grained sands (Fig. 19) with molluscan taxa from the subtidal sands and hard substrates (*B. reticulatum*), upper muddy-sand assemblage in sheltered areas

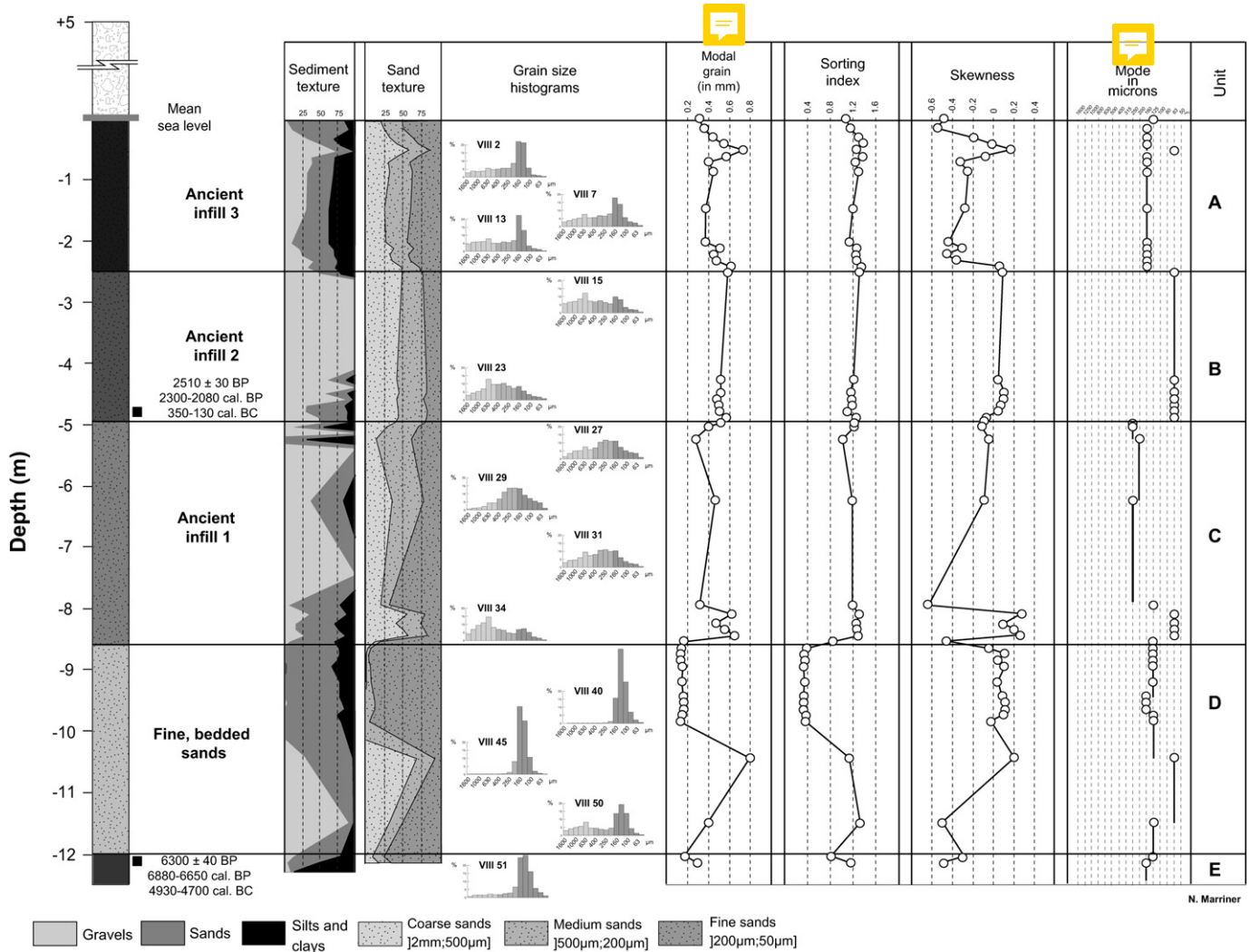


Fig. 19. Grain size analyses of core TVIII.

(*C. vulgatum*) and the subtidal sands assemblage (*R. lineolata*, *R. dolium* [Fig. 20]). A high faunal density population (~1000 tests per 10 g sand) of *C. torosa* dominates the ostracod fauna.

4.4.1.1.2. *Low-energy marine environment.* In unit D, transition to a fine-bedded sands unit corroborates a sheltered marine environment. Fine-grained sands and sorting indices of ~0.4 are consistent with a well-sorted subtidal beach environment. Four assemblages dominate the molluscan faunas: subtidal sands and hard substrates (*B. reticulatum*), upper muddy-sand assemblage in sheltered areas (*L. lacteus*, *Gastrana fragilis*, *C. vulgatum*), silty or muddy-sand assemblage (*R. dolium*, *R. lineolata*) and the subtidal sands assemblage (*Macoma tenuis*, *Dosinia lupinus*). The bottom part of unit C contained no ostracod faunas. The brackish water species *C. torosa* dominates the top of the unit, with secondary peaks of *Loxoconcha* spp., *X. aurantia* (marine lagoonal) and *A. convexa* (coastal).

The litho- and biostratigraphical proxies point to a low-energy environment protected by the offshore island. Such a depositional context would have been ideal for the establishment of an anchorage haven from the Bronze Age onwards.

4.4.1.1.3. *Infill phases.* Units A–C comprise coarse-grained gravels and sands. Poorly developed histograms and

poor sorting indices of ~1.1 to 1.3 are consistent with polder deposits. The sedimentological analyses put into evidence three different phases and/or sources of infill deposits, beginning during the Hellenistic period (2510 ± 30, 2300–2080 cal. BP). These are clearly differentiated by the modal values of the three units, 160 µm (unit A), 63 µm (unit B) and 250–63 µm (unit C) respectively.

The relative absence of molluscan and ostracod faunas further corroborates these infill phases. The molluscan fauna juxtaposes taxa from diverse ecological environments, spanning the muddy-sand assemblage to the hard substrate assemblage. The low number of tests, their poor taphonomic condition and the absence of juvenile individuals are not consistent with the development of an *in situ* biocenosis. Similar facies have been elucidated in core TXVI and indicate that parts of the ancient Hellenistic and Roman cities were founded upon artificial polder deposits.

4.4.1.2. *What can we say about the location of a southern harbour at Tyre?* New archaeological data and the two short cores drilled in Poidebard's supposed southern basin are not consistent with a seaport as long hypothesised by many

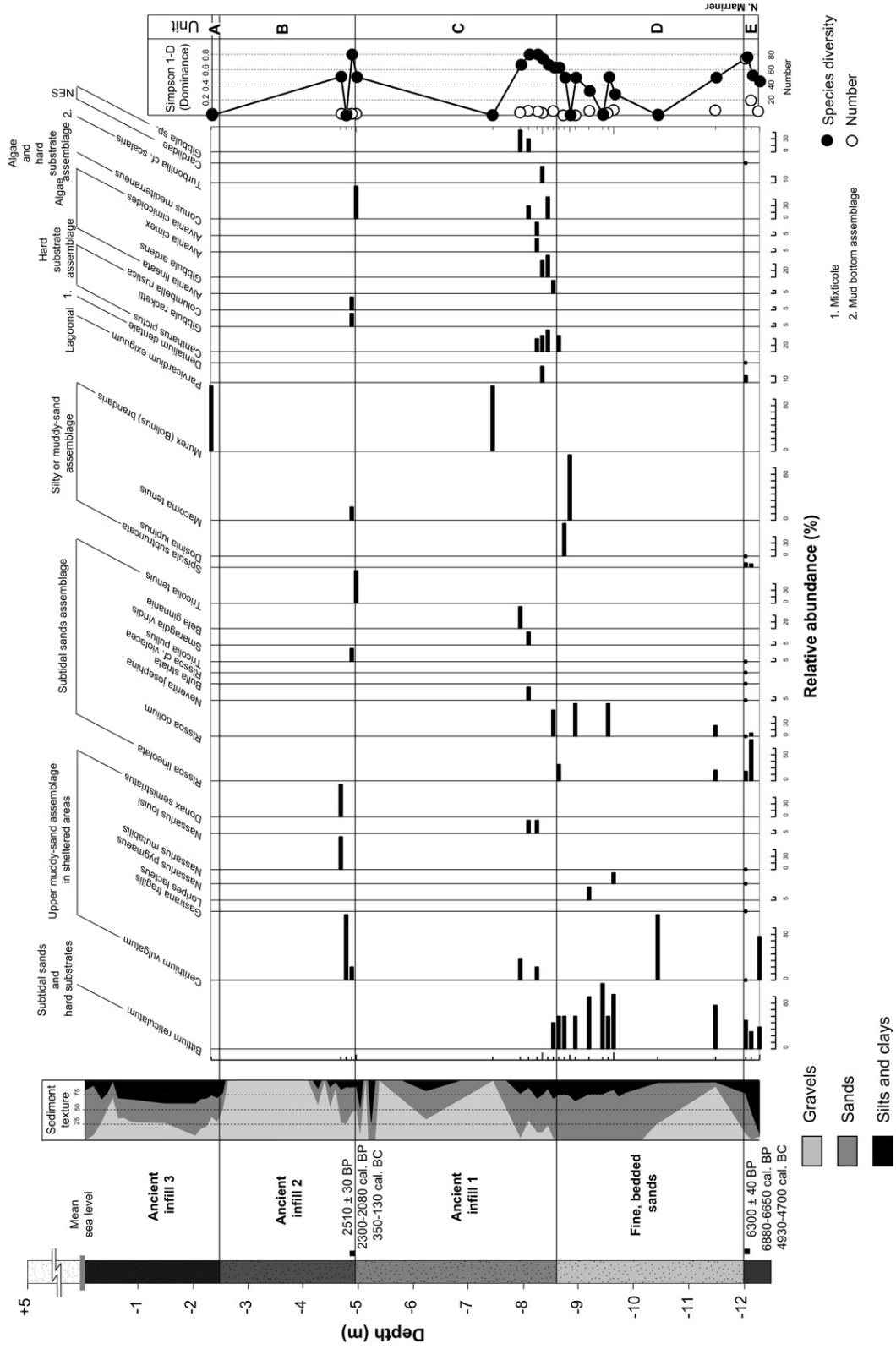


Fig. 20. Macrofauna data of core TVIII.

scholars. Modelling data presented in Marriner et al. (2007) suggest that this southern area was partially protected by a series of small sandstone islets, but not sufficiently enough to be favourable to the establishment of a second anchorage on the island. We evoke three reasons to explain Poidebard's misinterpretations. (1) The majority of his photographs were taken from high-altitude, at around 1000 m. Although these were good at yielding a very general rendering of the near-surface archaeological remains, optical distortions meant that the images failed to penetrate the totality of the water column. (2) Secondly, many of the archaeological remains have been significantly eroded by coastal processes since their submergence during the late Roman period. Great areas of the vestiges are today partially covered in tracts of sand, making their interpretation problematic. (3) Finally, and perhaps most importantly, Poidebard did not dive himself, but relied on reports from hard-hat workers. His personal *a priori* regarding the remains, allied with an absence of first-hand observations, appear to have significantly biased his interpretations. In spite of these flaws, the quality of Poidebard's research must not be undermined. His photographic archives and cartography of the Tyrian coastal zone are of an exceptional quality (Denise and

Nordiguian, 2004), and he remains one of the pioneers of underwater archaeology.

In the light of our new research, Renan's hypothesis of a southeastern harbour appears more plausible. The coastal stratigraphy clearly demonstrates that this leeward coastal fringe was a well-protected façade from the Bronze Age onwards. Although no diagnostic harbour facies have been found, we hypothesise that this area was the most conducive environment for the establishment of a second anchorage haven at Tyre. However, in the absence of archaeological data it is impossible to precisely reconstruct where, when and how this second basin evolved. It is possible that an artificial basin *sensu stricto* did not exist, but that rather the whole of this sheltered south-eastern façade served as a semi-natural anchorage. Archaeological data from this now landlocked façade are clearly lacking, rendering a robust geoarchaeological reconstruction for this area problematic. Manifestly more work is needed on this important question. Large-scale construction works have been evidenced during the Hellenistic and Roman periods, characterised by infill deposits (cores TVIII and TXVI). These must be put into relation with the drowned polder wall identified by El Amouri et al. (2005).

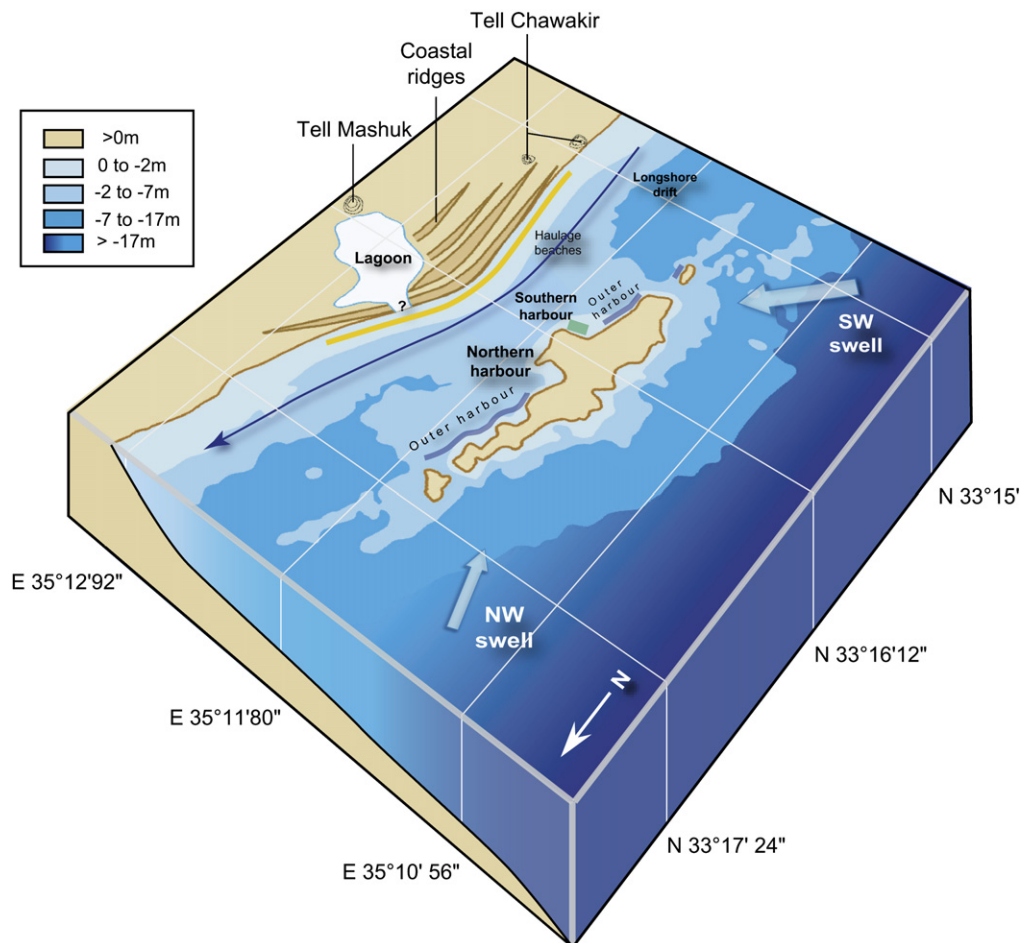


Fig. 21. Proposed reconstruction of Tyre's ancient anchorage complexes during the 1st millennium BC. We identify four main harbour areas on this maritime façade: (1) the artificially protected northern harbour, presently buried beneath the city centre; (2) a second harbour complex on the south-eastern fringe of the island; (3) a series of outer harbours that exploited the extensive subaerial ridges and reefs to the north and south of the city; and (4) the continental harbour complexes that operated in tandem with Tell Mashuk, Tell Chawakir and Tell Rachidiye.

4.5. Satellite anchorages

4.5.1. Tyre's outer harbours

The existence of outer harbours at Tyre is corroborated by (1) our palaeogeographical reconstructions of the Bronze Age and Iron Age islands (Fig. 21), (2) maritime archaeological finds (stone anchors, pottery) on the leeward side of proximal reefs (El Amouri et al., 2005; Frost, 1971; Poidebard, 1939), and (3) literary evidence (for example Achilles Tatius, II, 17, 3, mentions an outer anchorage on the distal northern sector of the sandstone ridge). Archaeological surveys have failed to unearth any artificial harbourworks in these areas, however, used in tandem with lighter vessels (Fig. 22), these outer anchorages greatly enhanced the capacity of Tyre to accommodate and transit goods from the hinterland and Mediterranean trade routes. To the north of the city ~1300 m of drowned reef have been evidenced, while to the south ~750 m would have been exposed during the second and first millennia BC. The elucidated Bronze Age and Iron Age topographies suggest that future archaeological work looking to understand the city's maritime façade should concentrate upon these areas.

4.5.2. Continental harbours

The absence of fertile agricultural land on Tyre implies that the city was dependent upon its hinterland and neighbouring continental settlements for food and freshwater supplies. This is corroborated by ancient Amarnian texts dating from the Late Bronze Age (~1500–1200 BC). Letter EA 149

(Moran, 1987), written by Abi-Milki of Tyre, discusses the capture of the agglomeration by Zimredda of Sidon. As a result, insular Tyre was deprived of its supply of timber and drinking water. Papyrus Anastasi I also underlines this same dependence of Tyre *vis-à-vis* the continent. Recent excavations of the necropolis at El Bass have demonstrated that the continent facing Tyre was used for burials during the Iron Age (Aubert, 2004).

A number of passages of the Bible (i.e. Ezek. 26:8) also evoke the 'daughters of Tyre' when referring to the Tyrian coast, a plurality that is consistent with three tell sites on the coastal seaboard parallel to the city: Tell Mashuk, Tell Chawakir and Tell Rachidiye. The existence of these three settlements indirectly implies a series of coastal hubs along the continental façade that assured the transportation of goods and services during the Bronze and Iron Ages. Although the spatial resolution of our data in these areas is not as good as for Tyre island, we nonetheless propose a number of plausible working hypotheses based on the chronostratigraphic data and geomorphology of these areas.

4.5.2.1. *Tell Mashuk and a possible lagoonal harbour.* Whilst it is equivocal which of the three tell sites was Palaeotyrus or Old Tyre *sensu stricto*, for many scholars the most eligible candidate is Tell Mashuk (Katzenstein, 1997; Kenrick, 1855). The site lies in the wave shadow of Tyre on the eastern axis of the city and has been occupied since the Bronze Age. It is likely to have served as a proto-settlement before the later colonisation of Tyre itself. At present, the tell remains are



Fig. 22. Beaching of boats and the use of lighter vessels in Tyre's northern harbour during the 1830s. There are a number of things to note in this lithograph: (1) the fishermen nearest the shore are only knee deep in water, attesting to the shallow, silted up nature of the harbour; (2) the fishermen in the foreground are standing upon the prograded beach unit elucidated in our harbour stratigraphy; and (3) finally, there is a total absence of harbourworks in this beach area (from D. Roberts: Port of Tyre dated April 27th 1839 in Roberts, 2000).

landlocked 1600–1800 m from the sea due to the significant progradation of the tombolo during the mid- to late Holocene. Our stratigraphic data demonstrate, however, that the coastal area to the west of the tell was flooded around 6000 BP and gradually prograded seawards. Although we have not cored immediately at the base of Tell Mashuk, the topography and our geomorphological surveys in this vicinity suggest that the maximum marine ingressions lay in proximity to the tell. Low accommodation space coupled with high sediment supply

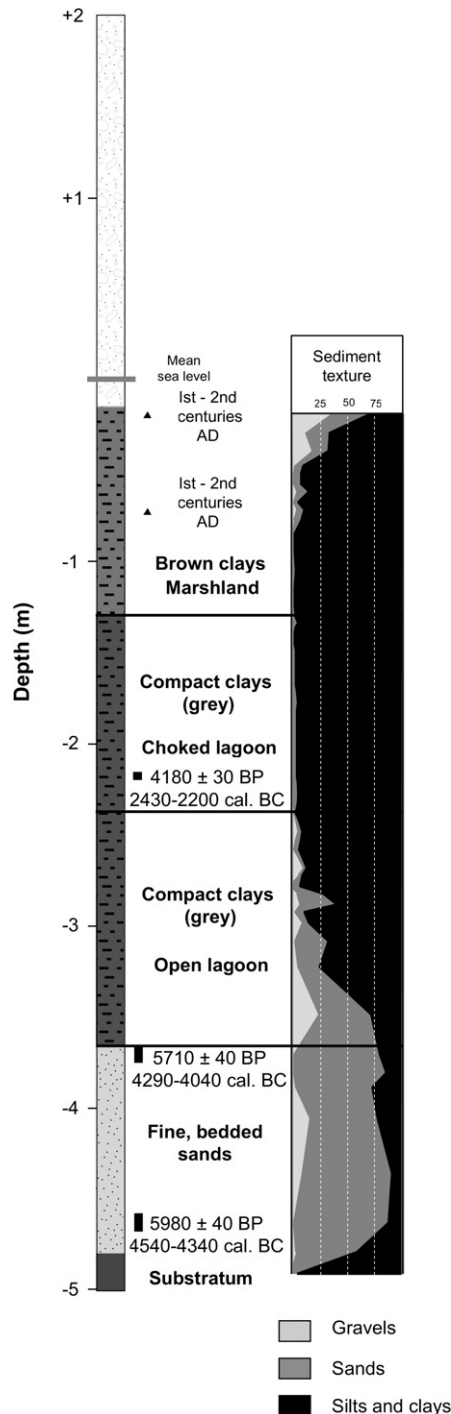


Fig. 23. Stratigraphy of core TXVIII.

and the pronounced wave shadow generated by Tyre island led to the rapid accretion of a salient strandplain. Diagnostic beach sedimentology at the base of the stratigraphy shallows up to a fine-grained plastic clays facies dominated by *C. glaucom*, a lagoon-tolerant taxa (>80% silts and clays). This stratigraphy suggests that by 5500 BP the area to the west of the tell formed a lagoon in communication with the open sea (Fig. 23). The mid-zone of the lagoon facies is dated 4180 ± 30 BP, or 2430–2200 cal. BC.

Although the precise dimensions and phases of infilling of this lagoon are not clearly known, we hypothesise that it was used as an anchorage haven during the Bronze Age (draught depth <1 m). Use of the lower reaches of wadis and lagoons as natural harbours was widespread in the Levant during the 3rd and 2nd millennia BC (Raban, 1987a, 1990). Phoenician colonies in the western Mediterranean (9th to 8th centuries BC) also frequently exploited lagoons as natural harbours as attested, for example, in Sardinia, Cagliari, Othoca and Bithia (Barreca, 1986). The natural low-energy conditions meant that there was no need for artificial harbourworks. Loading and unloading of cargo could take place on shallow-draught boats hauled onto the lagoon shoreline. This lagoonal harbour complex would also have been used in tandem with the sandy beach ridges that enclosed the lagoon to the west.

At what stage the lagoon became isolated from the sea is unclear. The existence of a lagoon and a rapidly prograding salient strandplain raises the question of the inlet. In the absence of a flushing fluvial system, any inlet would gradually have been blocked by beach ridge accumulation. It is possible that societies maintained an artificial link with the open sea until the Iron Age, although the wide haulage beaches meant that the viability of the settlement was not totally dependent on this shallow anchorage. By Roman times, the lagoon had significantly silted up and we observe a transition to marshland deposits characterised by plant macrorests and fossil snail tests. These marshlands persisted in the El Bass area until the mid-19th century (Carmona and Ruiz, 2004).

4.5.2.2. Tell Chawakir. Tell Chawakir lies at the southern limit of the tombolo salient. The area was transgressed around 6000 BP and prograded rapidly to form a beach ridge strandplain. None of our cores in proximity to the tell have yielded lagoonal lithofacies analogous to those at Tell Mashuk. Conversely, the stratigraphy evokes sandy beaches at the base of the tells that could have been used as natural haulage ramps. It seems plausible that some of the cargo from Tyre's southern outer harbours was ferried directly to and from the shoreline by lighter vessels based at Tell Chawakir, without necessarily transiting via Tyre *sensu stricto*.

4.5.2.3. Tell Rachidiye. Not all of Tyre's commerce was conducted by the sea. Terrestrial trade routes also existed with northern Syria, where the Tyrians traded with Uratu and Mesopotamia. Evidence of these land-based trade routes can be found at Rachidiye (Doumet-Serhal, 2004b). Rachidiye lies in proximity to outcropping springs at Ras El-Ain and was therefore important in supplying Tyre with its provision in

freshwater. The Romans, exploiting the subaerial tombolo (Marriner et al., 2007), later built an aqueduct linking Tyre directly with this freshwater spring. Material from its necropolis attests to close trade relations between Cyprus and Phoenicia during the Iron Age. The coastal area to the south of Tell Chawakir and north of Tell Rachidiye has been relatively stable during the Holocene. Our core stratigraphies from these areas reveal late Pleistocene palaeosols over a sandstone bedrock. No Holocene marine deposits have been found in this area. A series of drowned sandstone reefs is also manifest in aerial photographs to the west of the settlement. We hypothesise that these were used as outer anchorages for the larger vessels, although clearly greater work is required.

5. Conclusions

While our geoarchaeological work reveals the importance of Tyre's northern harbour as the city's main transport hub from the Bronze Age onwards, the role of its satellite infrastructures must not be underestimated. Traditionally, research has focused on Tyre's northern and southern harbours which catered for merchants during the Bronze and Iron Ages. Our new work shows that Tyre also possessed a series of secondary seaport complexes that were integral parts of this network, notably assuring the day-to-day running of Tyre (provision in water, food, building material, etc.). In total, we identify four harbour complexes on the Tyrian coastline: (1) the artificially protected northern harbour, presently buried beneath the city centre; (2) a second harbour complex on the south-eastern fringe of the island; (3) a series of outer harbours that exploited the extensive subaerial ridges and reefs to the north and south of the city; and (4) the continental harbour complexes that operated in tandem with Tell Mashuk, Tell Chawakir and Tell Rachidiye. Lighter vessels would have interlinked these harbour complexes. The partially drowned coastal ridge upon which the ancient city lay served as the protective umbrella structure for these harbour complexes. The evolution of the site since 6000 BP means that the main seaports are today buried beneath tracts of coastal sediments, while the outer harbours have been drowned by subsidence of the Tyrian horst during the late Roman period.

The multiplicity of harbour contexts elucidated at Tyre is a recurring theme of Phoenician settlements in both the eastern (Sidon) and western (Carthage, Cadix, Tharoos, Motye) Mediterranean. In a similar vein, bipartite geomorphological configurations, comprising insular and continental harbours, are consistently observed in offshore island contexts of Phoenician age (for example Arados and Perea in Syria; Cadix and Castillo of Doña Blanca in Spain; Rachgoun and Siga in Algeria). In addition to elucidating the geomorphology of Tyre's ancient harbours, it is envisaged that this new research will aid in defining a model of Phoenician seaports, whose origin can be traced back to the Bronze Age and subsequently diffused to the western Mediterranean via Phoenician colonies (Carayon, research in progress).

Future archaeological work at Tyre needs to focus on better understanding the evolution of maritime infrastructure since

the Bronze Age. Although modern urbanisation renders this task difficult around the fringes of the northern harbour, El Amouri et al. (2005) and Descamps et al. (personal communication) have shown the rich archaeological potential of ancient land surfaces presently drowned to the north and south of Tyre. Our research has not only reconstructed the palaeogeographical evolution of the city's ancient harbours since 6000 BP, but has also highlighted the chronostratigraphic impacts of seaport dredging, largely neglected in previous studies of this nature.

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