SIDON'S ANCIENT HARBOUR: NATURAL CHARACTERISTICS AND HAZARDS

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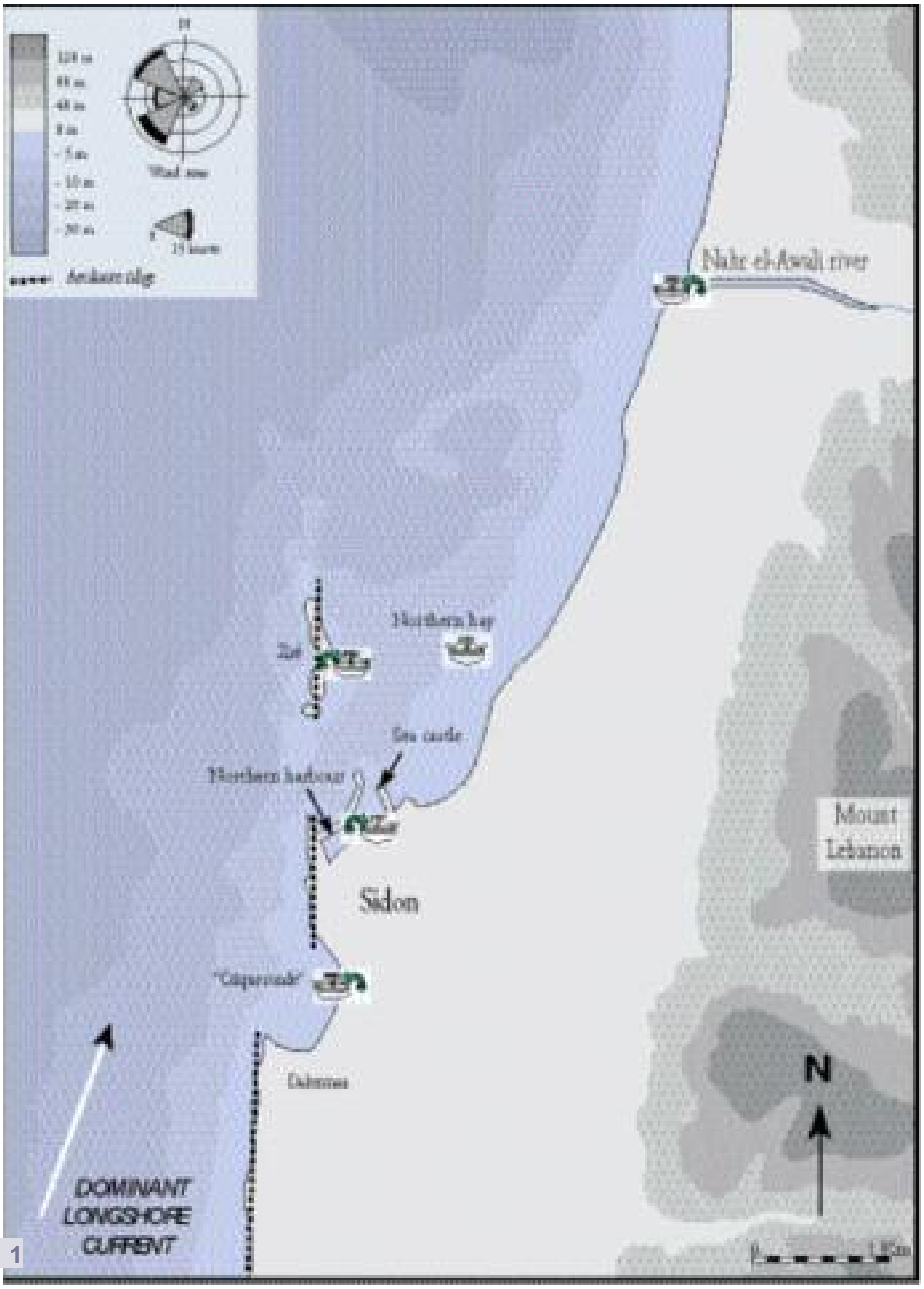
A multidisciplinary study combining geoscience, archaeology and history was conducted on Sidon's harbour (Lebanon). The natural characteristics of the site at the time of the harbour's foundation were determined, as well as the human resources that were needed to improve these conditions in relation to changes in maritime activity. In ancient times, Sidon was one of the most active harbours and urban centres on the Levantine coast [3]. It is therefore a key site to study ancient harbours, providing insight into both ancient cultures and the technological



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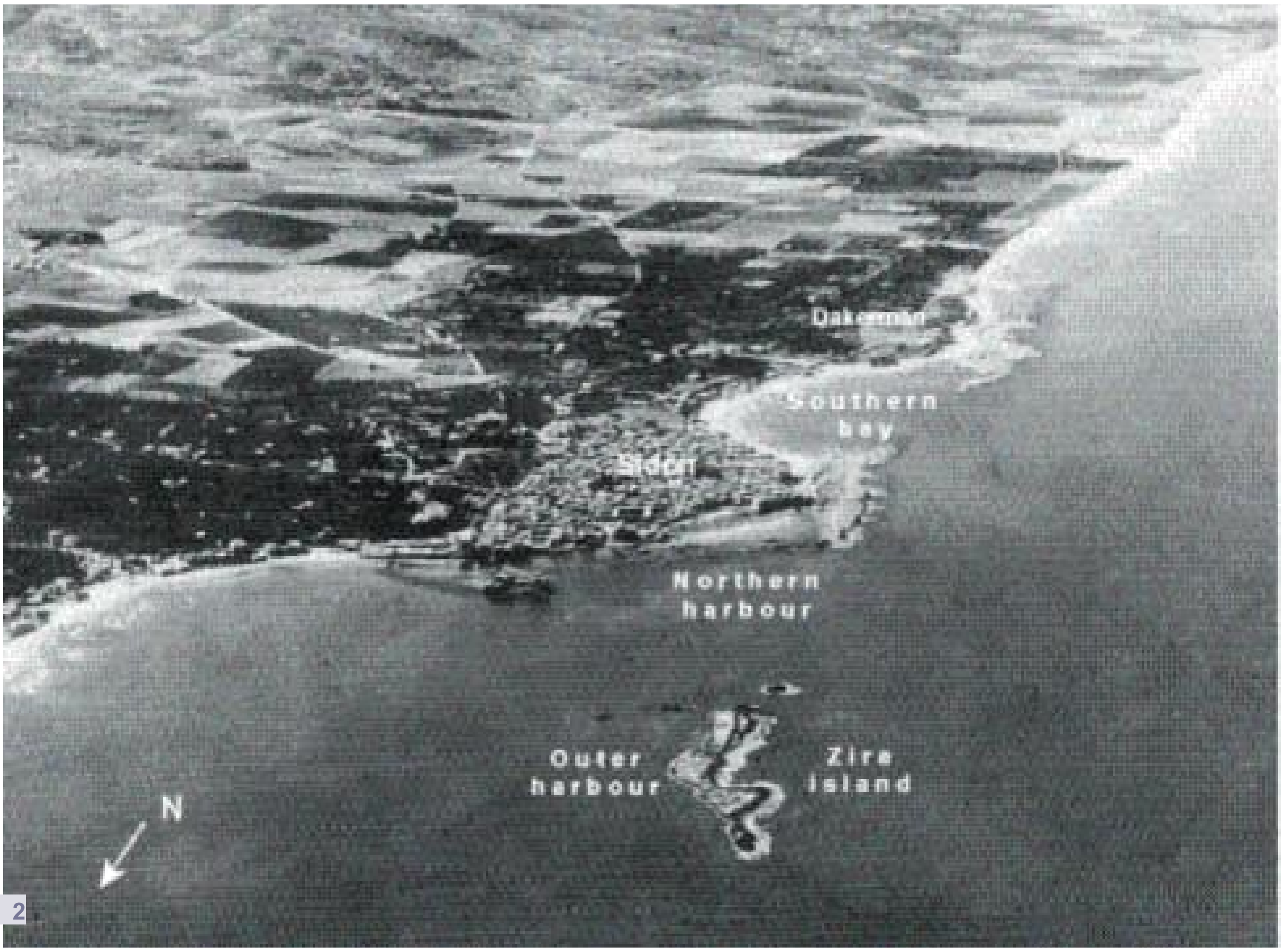
1 Sidon's coastal bathymetry.

apogee of the Roman and Byzantine periods. This article proposes a synthesis of Sidon's harbour system based on geomorphological characteristics that favoured the development of a wide range of maritime facilities, refashioned and improved by human societies from the second millennium BC until the Middle Ages.



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2 Aerial view of Sidon and Ziré during the 1940s (from A. Poidebard and J. Lauffray, 1951).

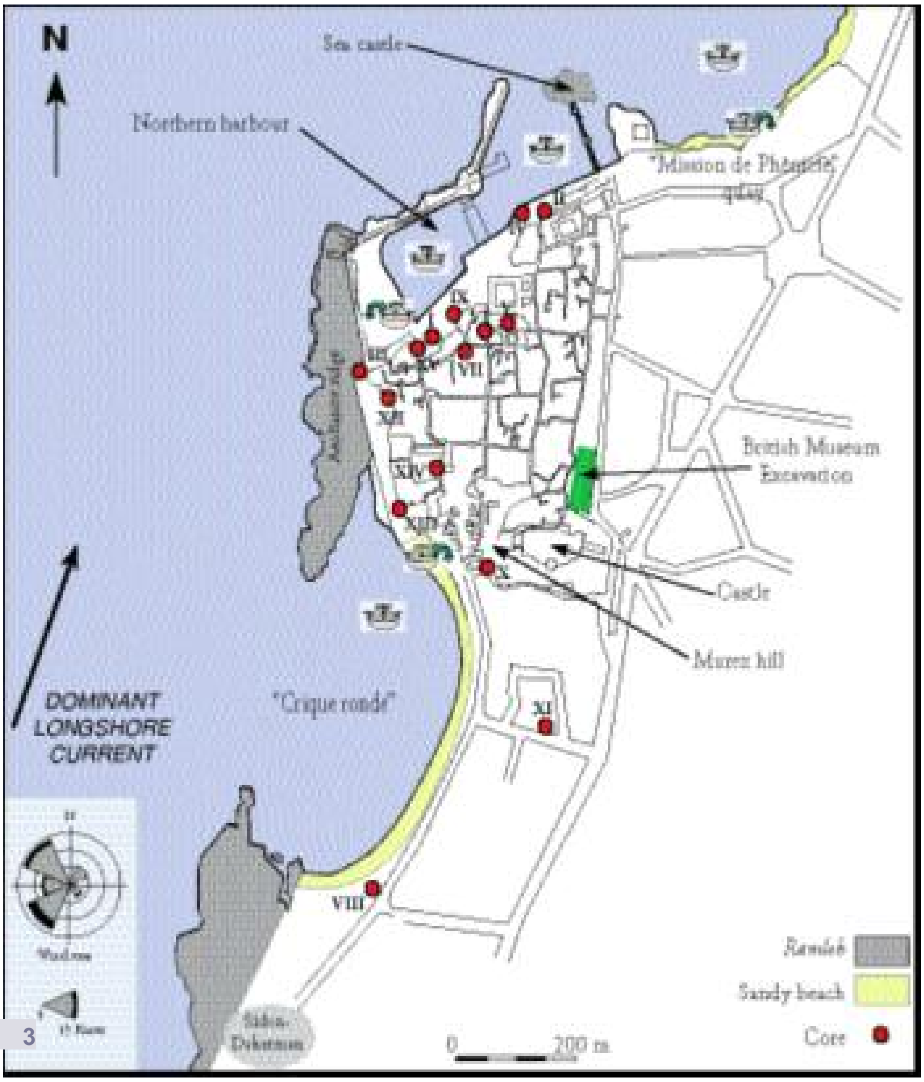
Sidon' s coastline (fig. 1-2)

The ancient urban center was developed on a rocky promontory dominating a 2 km wide coastal plain, flanked by the Nahr el-Awali river to the north, the Nahr el-Litani to the south and the first escarpment of Mount Lebanon to the east [4]. The coastline is low and forms a straight line, oriented south, south-west, north, north-east with sand beaches separated by occasional promontories. Sidon Tell overlooks one of these outcrops. In the south, the sandstone coastal ridge, partially submerged during the Holocene marine transgression, is interrupted by a semicircular bay named the *crique ronde*. From the tell, the outcrop is visible over a length of 580 m [5]. Oriented south-north, the coastal ridge diverges from the coastline that trends north to north-east. A pocket beach has formed in the corner between Sidon's promontory and the sandstone outcrop. In the north-east direction, a sandstone islet (*îlot du Château de la Mer*) emerges. Today, this bay is still used as an extension of Saida harbour. 700 m north of the promontory, Ziré island constitutes the third outcrop of the coastal bar, 740 m long, this island marks the western limit of a third water body, the outer harbour [6].

Natural characteristics in the 3rd millennium BC

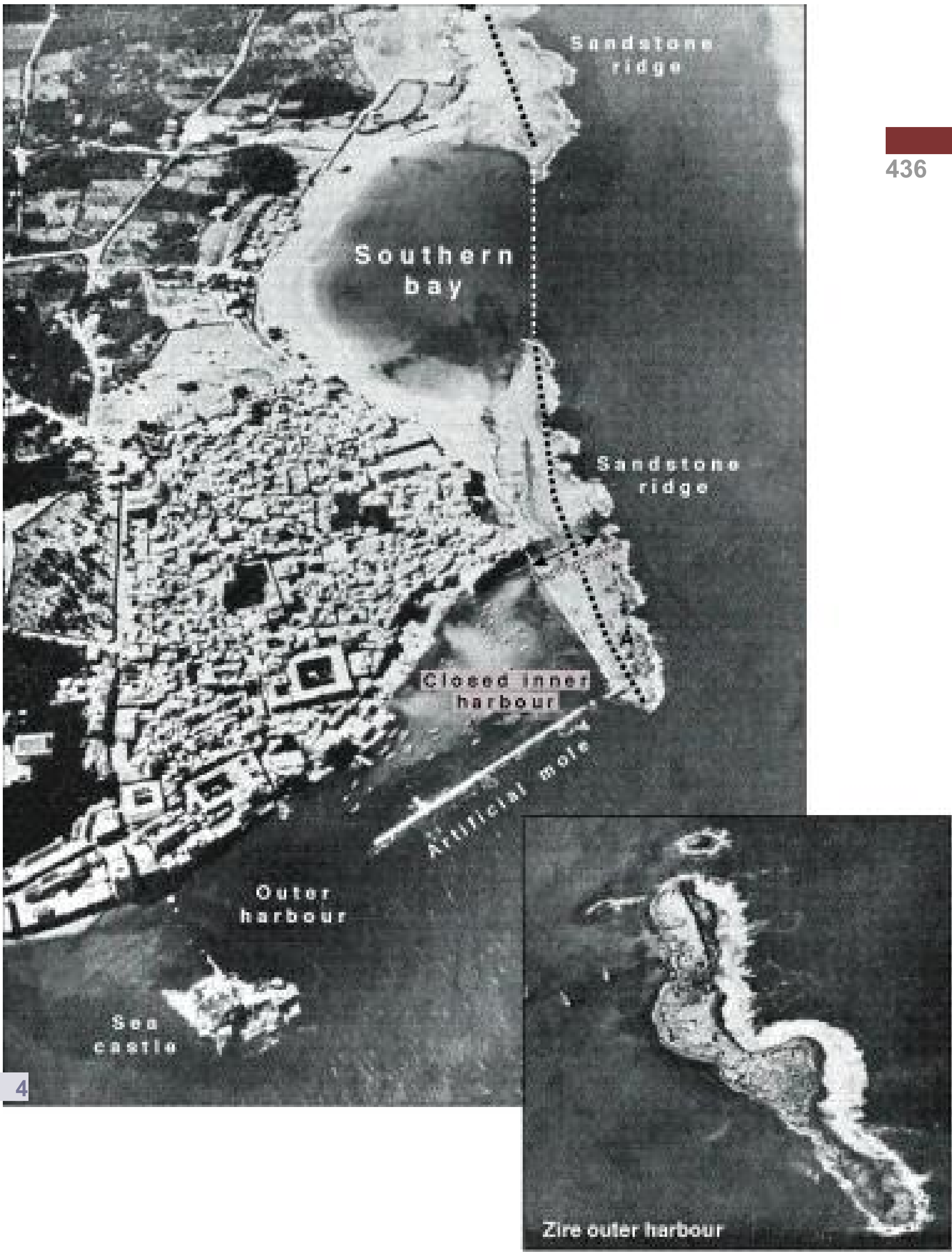
The earliest evidence for human occupation derives from the promontory of Sidon, Dakerman [7]. A small Chalcolithic settlement was found near the *crique ronde*. Excavations (College site) undertaken near the cultural centre of Saida attest to a relocation of the habitat from Dakerman towards Sidon's promontory at the beginning of the 3rd millennium BC [8] (fig. 3-4). Six different habitat levels have been ascribed to the Early Bronze Age, illustrating the continuous development of the settlement during the 3rd millennium BC. Only one hiatus was identified, characterized by a layer of sand, separating the end of the Early Bronze I and the beginning of the Early Bronze II ages, around 2900 BC.

To understand Sidon's harbour environments at the time of its foundation, we reconstructed the ancient geomorphological context of the coastline. Several drilling campaigns conducted in Byblos, Beirut, Tyre



3 Sidon's ancient harbour areas and location of cores.

and Sidon [9] have complemented earlier work by Sanlaville (1970 and 1977). This work combines geoscience, historical and archaeological techniques to reconstruct coastal modifications. The results have improved our geographical and archaeological understanding of ancient harbours in Lebanon.



4 Sidon's ancient harbour areas (from A. Poidebard and J. Lauffray, 1951).

Sidon's wind climate is characterized by the predominance of south-westerlies and north-westerlies. The south-westerly winds are more intense and frequent. They blow throughout the year and can reach 25 knots in winter (Beaufort scale force 5). North-west winds are also common, although they are less frequent. They blow mainly during the winter season and can be violent (fig. 5). Sea breezes from the west are relatively frequent and can reach 15 knots. Land breezes are far less frequent because the mountain chain of Mount Lebanon acts as a natural barrier. Sea breezes are also superimposed on the annual wind climate [10].

Laboratory analyses of the sediment cores drilled in Sidon has allowed us to reconstruct the coastal geomorphological context during the 3rd millennium BC [11] (fig. 3-6).

5

Month	N	N-E	E	S-E	S	S-W	W	N-W	Calm
March	9	1	1	0	3	10	4	3	0
April	8	1	0	1	2	6	10	2	0
May	8	4	0	1	1	7	7	3	0
June	5	0	0	0	0	10	10	5	0
July	1	1	0	0	1	8	15	5	0
August	3	0	0	0	1	11	13	3	0
September	7	0	0	0	3	4	11	5	0
October	10	3	0	0	1	3	9	7	0
November	4	1	0	1	2	8	12	3	0

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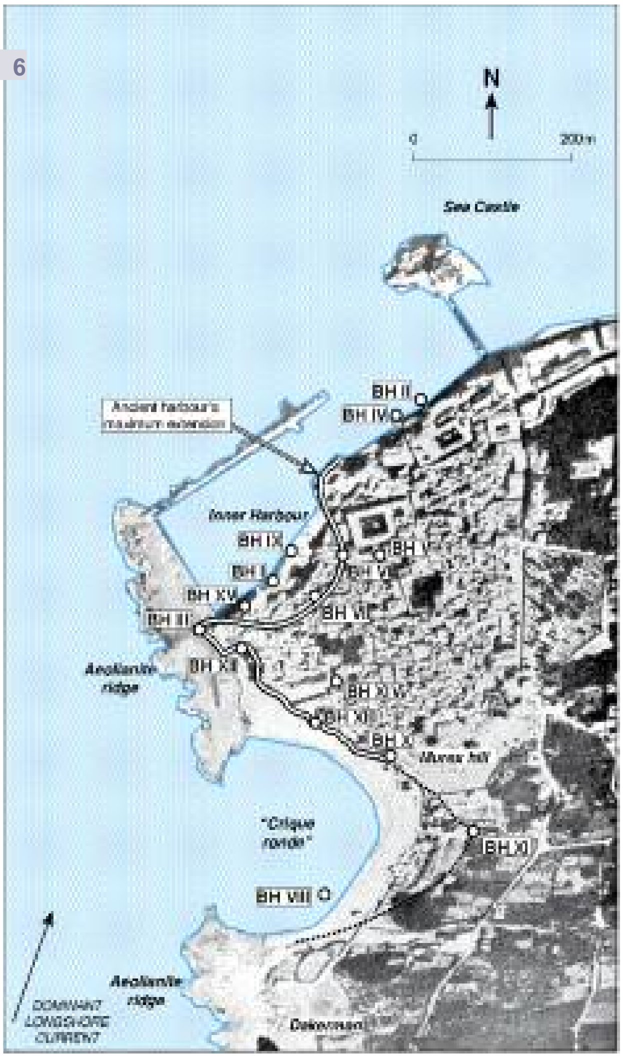


The southern bay

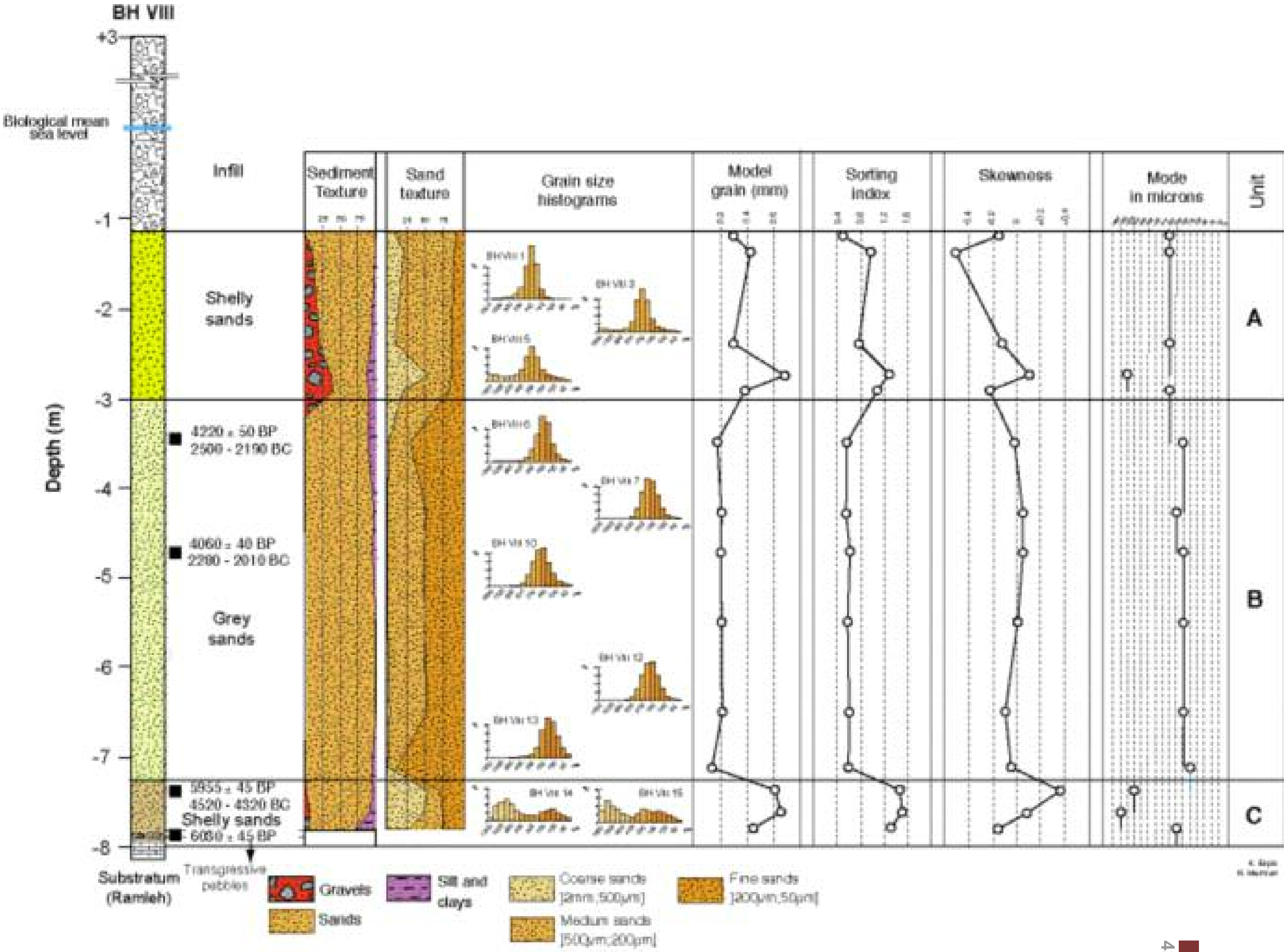
South of Sidon's promontory, core BH VIII was taken in the *crique ronde*. It does not attest to any sudden modification in the sediment facies that could be attributed to harbour development (fig. 7-9). At the base of the core, the sandstone substrate is covered by a unit containing sand and pebbles (unit C) typical of the Holocene marine transgression. Radiocarbon analysis dated this unit to the 5th millennium BC (6030 ± 45 years BP; 4630-4360 years cal. BC). The unit immediately after the Holocene marine transgression (unit B) presents a medium to fine-grained sand facies with a rich macrofauna characteristic of diverse ecosystems: infralittoral sands, silty sand deposits in quiet water, fine sands, silty sands, and lagoonal assemblages. This unit began accreting after 5945 ± 45 years BP (4520-4320 cal. BC) and lasted until the very end of the 3rd millennium BP. Sample BH VIII 10, taken approximatively in the middle of unit B was dated by radiocarbon analysis to 4060 ± 40 BP (2280 – 2010 cal. BC). Finally, the top unit (unit A) is typical of a prograding shore. The macrofauna is poor and essentially comprises reworked shell fragments.

5 Statistic view of the winds in the Levant between 1846 and 1954 (number of days by month) (from D. Arnaud, 1995).

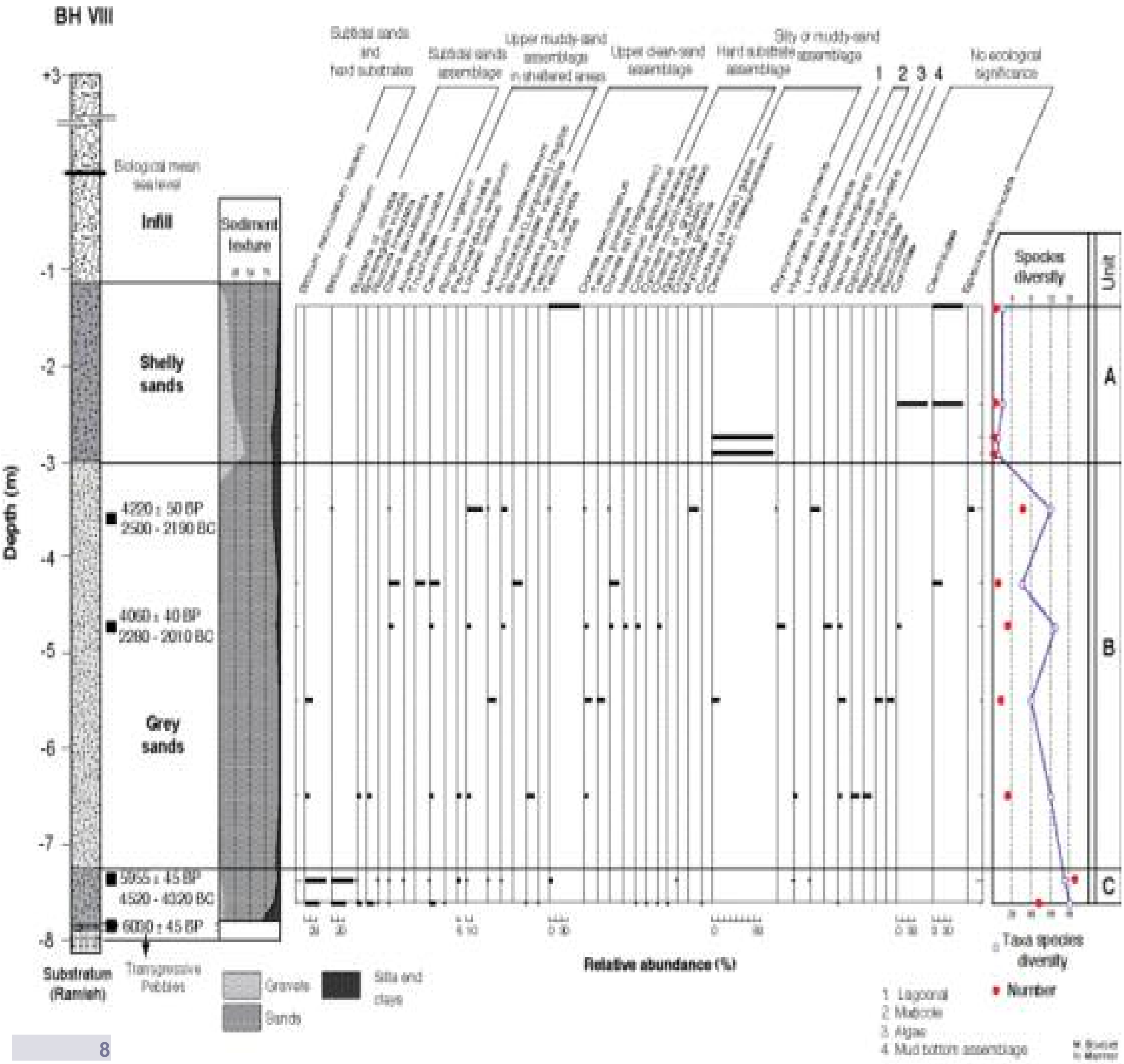
6 Sidon's reconstructed harbour limits in antiquity.

7 Sedimentology of core BH VIII (*crique ronde*).

The *crique ronde* was larger during the 3rd millennium and extended to the foot of the Tell. The sediment facies and the macro-assemblages or microfauna indicate that the environment was open to marine dynamics and storms. We suggest that this shallow bay was used by Chalcolithic fishermen at Dakerman or Sidon during the Bronze Age. It acted as a fair-weather harbour for small vessels. Progradation and partial silting-up of the cove have occurred since the Late Bronze age. Nonetheless, this tendency was not sufficient to hinder its use by shallow-draught fishing boats during fair-weather conditions. We hypothesize that Murex Tell, adjacent to the cove, was related to fishing activities. In summary, the geoarcheological study has allowed us to refute the hypothesis of artificial seaport structures in the southern bay.



BH VIII
Biological mean sea level
Depth (m)
+3
-1
-2
-3
-4
-5
-6
-7
-8
Infill
Shelly sands
4220 ± 50 BP
2500 - 2190 BC
4060 ± 40 BP
2200 - 2010 BC
Grey sands
5955 ± 45 BP
4520 - 4320 BC
Shelly sands
6080 ± 45 BP
Transgressive pebbles
Substratum (Ramleh)
Sediment Texture
Sand texture
Grain size histograms
Model grain (mm)
Sorting index
Skewness
Mode in microns
Unit
A
B
C
Gravels
Sands
Silt and clays
Coarse sands [2mm;500µm]
Medium sands [500µm;200µm]
Fine sands [200µm;50µm]



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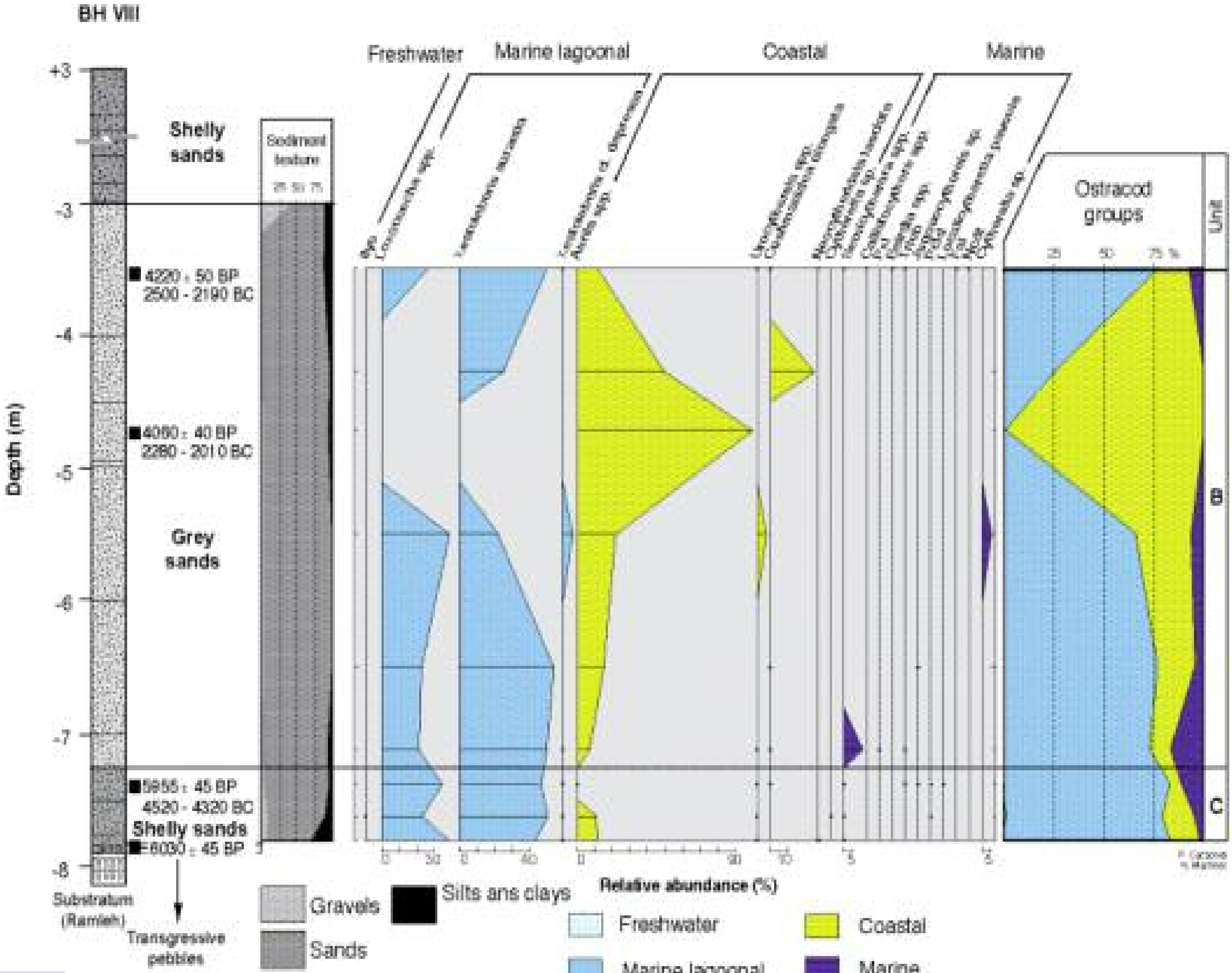
8 Molluscan macrofauna from BH VIII (*crique ronde*).

The northern harbour

In the northern harbour, sediment cores have yielded information for the Holocene evolution of the pocket beach. The basal unit D of cores BH I (fig. 10-12) and BH IX (fig. 13-15) is composed of pebbles characteristic of the Holocene transgression. Unit C of core BH I and unit C2 of core BH IX are characterized by a layer of shelly sands, with weak sorting indices and faunal assemblages related to infralittoral sands, fine sands, silty sands, and lagoonal environments. Marine species are present but *extra situ*. The base of unit C2 in core BH IX was dated to 4410 ± 40 BP (2750-2480 cal. BC) and unit C of core BH I to 4931 ± 62 BP (3475-3070 cal. BC). The biosedimentary data indicate that, at the time of its foundation, the Sidon harbour was approximately 50 % larger than today, protected from the south-westerly winds and currents by the offshore bar, and closed by the islet (Sea Castle) to the north-east. This natural semi-protected bay provided sheltered anchorage for ships during strong south-westerlies. The bay's pocket beach was probably used for beaching. We note that the northern harbour remains open to maritime dynamics from the north-west, frequent in the winter and often violent. It was therefore subject to a natural silting-up process.



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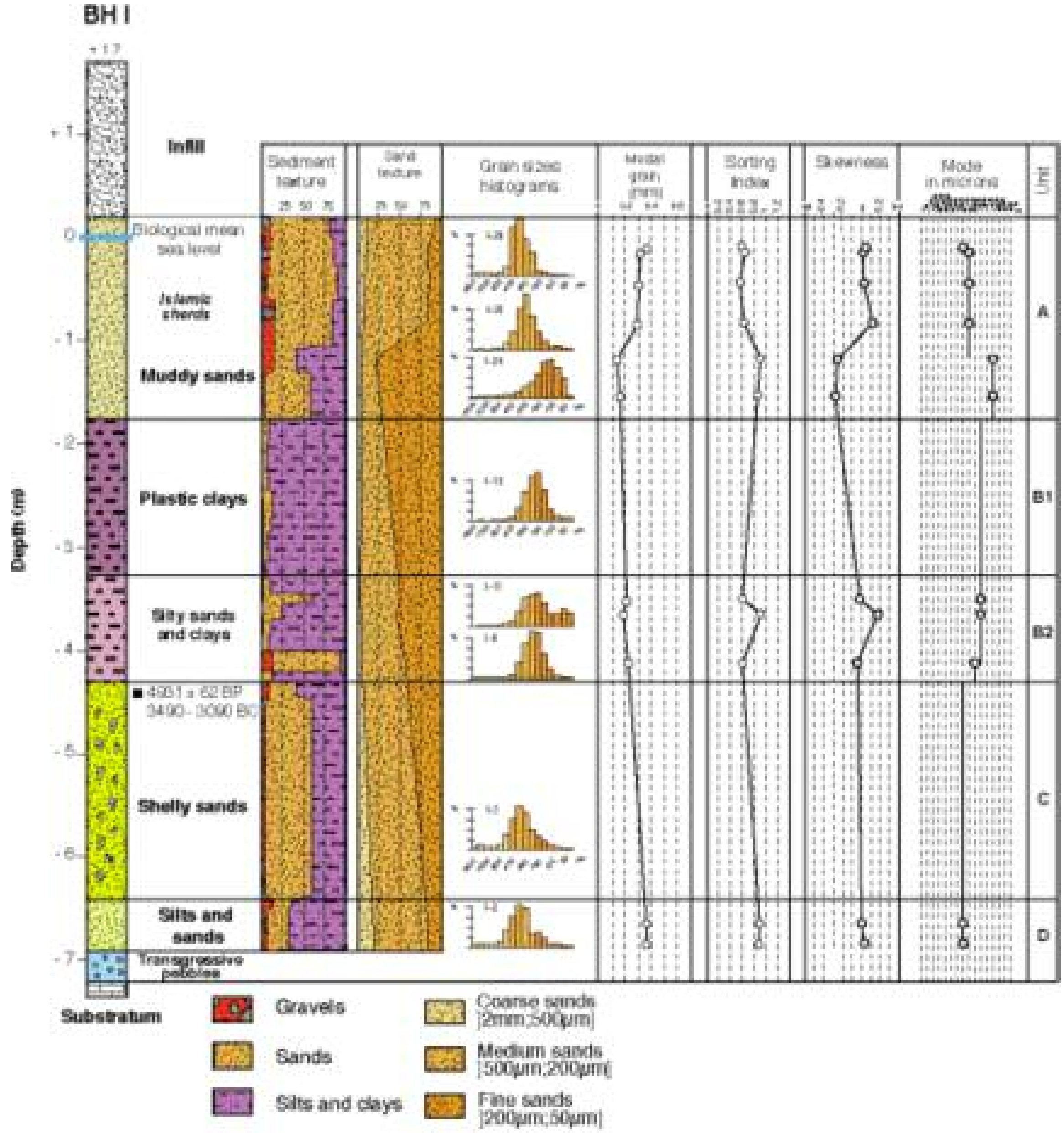
9 Ostracod macrofauna from BH VIII (*crique ronde*).

The northern bay

No sediment cores were drilled on the coastline to the north of the *Château de la Mer* and there is a paucity of data for the coastal modifications between the promontory of Sidon and Nahr el-Awali river that forms a delta. It is possible that Eschmoun in Bostan-esh-Cheikh, today about 1 km upstream of the Awali outlet, dominated the bottom of a ria. Examples of similar geomorphological processes during the Bronze Age are attested at Beirut [12], Tell Tweini in Syria [13] and in Palestine [14].

The island of Ziré acts as a natural breakwater for this large stretch of water. Up until recent times, ships still anchored on its naturally protected eastern flank. An aerial photograph taken by A. Poidebard illustrates the diffraction of marine swell around the island (fig. 16). In contrast, before it became a quarry, the islet had the appearance of an eroded rocky crest, without water sources, and with steep shores difficult to access. Although the anchoring site on its eastern side might have been used for fishing, no wharf structures from the Early Bronze Age have been uncovered.



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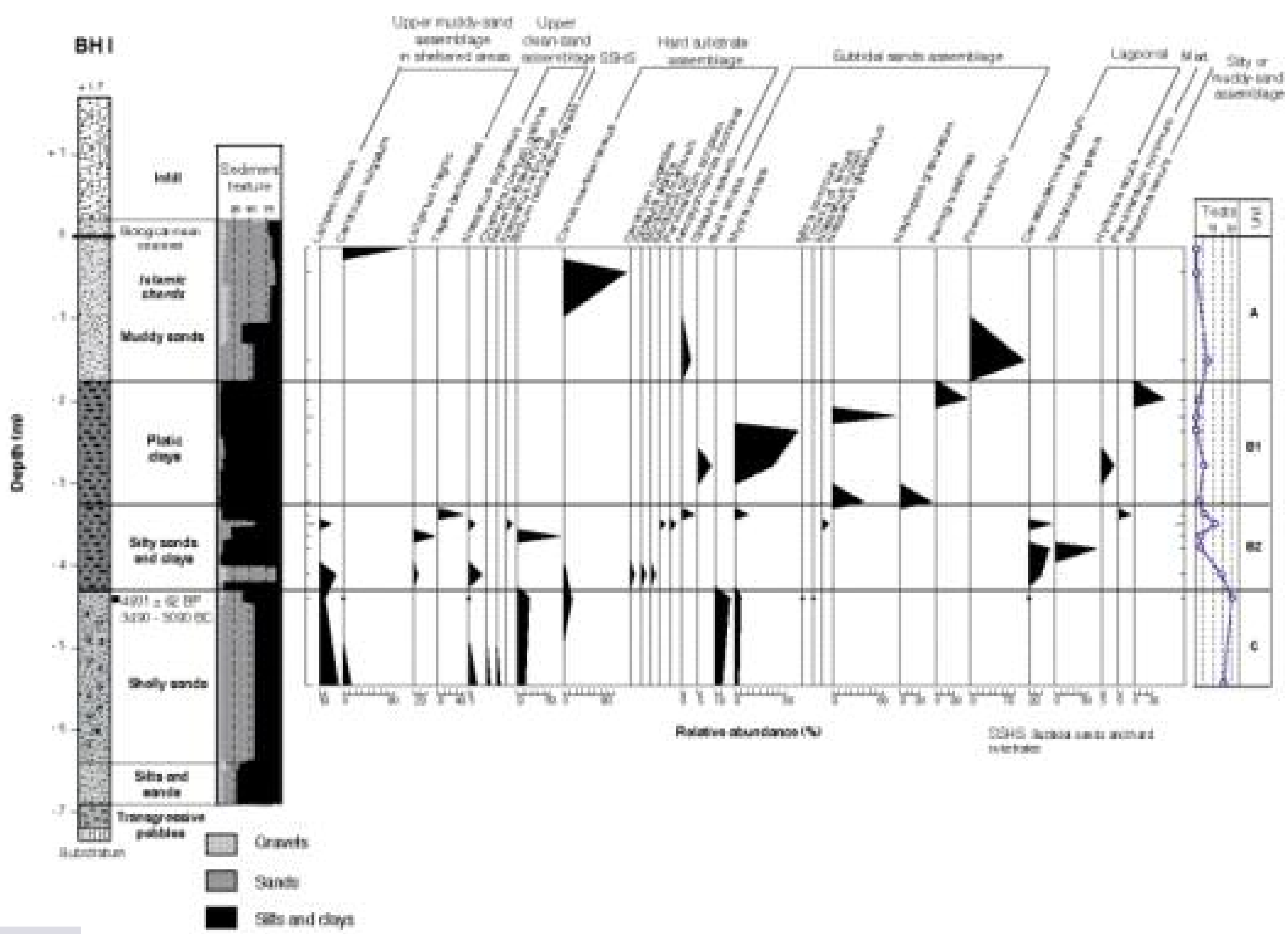
10 Sedimentology of core BH I (northern harbour).

With the settlement of a sustainable habitat on Sidon's promontory, the population benefited from a natural configuration that, with respect to the harbour situation especially, was much more favorable than the promontory of Dakerman. The city of Sidon dominates the *crique ronde* to the south, and a harbour complex in the north is formed by two aligned stretches of water: the outer harbour and the currently used northern harbour. The latter offers better protection to ships when the meteorological conditions deteriorate. The shoreline can be used to beach small fishing boats. Even though Ziré forms a natural breakwater, the use of the bay (outer harbour) as an anchorage site is restricted to periods of fair weather.

Semi-artificial harbour developments in the Middle and Late Bronze ages

The transition between the Early Bronze Age and the Middle Bronze Age is represented at Sidon, on the College excavation site, by a 1. 5 m thick layer of marine sands containing a few foraminifera and urchin spines. The layer was deposited at the end of the Early Bronze Age IIIB and before or during the Middle Bronze Age I/IIA (beginning of the 20th century BC) [15]. In Sidon, 36 graves were found in the sand layer. They all belong to the Middle Bronze Age and can be differentiated on the



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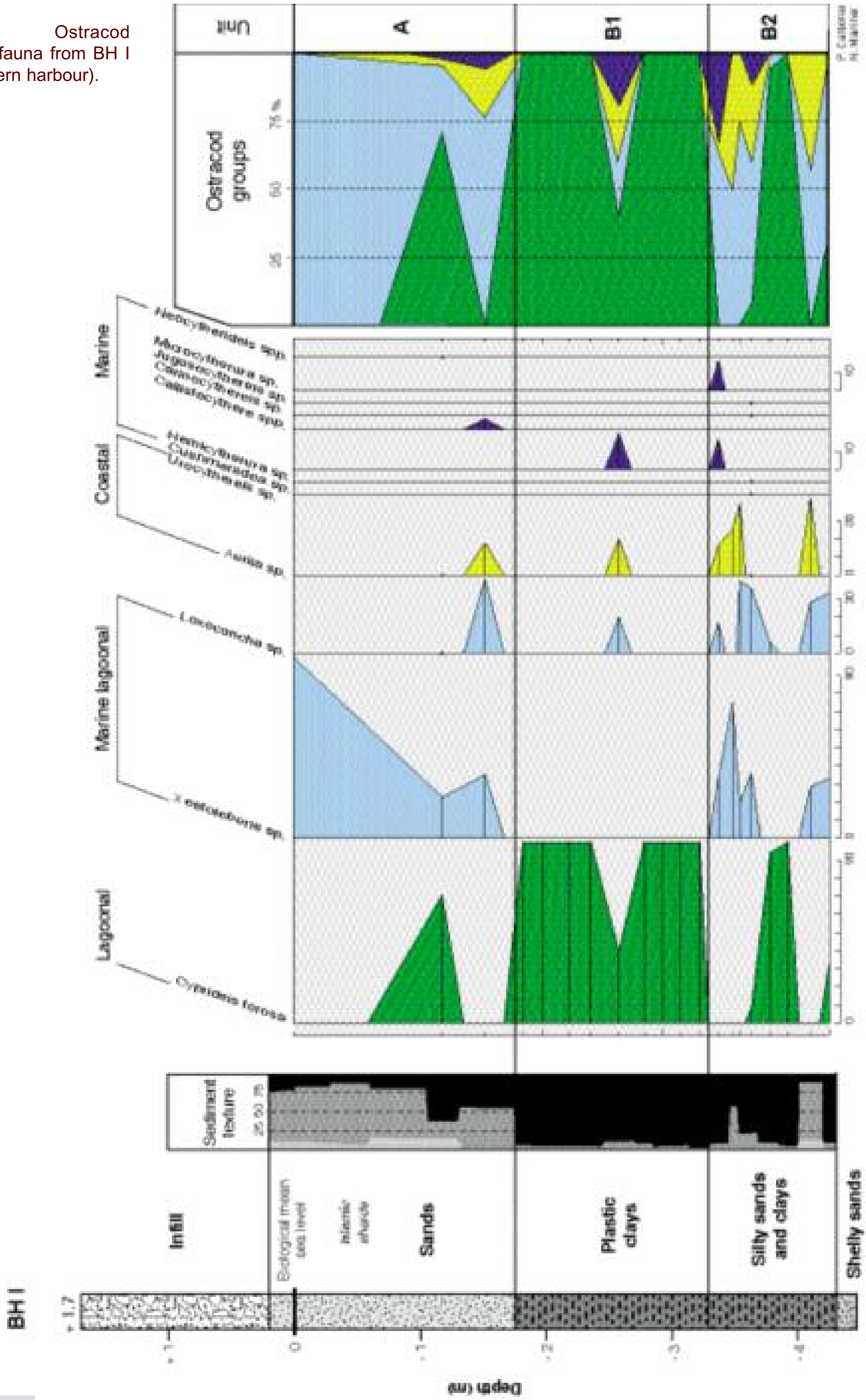
11 Molluscan macrofauna from BH I (northern harbour).

basis of their type, the nature of their funerary content, the position and orientation of the buried body.

During the Late Bronze, Aegean imports to Sidon were more frequent [16]. A large number of Mycenaean sherds and terracotta, as well as the head of a small figurine with a *psi* shape, were found.

According to ancient documents, the Late Bronze Age was synonymous with economic vitality in Sidon. D. Arnaud (1992) has shown that, according to Akkadian documents, Sidon was one of the most active harbours of the Levantine coast. It is also mentioned in the letter of Tell Amarna EA 101 [17]. Sidon had a fleet, mentioned in the letters EA

12 Ostracod macrofauna from BH I (northern harbour).

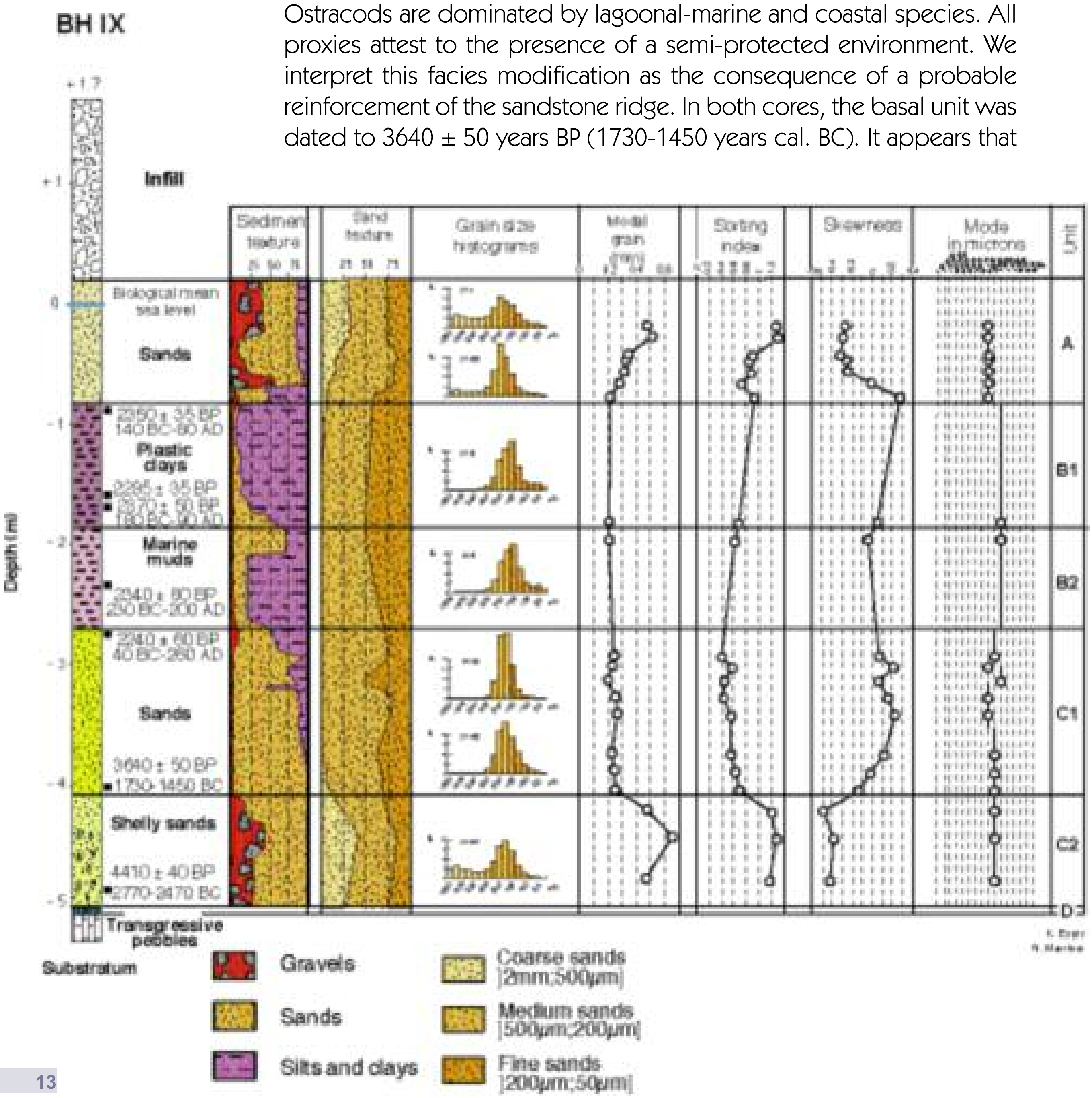


114 and EA 119. Archaeological findings from palace archives at Ras Shamra (RS 34.145) attest to maritime contacts with Aegean cities.

The northern harbour: artificial breakwater and quay

The study of sediment samples has allowed us to reconstruct the first harbour structures of Sidon. The northern harbour's stratigraphy is characterized by several sudden modifications in facies that we interpret as human impacts. In cores BH IX and BH XV, unit C2 can be differentiated from unit C1 because of the increasing presence of silt that reflects a decrease in coastal energy. The macrofauna is characterized by species typical of infralittoral silts, silty sands and fine sands. Ostracods are dominated by lagoonal-marine and coastal species. All proxies attest to the presence of a semi-protected environment. We interpret this facies modification as the consequence of a probable reinforcement of the sandstone ridge. In both cores, the basal unit was dated to 3640 ± 50 years BP (1730-1450 years cal. BC). It appears that

13 Sedimentology of core BH IX (northern harbour).



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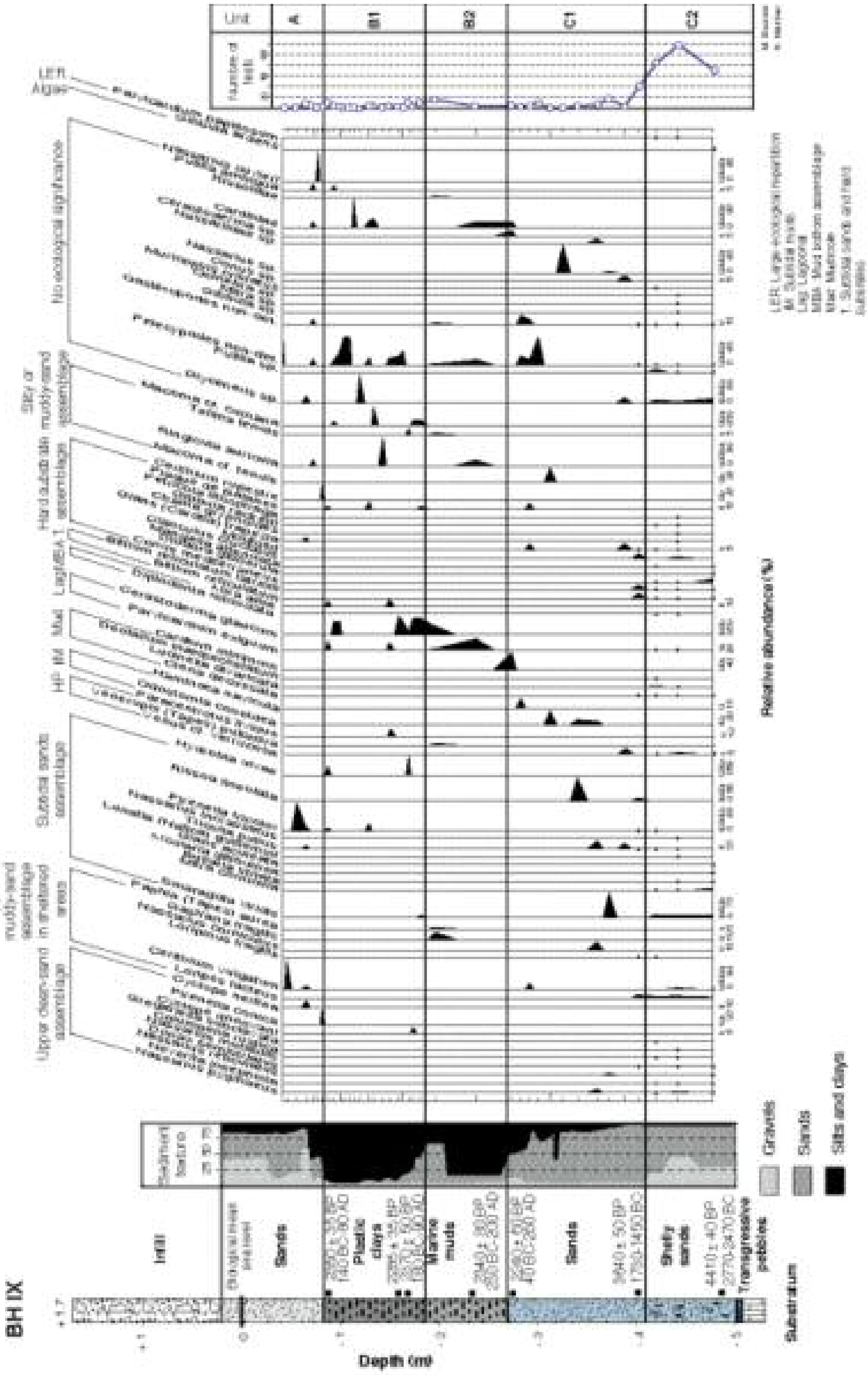
the harbour's natural potentialities, as described for the 3rd millennium, were no longer sufficient to sustain the activities of this urban centre during the 2nd millennium (Late and Middle Bronze Ages). This is consistent with ancient documents and archaeological findings (College site).

14 Molluscan macro-fauna from BH IX (northern harbour).

In the north, the sediment facies is interpreted as resulting from an artificialisation of the sandstone ridge (fig. 17-18), aimed at improving basin protection against the dominant winds. Initially, the sandstone bar was used as a dike, allowing the construction of a seawall cut in



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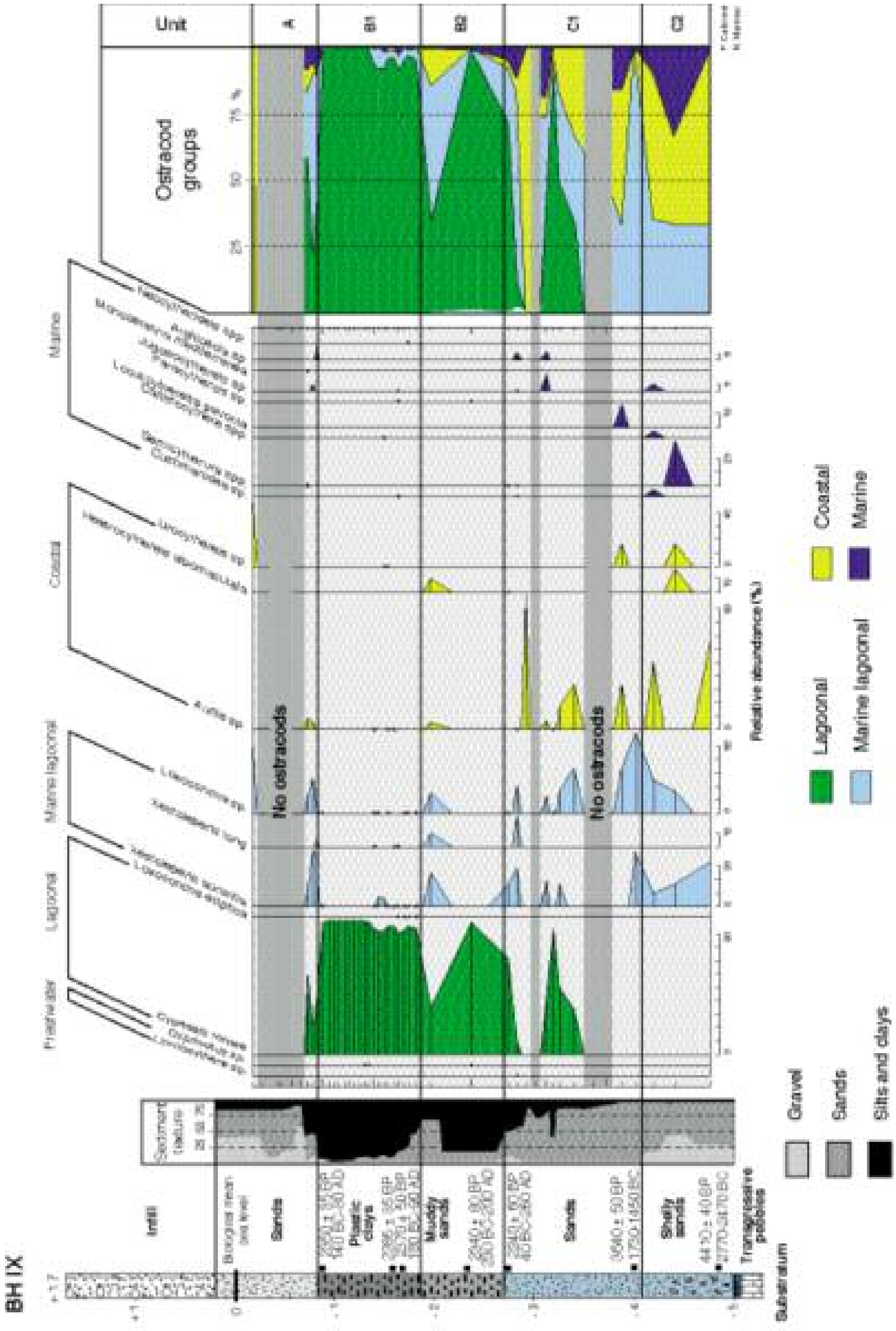
the rocky substrate for around 350 meters to separate the harbour basin from the sea (fig. 19). When the sandstone outcrop was not elevated enough, it was flattened to create the base of a superstructure still partly visible today (fig. 20). In the south, several flights of steps provided access to the upper part of the structure. It is therefore probable that it was used as road guard. Between the breakwater wall and the harbour an area of 70 x 40 m was used by the quarry workers.

15 Ostracod macrofauna from BH IX (northern harbour).



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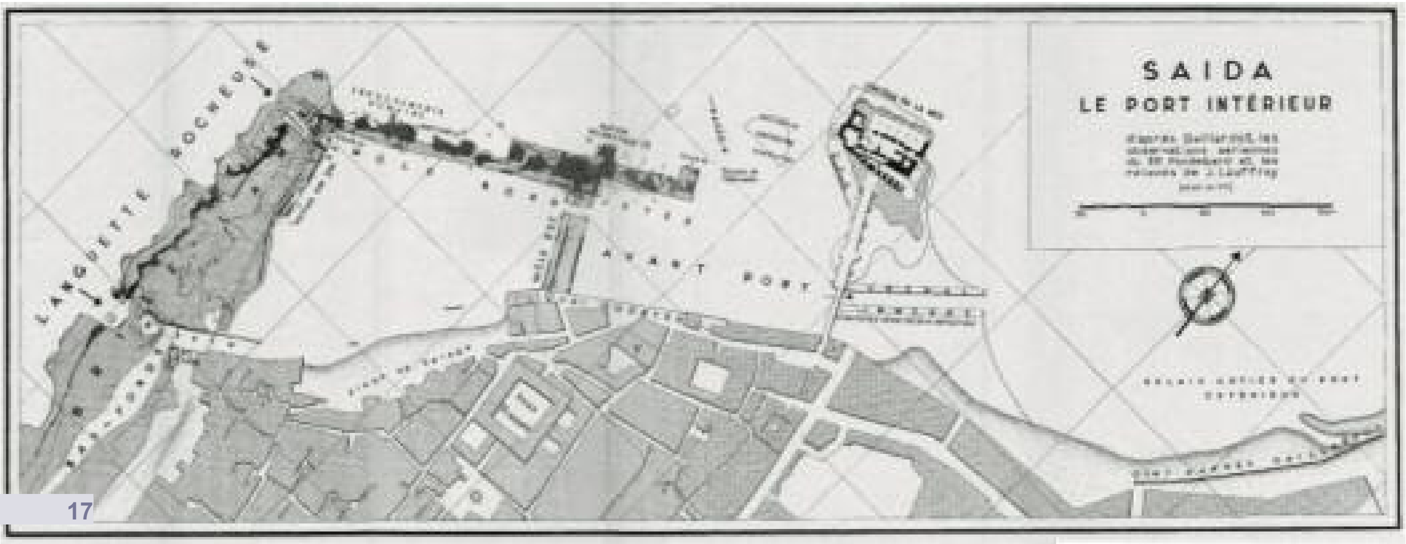
A. Poidebard and J. Lauffray (1951) have noted the presence of transverse foundation ditches. In the north, a canal network 80 cm wide and 50-60 cm deep was dug in the sandstone. Interpreting these structures is difficult, however they reveal that activities other than stone extraction took place here. Traditional archaeological approaches have not enabled us to estimate the age of the superstructures on the sandstone ridge. The paleoenvironmental study of the harbour basin allows us to attribute these structures to the Middle Bronze Age or the beginning of the Late Bronze Age.

16

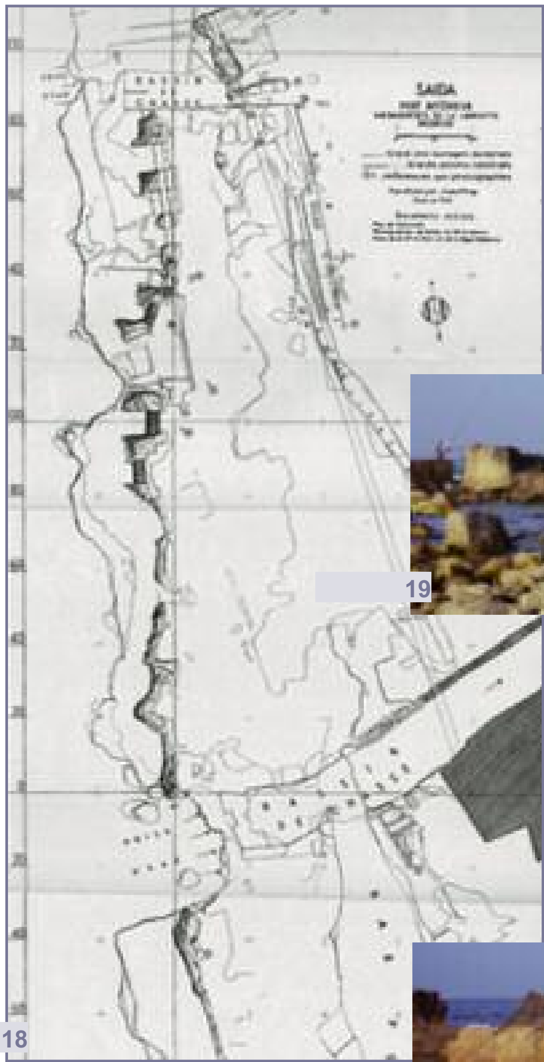
16 Aerial view of Ziré showing the diffraction of marine swell around the island (from A. Poidebard and J. Lauffray, 1951).

Ziré: seawall, quarried quay and anchorage complex

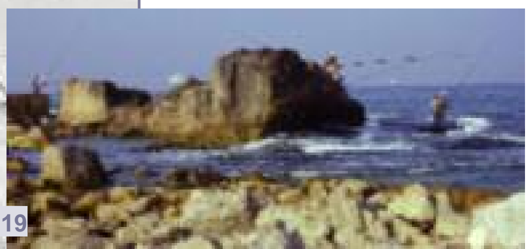
The island of Ziré has revealed remains similar to the sandstone ridge wall. In addition to the island's role as a natural breakwater, the quarry on Ziré has facilitated the construction of a seawall identical to the one observed on the aeolianite ridge, creating a zone protected against the swell (excavation sites A, B and C) (fig. 21)[18]. In Ziré, the seawall extends over three quarters of the island's length. Towards the west, marine erosion has carved a sidewalk/bank about 10 m wide that separates the sea from the seawall. However, this structure does not protect the wall from the assaults of the sea and it is eroded on its western flank. Towards the east, three large quarries (A, B and C) form flattened zones large enough to accommodate harbour activities (fig. 22). Thirty-one anchor bollards attest to harbour activity. They are distributed according to four types (1, 2, 3 and 4). The first type is regular rocky lugs cut in the seawall, pointing towards the bay, with a narrow base to allow mooring (n°9-31) (fig. 23). These bollards might be contemporary with the seawall. Similarities between the sandstone ridge structures and those on the island of Ziré suggest that the two sites are contemporary and can be attributed to the end of the Middle Bronze Age or the beginning the Late Bronze Age.



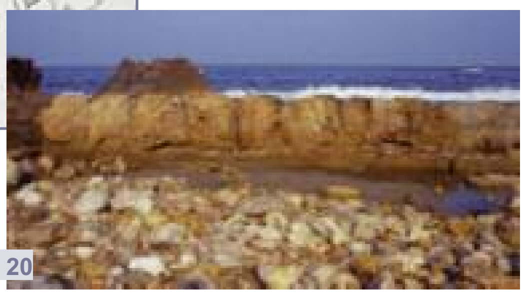
17 The northern harbour of Sidon from A. Poidebard and J. Lauf-fray (1951).



18 Artificialisation of the sandstone ridge on the northern harbour (from A. Poidebard and J. Lauffray, 1951).



19 The ancient seawall in the northern harbour of Sidon (photograph: N. Carayon).



20 Headers of the ancient seawall in the northern harbour of Sidon (photograph: N. Carayon).

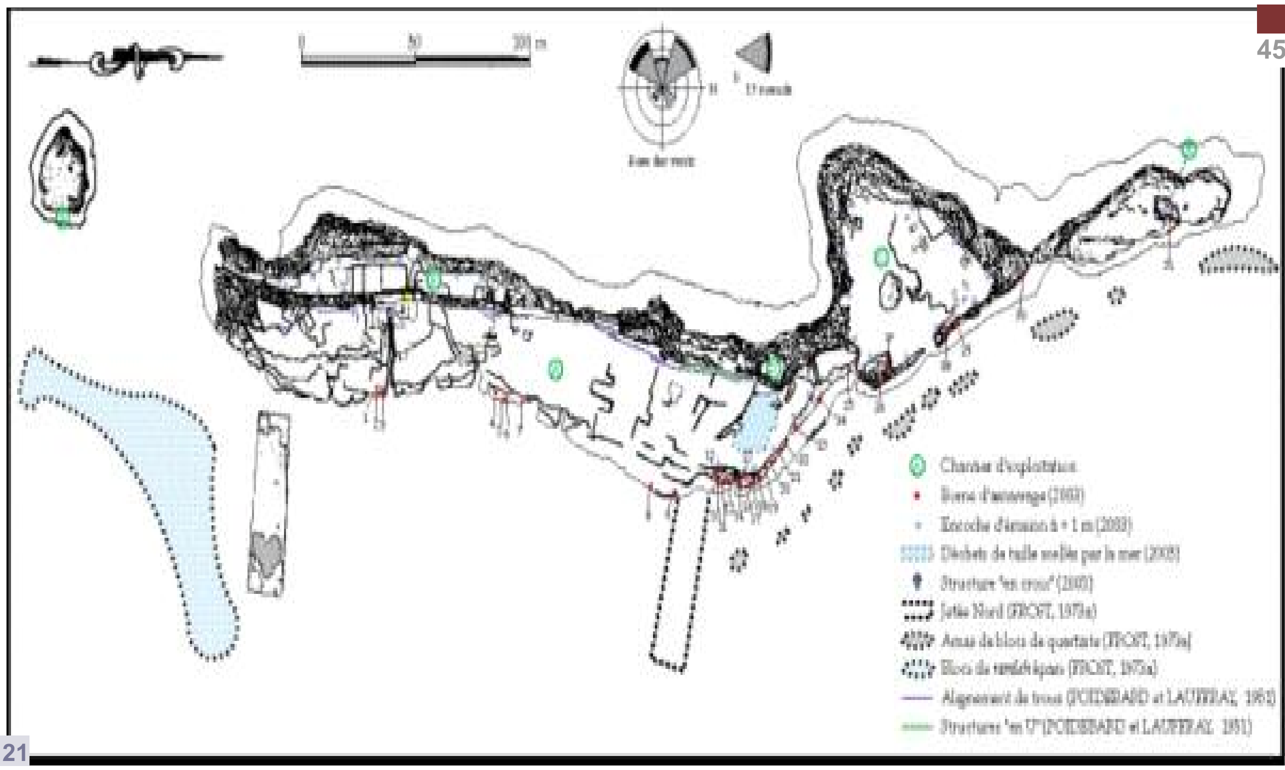
Studies carried out in Sidon demonstrate that from the 2nd millennium onwards, human societies did not just use the natural harbour systems, but also adapted artificial technology to improve the natural protection. The development of a seawall cut into the rocky substrate allowed them to improve the protection of the natural harbours and wharfs during bad weather conditions. Similarly, modification of the natural breakwater on Ziré allowed ships to anchor frequently and safely. This also demonstrates the integration of the island into Sidon's harbour complex.

Although natural harbours were the rule during the Early Bronze Age, commercial needs necessitated a harbour complex able to function in difficult meteorological conditions. Cutting seawalls in the rock, in tandem with quarrying, is one of the most ancient techniques used to improve natural harbours. These types of archaeological remains have also been identified at other Bronze Age harbour sites of the Levant, for instance at Batroun or Tripoli in Lebanon [19], Arwad in Syria [20] or Tell Dor in Israel [21].

Harbour development during the Iron Age

The urban centre that developed on the promontory of Sidon during the Iron Age is known through iconographical and written sources. The levels dated from the 1st millennium BC at College site revealed the regular trade between Phoenicia and the Aegean [22]. The large number of Euboean ceramic fragments indicate the presence of Greek merchants. As for the harbour, its presence during the Iron Age is mentioned in the account of Ounamon describing about 50 vessels at anchor and related to the name of Warkat-Ali, a Semite based in Tanis in the Nile delta [23]. Assyrian texts from Iron Age II mention the transfer by boat of tributes paid by Tyre and Sidon during the reign of Shalmaneser III (858-824 BC) (*ANET*, p. 276-281). A text from Nimrud [24], probably dating from the reign of Teglath-Phalasar III (744-727 BC), mentions the harbour of Sidon under Assyrian administration. A relief sculpture found in Niniveh [25] was wrongly interpreted as representing Lulî's escape from Sidon towards Cyprus, also mentioned in the annals of Sennacherib (704-681 BC) [26]. Even though the scene does not represent the episode related in the Assyrian annals, it is possible that the city depicted is Sidon. Confronted with the hostile army of Assarhaddon (680-669 BC), king Abdi-Milkutti escaped via the sea [27]. During the Persian period (Iron Age III), the vessels of Sidon, often commanded by the Phoenician king, are mentioned within the fleet of the Great King wherein they are honoured [28]. The harbour was used as a naval base by Darius Ier (522-486 BC) who ordered the equipment of two triremes and a cargo ship (*gaulos*) [29]. The Pseudo-Scylax (§ 104) mentions Sidon as 'a city with a closed harbour'.

The economic vitality of the harbour of Sidon during the Iron Age is well attested. It is therefore not surprising that several modifications were undertaken. These infrastructures have been illustrated by the geoarchaeological study of the northern harbour and by the work of Poidebard and Lauffray in the harbour of Ziré.



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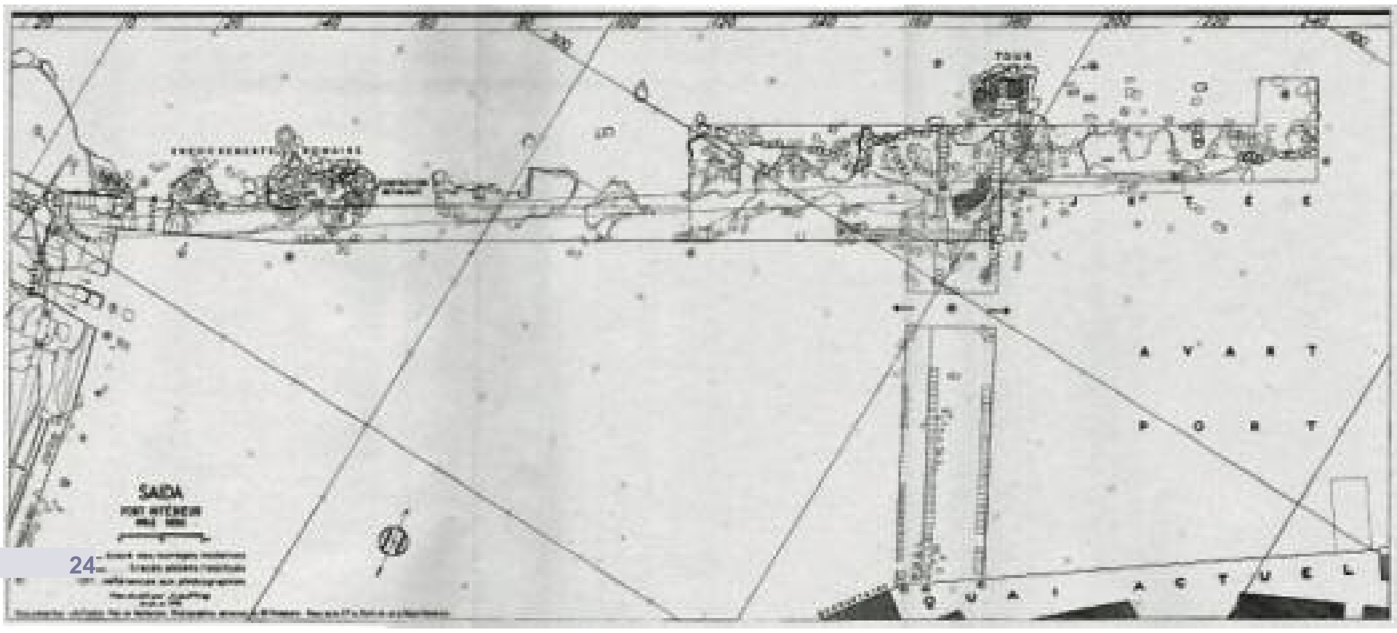
21 Ziré island by N. Carayon (2003).

22 Quarry A in Ziré from the South (photograph: N. Carayon).

23 Mooring bit of the first type on Ziré (photograph: N.

Confinement of the northern harbour

Analysis of cores BH IX and BH XV has allowed us to reconstruct an artificialisation of the environment during the Iron Age. Unit B2 presents a well-defined change in sedimentation, characterized by fine-grained sediments. The mean grain size (160-200 μm) and sorting indices attest to the presence of a protected beach. The macrofauna is dominated by lagoonal species, and fine sands and silty sands assemblages. Ostracods are poor, dominated by lagoonal and marine-lagoonal species that indicate a protected environment. A few drifted-in shells attest to a connection with the open sea. The top of unit B2 was dated 2515 ± 30 BP (790-530 years cal. BC) in core BH XV, which indicates that the development of the northern harbour took place from Iron Age II onwards. By contrast, the top unit was dated 2340 ± 80 BP (230 years cal. BC - 200 years cal. BC) in core BH IX. This chronological anomaly was ascribed, after comparison with similar results from a core taken in Tyre, to several phases of dredging, from the Roman period onwards, that were at the origin of sedimentary hiatuses and chronostratigraphical inversions [30].



24 Plan of the northern mole, the eastern mole and the jetty of the northern harbour (from Carayon).

Sediment facies modification in unit B2 has been interpreted as resulting from the construction of the northern mole, uncovered and studied by A. Poidebard and J. Lauffray (1951) (fig. 24). Today, this mole has disappeared under the modern harbour infrastructure. In the past, it closed the northern side of the basin and offered additional protection to the sandstone ridge and artificially-cut seawall. A line of outcropping reefs upon which a structure was built dictates its general orientation, from east to west, 230 m long and prolonged by the north jetty thereafter (cf. *infra*); its width is variable. To the west, it lies against the breakwater wall that forms a rocky spur towards the open sea (fig. 25). Two foundation layers of this structure were preserved. The stone blocks, sometimes 4 to 5 m long, were laid without mortar directly upon the quarried bedrock. Many quarried blocks bear a notch to match the bedrock and lock the foundations together. Sometimes, a lug was dug in the substrate to insure better stability and prevent sliding of the most exposed blocks. Around 50 m to the east, the mole tends slightly towards the north. At this level, it is partly built on surfacing reefs, but when the reef is absent the gaps were infilled with large stone blocks laid randomly, the largest ones weighing up to 5-6 tonnes. On the platform itself a few construction ruins are still visible: walls comprising ashlar blocks of 2 x 1. 25 m. There is evidence for maintenance and repair with smaller cemented stone blocks. Using pottery fragments incorporated into the mortar, they have been dated to the Roman period, illustrating the maintenance of the structure during more recent periods. It also underlines the importance of a protected northern harbour.

Ziré's jetties

At Ziré, two jetties were implemented during the Persian period [31]. The most southern stretches perpendicularly to the rock-cut quay, at the south-western extremity of the seawall, over a length of 50 m and with

A. Poidebard and J. Lauf-fray, 1951).
25 Western extremity of the northern mole

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a width of 15 m (fig. 26). Its function is clear: it deflects the south-westerly swell and improves the natural harbour conditions. The upper foundations are visible and have been described by A. Poidebard and J. Lauffray. We observe that different construction techniques have been used. The upper foundations of the southern face, the most exposed one, presents an irregular alternation of tiles and headers. The inner foundations are made with 4 to 5 m long headers. The north front shows several foundations composed of small blocks. The corner stones at the extremity of the jetty are more than 5 m long and the sea has displaced those in the south-eastern corner. It is surprising to note that the jetty is not linked to the quay, an 8 m wide pass between the two was put into place. Small boats still use it. The traces of a structure that was built on the jetty are still visible. They contain pottery fragments from the Roman period. The upper foundations of the structure are certainly more recent than the initial construction, it is therefore likely that repairs were made.

The northern jetty, at a distance of 160 m from the south jetty, was not mentioned by A. Poidebard and J. Lauffray (1951) but H. Frost hypothesized its presence in the 1960s. It is also oriented perpendicular to the shore touching the extremity of one of the seawall arms. Only the bedrock cut for the first foundation remains and three recumbent bondstones, presenting a mortar on their upper front, are drowned 3 m below sea level. Having a similar orientation and construction technique, it is probable that the two jetties belonged to the same construction period.

The temple of Eschmoun in Bostan-esh-Cheikh is an important element of the city-state of Sidon in the 1st millennium BC, especially during the Persian period. Many architectural and epigraphical findings attest to a peculiar development of this urban centre during the Iron Age III. We suggest that the temple was connected to the sea through the Awali. It is possible that a harbour was linked to it. A paleoenvironmental study of the ancient delta would help to understand this site.

(from A. Poidebard and J. Lauffray, 1951).

26 View of the southern jetty of Ziré (from A. Poidebard and J. Lauffray, 1951).

27 Block from the pilaster of the Byzantine monumental door (from A. Poidebard and

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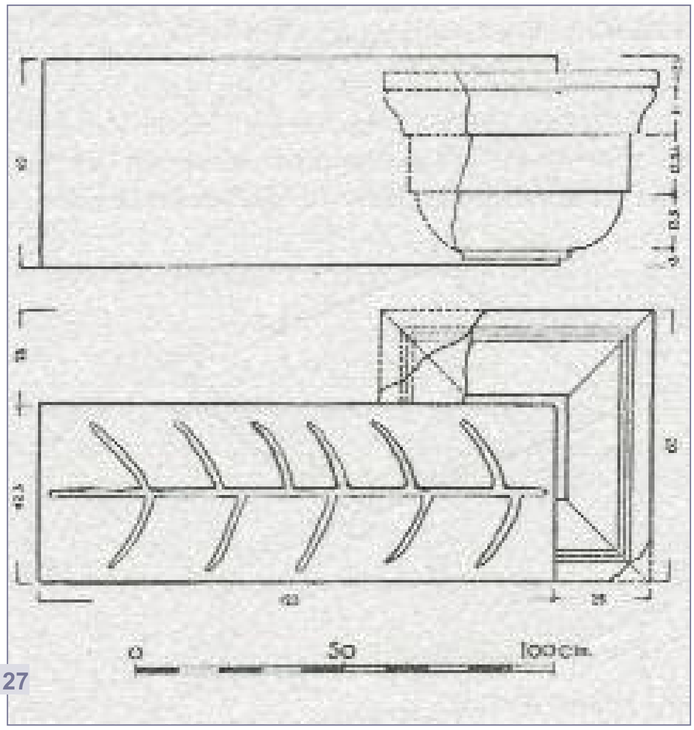

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Harbour confinement during the Roman and Byzantine periods

During the centuries following its foundation, the urban centre of Sidon was improved using the site's natural endowments. Harbour development reinforced the north basin's protection against the swell and winds. The architectural techniques are typical of a proto-harbour [32]. These developments were undertaken earlier than the harbour constructions with hydraulic cement (pouzzolane, 2nd century BC) developed during the Roman period.

From the Roman period onwards, new infrastructure was developed in the northern harbour as shown by additional cores. In unit B1, 90% of the coarse sediments contain silt and clay. The fauna is characterized by the lagoonal and silty sand assemblages. The rich faunal density and the predominance of *Cyprideis torosa* indicate that the basin was very well protected.

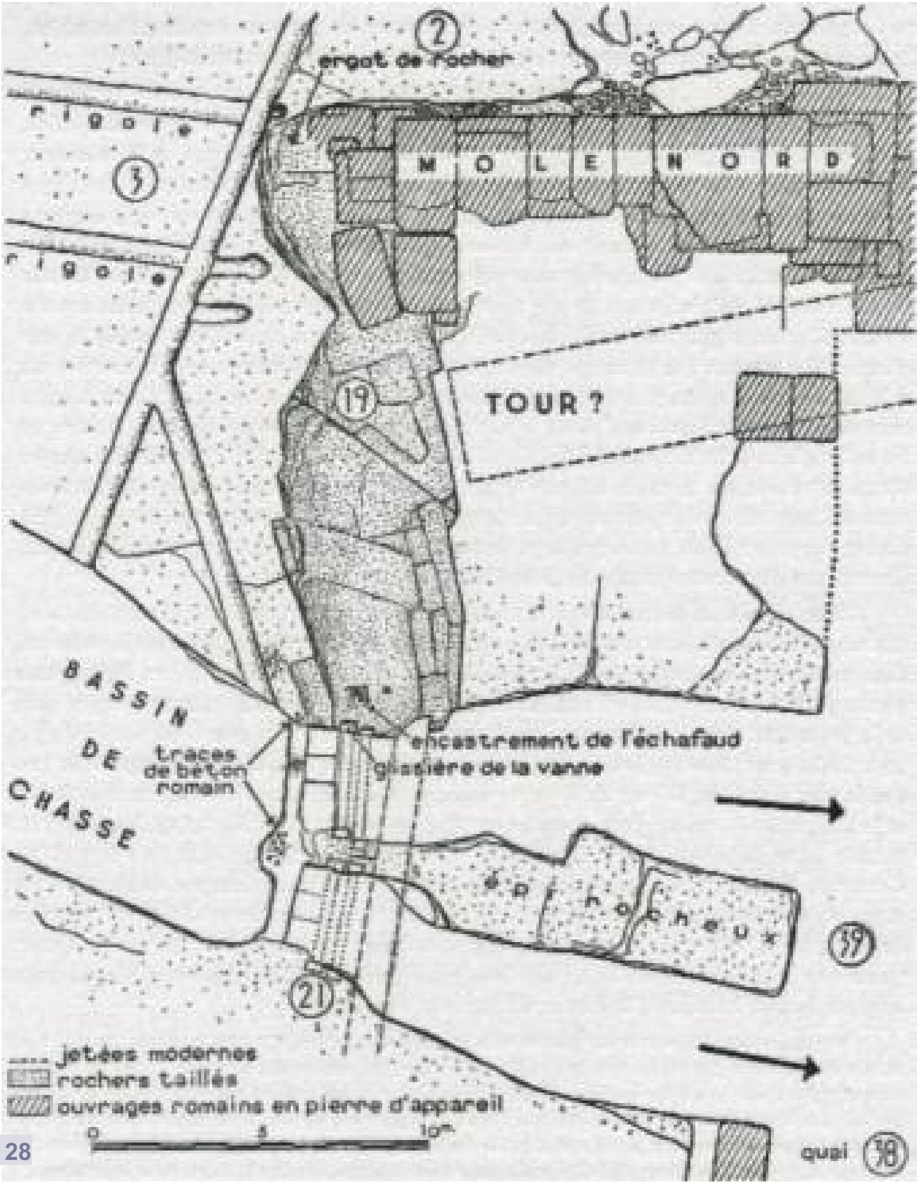
The facies modification is interpreted as subsequent to basin developments during Roman and Byzantine periods, described by A. Poidebard and J. Lauffray. Repairs were made along the northern mole and the northern jetty was constructed, extending the mole by 75 m. This jetty had totally disappeared by the time of A. Poidebard and J. Lauffray (1951). To the west, at its junction with the mole, a tower projecting above the sea was built, with an eastern detachment forming the jetty extremity. Many cut stones remaining from this structure have been scattered around the site.

Another structure, the eastern mole, contributed considerably to diminish the energy dynamics in the basin. It presented two parallel faces separated by 10 m and was made of bondstones of variable dimensions (190-230 x 125-100 x 100-75 cm). A third face, constructed with smaller blocks (110-80 x 50-40 x 45-30 cm) made of tiles and bondstones, was identified in the bottom of the harbour. Some of them were maintained by pieces of wood (tenons) cut to fit into dovetail mortises. This third structure is more recent than the two others. It was probably undertaken to widen the structure. The mole separated the northern harbour into two basins: an outer harbour and an inner harbour. Access to the inner harbour was narrower. The access channel (8 m width) to the inner harbour was identified during dredging at the end of the 1940s. A cornice block was excavated (fig. 27). This architectural element probably belonged to the pilaster of a monumental door with a Byzantine moulding [33].

Coastal progradation at Sidon

Sidon's coastline was modified by the natural progradation of the shore, partly due to the proximity of estuaries. It is an important characteristic because it is at the origin of the harbour potentialities since its foundation. With the increasing development of their activities, human societies needed to improve natural harbour conditions. The main function of these improvements was to protect harbours against natural hazards such as storms. However, by doing so, sedimentation rates in harbours were increased leading to basins silting-up. Studies show that dredging was a solution to the problem from the Roman period onwards. Chronostratigraphical inversions identified in the sediments indicate that considerable dredging operations were carried out. Hydraulic cement was a significant technological progress that allowed the Romans to design and construct well-protected harbours. Dredging was another technological breakthrough aimed to combat silting-up. The use of this technology has been described in the study of several harbours around the Mediterranean, including Sidon, Tyre [34], Marseilles [35] and Naples [36].

At Sidon, the use of another technique has been documented. The breakwater formed by the rocky strip is interrupted in two different places, to the north and to the south, by the presence of basins dug into the substrate and connecting the harbour on one side and the sea on the other side. These basins were implemented after the construction of the seawall. They were equipped with a valve using a wooden mechanism that has disappeared, but their base, cut in the sandstone, still remains (fig. 28-29). Presumably, this system would have allowed the creation of a water current inside the harbour. However, sediment stratigraphy shows that this means was insufficient to stop the silting process.

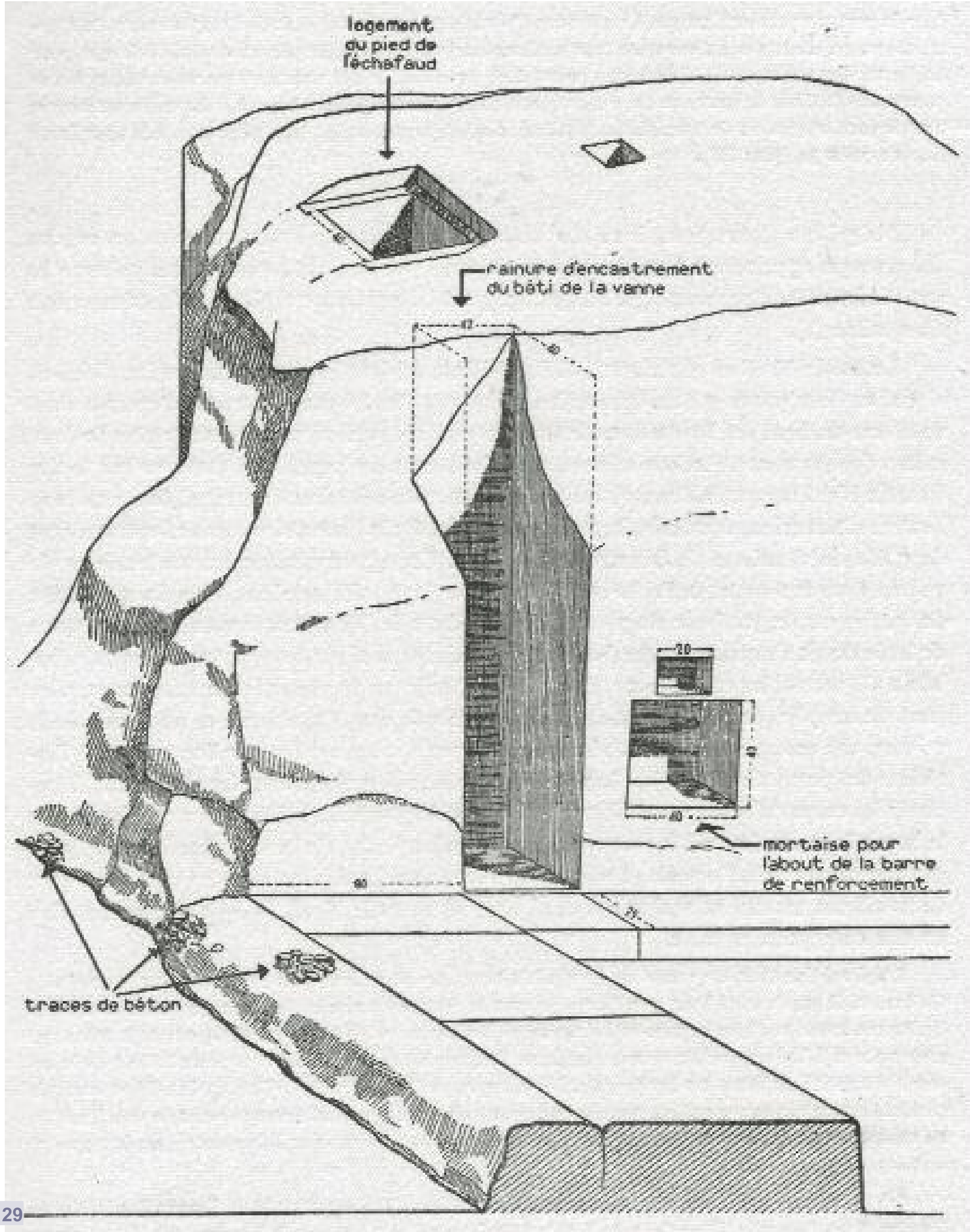


28 Plan of the flushing channel system in the northern harbour (from J. Lauffray, 1951).

Harbour decline: the Islamic period and high-energy events

The decline of Phoenician activities is illustrated by the reopening of Sidon's harbour to offshore influences during the Islamic period. Unit A of cores BH IX and BH XV shows a net increase in the sand fraction. Similarly, biosedimentary data underline the absence of protection from offshore influences.

Although the end of the Byzantine supremacy on the Levantine coast during the 6th and 7th centuries AD is well established, the conse-



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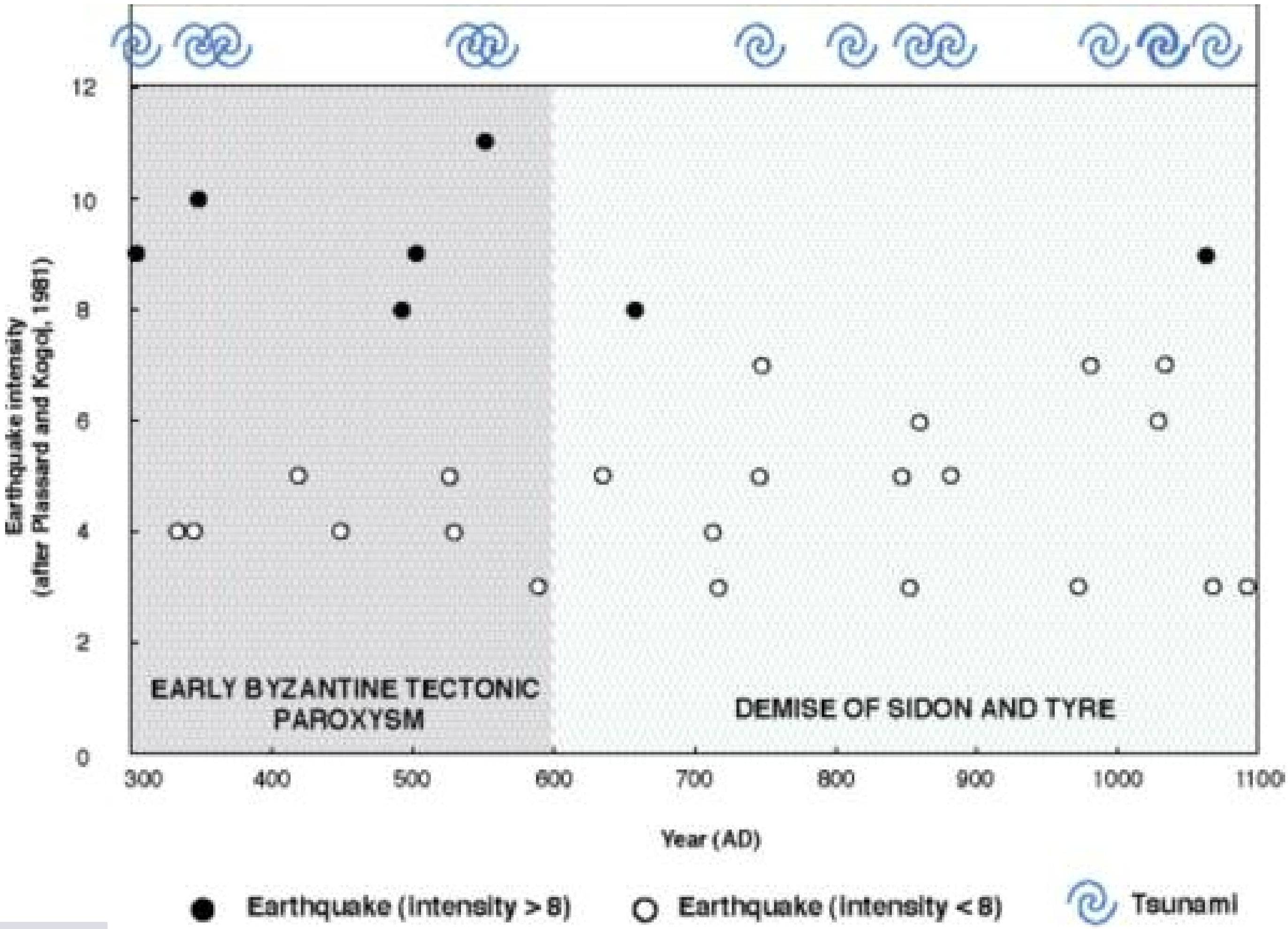
A. Poidebard and J. Lauffray, 1951).
29 Base of the valve using a wooden mechanism; cut in the sandstone (from A. Poidebard and J. Lauf-

quences of these historical and economic changes cannot solely explain the reopening of Sidon's harbour to the offshore influences. Absence of maintenance for most ancient harbour structures must be taken into account, however it is not the sole cause for the reopening. Major seismic activity might also have played a considerable role [37] (fig. 30). At Sidon, sea-level modification of 50 cm is recorded on Ziré. The submersion of part of the island is documented both by a marine erosion notch 50 cm above present sea level and quarry remains sealed on the sea bottom (fig. 31). A sample of *Pirinella conica* marine shells taken on these remains has been dated to 2210 ± 50 BP (46-267 cal. AD). Their good preservation suggests that tectonic movement is at the origin of the end of the use of Ziré as a quarry. However, this event is earlier than the northern harbour reopening in the 6th century AD.

Conversely, between the 6th and 11th centuries AD, a dozen tsunamis struck the Levantine coast [38]. The tsunami that struck Beirut, Sidon and Tyre in 551 AD is the best documented [39]. We suggest that it severely damaged harbour infrastructure at Sidon.



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fray, 1951).

30 Chronology of earthquake and tsunami events affecting the Levantine coast between AD 300 and AD 1100.

31 Uplifted notch on Ziré at + 50 cm pertaining to a short sea-level oscillation around 2210 ± 50 BP (photograph: N. Carayon).

31

NOTES

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