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Mind the (stratigraphic) gap: Roman dredging in ancient Mediterranean harbours

Introduction

It is generally speculated that primitive harbour dredging began during the Bronze Age along the Nile, Euphrates, Tigris and Indus rivers[1]. For the Roman period, Vitruvius gives a few brief accounts of dredging, although direct archaeological evidence has, until now, remained elusive[2]. Here we report chronostratigraphic and sedimentological datasets from Marseilles, Naples, Sidon and Tyre showing evidence for extensive coastal dredging from the late 4th century BC onwards (fig. 1). Our aim is to compare the chronology and stratigraphic impacts of these activities.

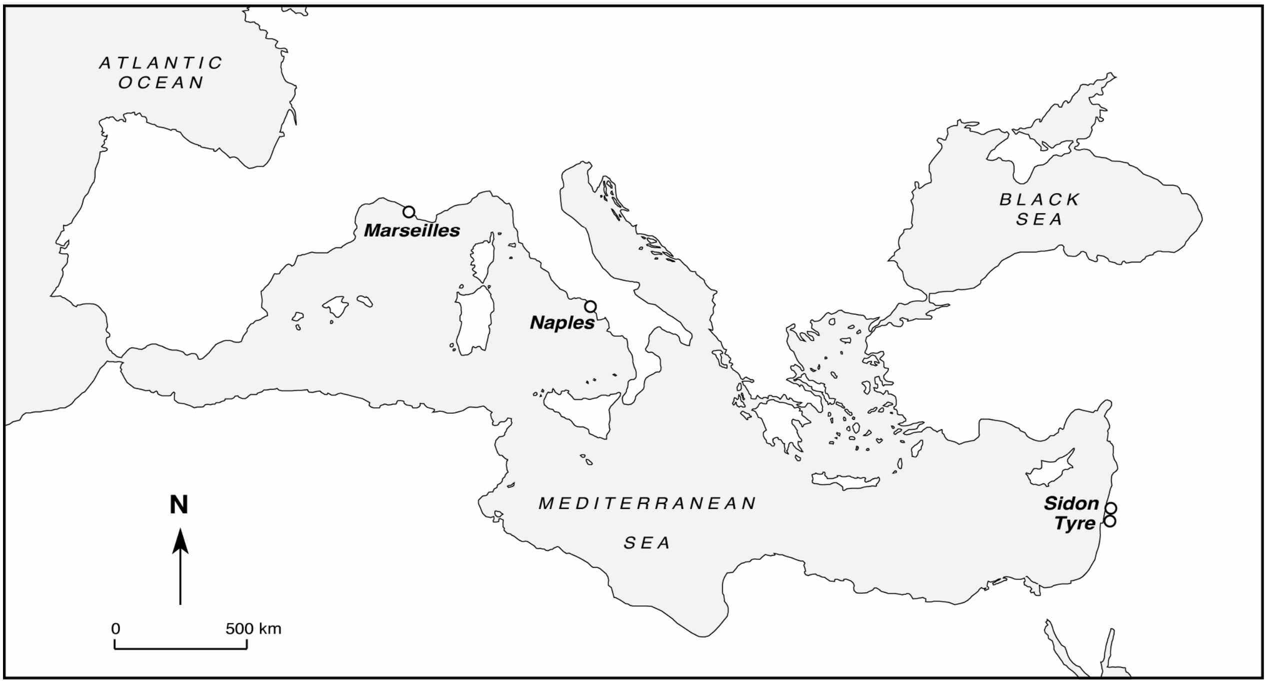

Fig. 1 – Location of studied sites.

[1] FABRE 2004-2005.
[2] HESNARD 2004a; 2004b.

In recent years, a number of studies have shown ancient harbours to be rich time-series of human-environment interaction since the Bronze Age[3]. Sediment base-level accumulation in ports is the terminal transport pathway for fine-grained sediments in the coastal zone. Understanding how sediment accumulation rates have varied in space and time has helped to shed light on regional sediment transport conveyors, depocentres and anthropogenic impacts. Societies have had a significant role to play in coastal sedimentation, where ports act like artificial sinks accumulating thick sequences of fine-grained sediments over many millennia.

Methods

Dredging has not readily been assimilated in the archaeological literature until now and we present three types of data: (1) fossilised taluses; (2) chronological inversions and (3) chronostratigraphic gaps. We propose to interpret these stratigraphic aberrations, most often ignored or rejected, as dredging impacts.

Marseilles and Naples have both undergone extensive excavations, with specialists from numerous disciplines contributing to the projects. Multidisciplinary work at Marseilles has been underway since the early 1990s and extensive datasets now exist for the site[4]; in a similar research vein, work on Naples' Metropolitan line has unearthed significant areas of the city's ancient harbour[5]. Large stratigraphic sections have been exposed at both sites, with field measurements and subsequent laboratory analyses constrained by ceramic dates.

At Tyre and Sidon, geoarchaeological research has led to the extraction of 40 cores that have facilitated a chronostratigraphic reconstruction of basin silting[6].

In this paper we present radiocarbon dates plotted against mean sea level. The field and laboratory methods employed have already been extensively described elsewhere[7]; multi-proxy data (macrofauna, microfauna, sedimentology) allow us to precisely reconstruct the harbour stratigraphies and basin evolution through time.

Results and discussion

The new datasets allow three questions to be resolved:

(i) Why dredge?

Two variables can be used to explain the long-term viability of ancient harbours: (1) relative sea-level changes; and (2) sediment supply and its role in modifying the draught depth. Since relative sea-level changes have been relatively modest on stable Mediterranean coasts during the past 6000 years (within 2-3 m of present), this variable has been only minor in explaining coastal deformation[8]. On centennial timescales continued silting up induced a concomitant shortening of the water column (i.e. accommodation space reduction and subsequent coastal progradation). On short decadal timescales de-silting infrastructure, such as sluice gates, vaulted moles and channels, partially attenuated the problem but in the long term these appear to have been relatively ineffective[9]. In light of this, repeated dredging was the only means of maintaining a viable draught depth and ensuring long-term harbour viability.

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[3] Reinhardt *et al.* 1998; Morhange *et al.* 2000; Kraft *et al.* 2003.
[4] Hesnard 1994; Morhange 1994.
[5] De Caro and Giampaola 2004.
[6] Marriner *et al.* 2006a; 2006b; Marriner 2007.
[7] Reinhardt and Raban 1999; Marriner and Morhange 2007.
[8] Laborel *et al.* 1994; Lambeck and Purcell 2005; Pirazzoli 2005.
[9] Blackman 1982a; 1982b.

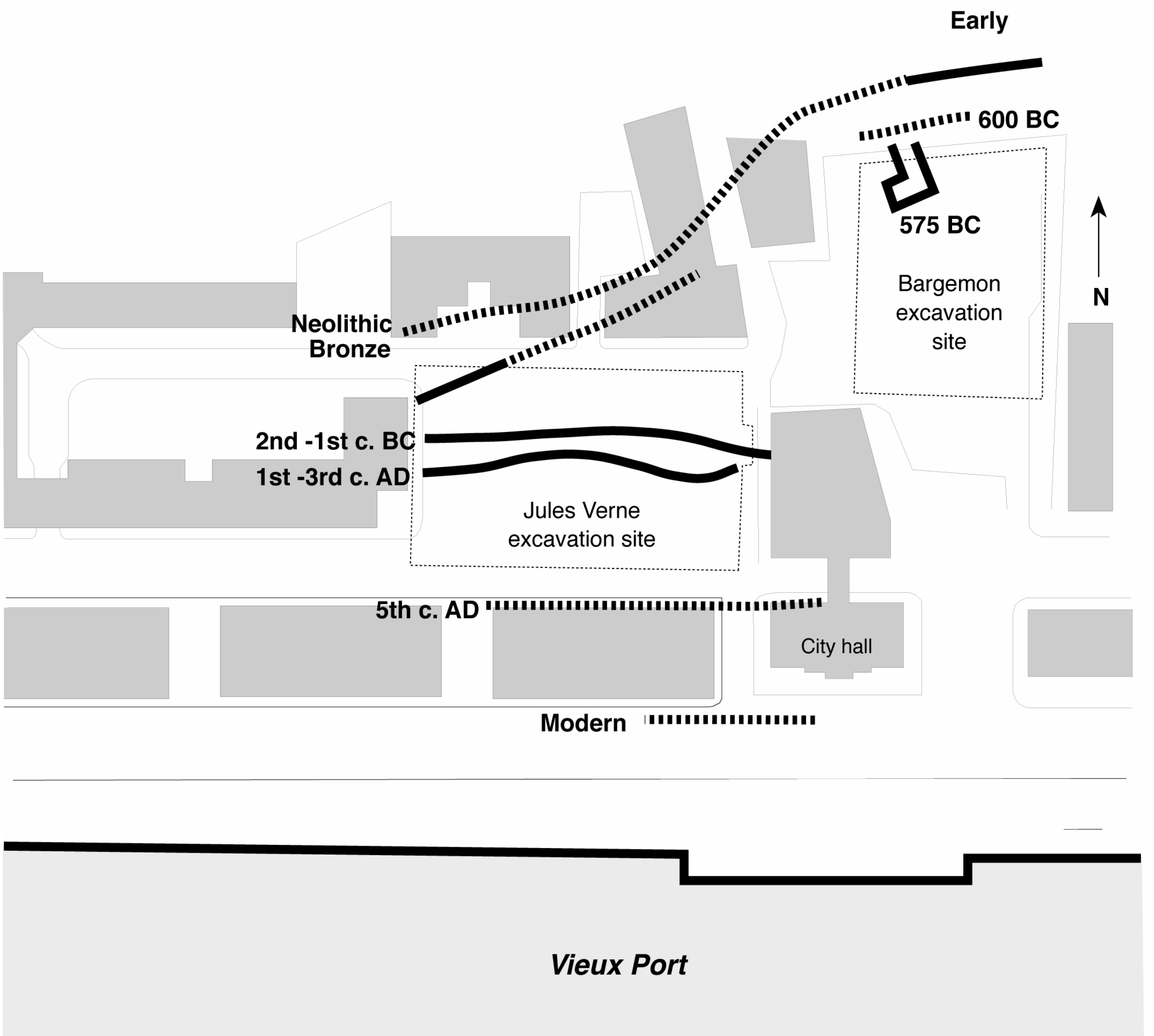

Fig. 2 – Progradation of Marseilles' northern harbour coastline since the Neolithic.
The Greek to Roman period coastlines were studied in section during excavations at the Jules Verne site (centre)
(photo CCJ/CNRS).

(ii) When?

Marseilles

Archaeological excavations at Marseilles have uncovered around 8000 m² of the city's buried port (fig. 2). Litho- and biostratigraphical studies elucidate a long history of human impacts stretching back to the late Neolithic period[10]. Rapid shoreline progradation is recorded following the foundation of the colony in 600 BC. During the 1st century BC, after over 500 years of Phocaean rule, the demise and fall of the Greek city is translated by wide-reaching changes in the spatial organisation of the harbour area[11]. Although dredging phases are recorded from the 3rd century BC onwards, the most extensive enterprises were undertaken during the 1st century AD, at which time huge tracts of Greek sediment were extracted down to a hard midden

[10] MORHANGE *ET AL.* 2003.
[11] HERMARY *ET AL.* 1999.

Fig. 3 – Example of a scouring talus at Marseilles.
The highly cohesive nature of the harbour muds (>90 % silts) means these have been well-preserved in the stratigraphic record.

layer of oysters (fig. 3)[12]. Notwithstanding the creation of artificial accommodation space, this rapidly infilled and necessitated regular intervention. Repeated dredging phases are evidenced up until late Roman times, after which time the basin margins were completely silted up (fig. 2). Despite this partial loss of accommodation space it is interesting to note that the seaport is still in use today, more than 2500 years after its foundation.

Naples

In Naples, recent excavations at the Piazza Municipio show the absence of pre-4th century BC layers due to extensive dredging between the 4th and 2nd centuries BC[13]. Unprecedented traces 165 to 180 cm wide and 30 to 50 cm deep attest to powerful dredging technology that scoured into the volcanic tufa substratum, completely reshaping the harbour bottom (figs. 4 and 5).

Fig. 4 – (A-B) Tufa substratum scouring marks resulting from Roman dredging of the harbour bottom at Piazza Municipio, Naples (photo *Soprintendenza Speciale per i beni archeologici di Napoli e Pompei*).

[12] HESNARD 2004a.
[13] GIAMPAOLA *ET AL.* 2004; GIAMPAOLA and CARSANA 2005.

Fig. 5 – Dredging talus at Naples (Piazza Municipio) (photo *Soprintendenza Speciale per i beni archeologici di Napoli e Pompei*).

Dateable archaeological artefacts contained within the deposits allow for a very detailed time series of sediment fluxes, with much greater temporal resolution than traditional radiometric methods. Investigated stratigraphic sections were dated to the 3rd century BC and the beginning of the 6th century AD. Calculated fluxes are concurrent with intercentennial variability throughout this period (fig. 6). Rapid settling velocities of 17 to 20 mm/yr are recorded during the 2nd century BC and the 1st and 5th centuries AD.

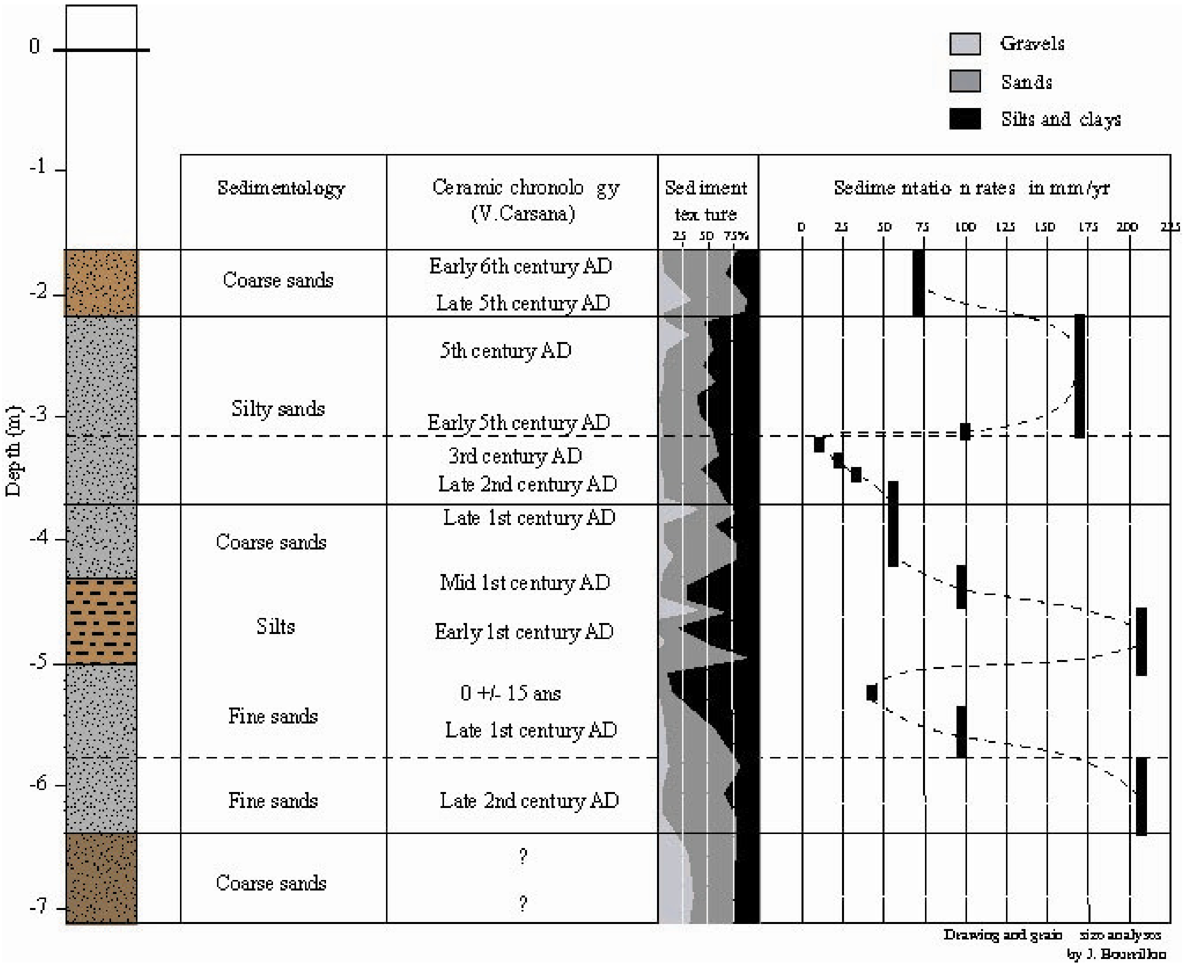

Fig. 6 – Stratigraphic section from Naples harbour showing the high variability of sedimentary fluxes. Anthropogenic impact is fundamental in explaining the harbour silting up (photo *Soprintendenza Speciale per i beni archeologici di Napoli e Pompei*).

Low sedimentation fluxes of 0 to 5 mm/yr are evidenced during the 1st century BC, and the late 2nd and early 5th centuries AD. The most rapid rates are consistent with data from Archaic Marseilles (20 mm/yr)[14], Roman Alexandria (15 mm/yr)[15] and Roman and Byzantine Tyre (10 mm/yr)[16]. Three possible explanations can be evoked for the contrasting detritic fluxes: (1) hypothetic changes in climatic conditions; (2) human agency and changes in land use patterns, both regionally in the watershed and locally in the urban settlement; or (3) dredging activity. We posit that anthropogenic impact is most determinant in explaining the majority of harbour silting up, whereby the basins served as base-level waste dumps.

Phoenicia

At Sidon and Tyre, unique chronostratigraphic patterns from over forty radiocarbon dates have yielded strong evidence in support of the dredging findings from Marseilles and Naples (fig. 7)[17]. Naturally accreting marine bottoms are observed between ~6000 BC and ~1500 BC, with a pronounced sediment hiatus spanning the Middle Bronze and Iron Ages. Rapid rates of sediment accretion and persistent age depth inversions are evidenced from the 3rd century BC onwards, inconsistent with a natural sedimentary system. Chronostratigraphic patterns from the cities' natural coastlines do not manifest similar patterns, discarding the hypothesis of radiocarbon discrepancies at the two sites.

(iii) How?

The discussed data assert that Roman dredging was a well-organized management technique, not as crude as previously speculated. Bed shear stress in co-

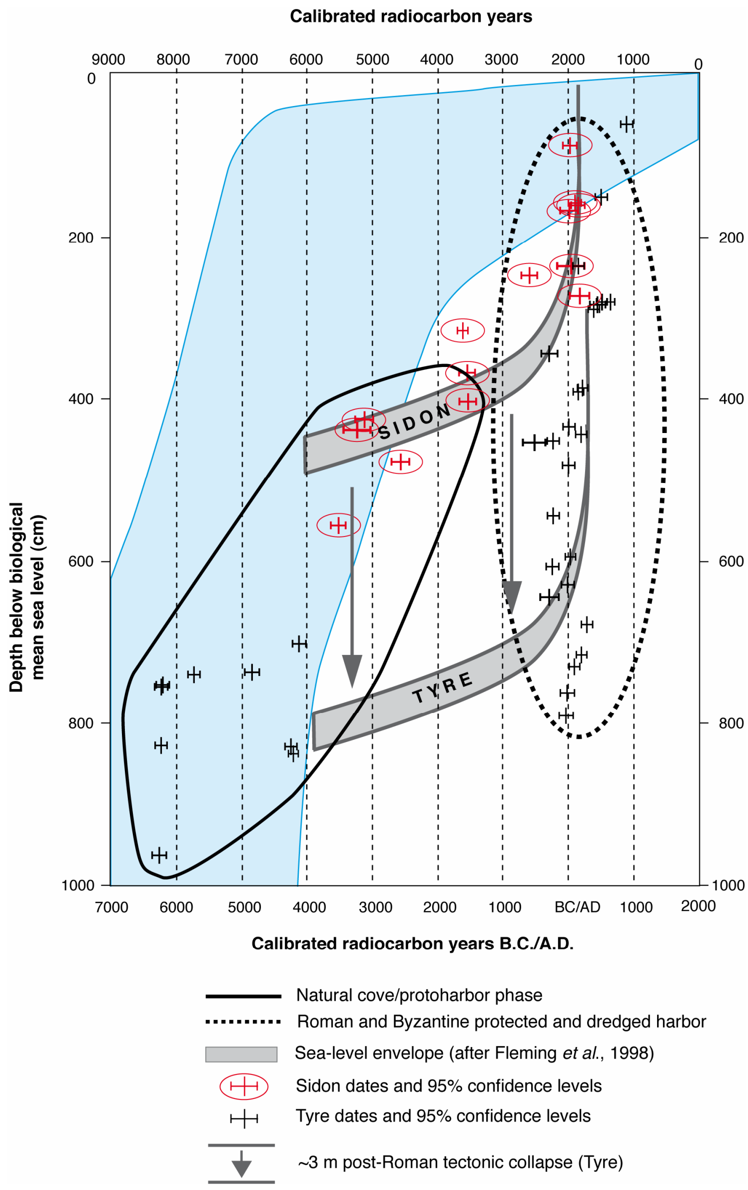

Fig. 7 – Chronostratigraphic evidence for Roman and Byzantine dredging of Sidon and Tyre's ancient harbours. The older radiocarbon group corresponds to a naturally aggrading marine bottom. Quasi-absence of a chronostratigraphic record between BC 4000 to 500, coupled with persistent age depth inversions, are interpreted as evidence of harbour dredging. The 3 m difference in heights is explained by post-Roman subsidence of the Tyre block.

[14] Morhange *et al.* 1994.
[15] Goiran 2001.
[16] Marriner *et al.* 2005.
[17] Marriner and Morhange 2006a.

Fig. 8 – Shipwreck *Jules Verne 3*, a Roman dredging boat unearthed in Marseilles' ancient harbour. The vessel dates from the 1st to 2nd centuries AD. The central dredging well measures 255 cm by 50 cm (photo CCJ/CNRS).

hesive harbour clays is considerable, and powerful vessels are inferred from the depth of scour marks and the shear volume of sediment removed. Three dredging boats, *Jules Verne 3*, *4* and *5*, have been unearthed and studied at Marseilles[18]. These were abandoned at the bottom of the harbour during the 1st and 2nd centuries AD. All three vessels are characterised by an open central well that is inferred to have accommodated the dredging arm. *Jules Verne 3*'s reconstructed length is ~16 m and the central well measures 255 cm long by 50 cm wide (fig. 8). Although the exact nature and mechanics of the dredging arms are not known, dredging taluses ~30 to ~50 cm deep have been fossilised in the stratigraphic record at Marseilles. No such dredging vessels have been unearthed in Naples, although large taluses and consistent ceramic mixing are widespread throughout the basin. Figure 9 depicts eighteenth and nineteenth century dredging equipment used in fluvial contexts. The nature of the fossilised dredging scours at Marseilles and Naples leads us to hypothesise that similar methods were employed during antiquity. It seems likely that the technique had evolved very little since this time.

Conclusion: more gaps than records?

These chronostratigraphic data, coupled with the discovery of Marseilles' dredging wrecks, assert that dredging was a well-organized management technique essential in sustaining the viability of Mediterranean harbours. During the Roman period, it entrained the removal of large parts of the Bronze Age and Iron Age archaeological records and has created an interesting paradox of quasi-archiveless ancient harbours (i.e. Phoenician harbours without Phoenician sediments). After the late Roman period, poor port

[18] POMEY 1995; POMEY and RIETH 2005.

maintenance culminated in the burial of many harbours throughout the Mediterranean. These findings have widespread implications for assessing the scope of records in coastal archaeology.

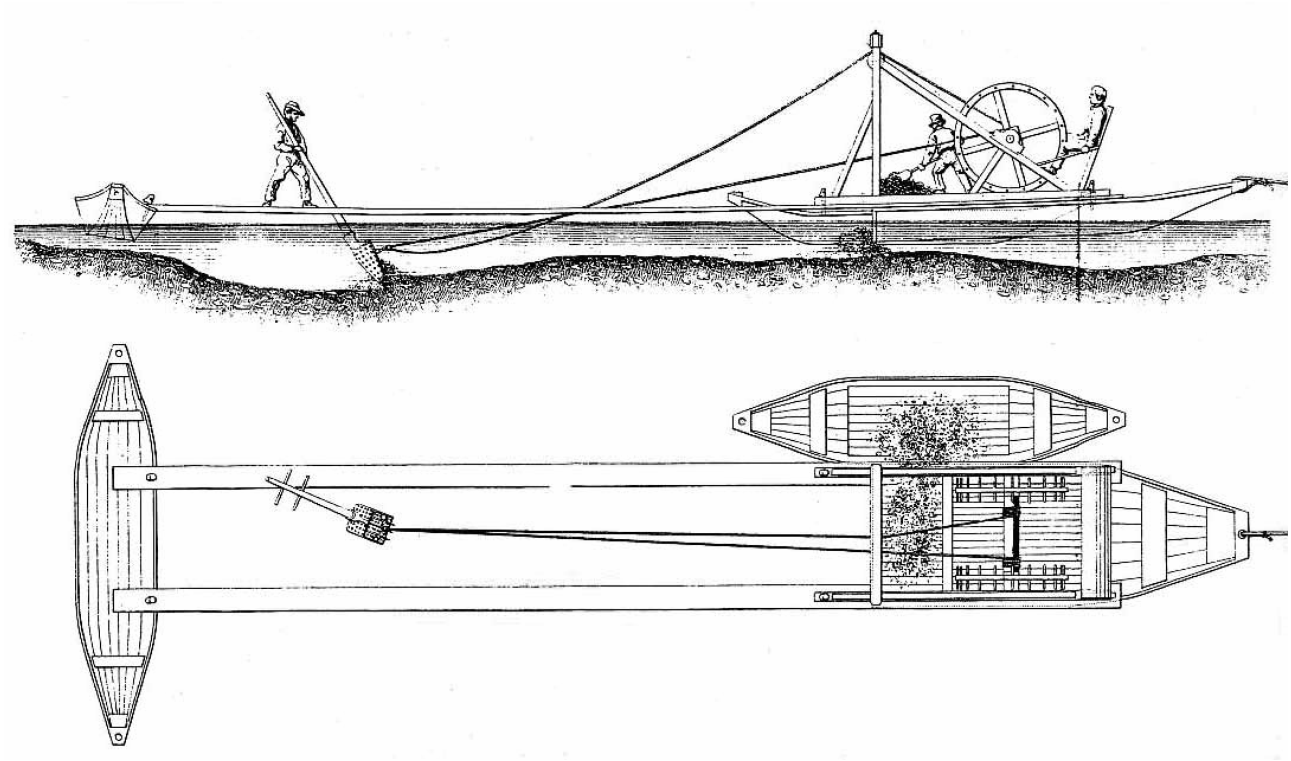

Fig. 9 – Eighteenth and nineteenth century dredging equipment used in European fluvial contexts. The vessel immediately adjacent to the 'pull boat' is equipped with a removable bottom, to facilitate the dumping of dredged material at a distal location (engraving in BILLAUD and MARGUET 2006).

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Bibliography

BILLAUD Y. and MARGUET A., 2006. Historique des recherches. In A. DUMONT (ed.), *Archéologie des lacs et des cours d'eau*. Paris, 9-28.

BLACKMAN D.J., 1982a. Ancient harbours in the Mediterranean, part 1. *The International Journal of Nautical Archaeology and Underwater Exploration*, 11, 79-104.

BLACKMAN D.J., 1982b. Ancient harbours in the Mediterranean, part 2. *The International Journal of Nautical Archaeology and Underwater Exploration*, 11, 185-211.

DE CARO S. and GIAMPAOLA D., 2004. La Metropolitana approda nel porto di Neapolis. *Civiltà del Mediterraneo*, 4-5, 49-62.

FABRE D., 2004-2005. *Seafaring in ancient Egypt*. London.

GIAMPAOLA D. and CARSANA V., 2005. Le nuove scoperte: la città, il porto e le machine. In E. LO SARDO (ed.), *Eureka! Il genio degli antichi*. Napoli, 116-122.

GIAMPAOLA D., CARSANA V. and BOETTO G., 2004. Il mare torna a bagnare Neapolis. Parte II: dalla scoperta del porto al recupero dei relitti. *L'Archeologo Subacqueo*, 10 (3), 15-19.

GOIRAN J.-P., 2001. *Recherches géomorphologiques dans la région littorale d'Alexandrie, Egypte*, PhD thesis, Université de Provence. Aix-en-Provence.

GOIRAN J.-P. and MORHANGE C., 2003. Géoarchéologie des ports antiques de Méditerranée. *Topoi*, 11, 645-667.

HERMARY A., HESNARD A. and TREZINY H., 1999. *Marseille grecque: la cité phocéenne (600-49 av. J.-C.)*. Paris.

HESNARD A., 1994. Une nouvelle fouille du port de Marseille, Place Jules Verne. *Comptes Rendus des Académie des Inscriptions et des Belles Lettres*, 1, 195-217.

HESNARD A., 2004a. Terre submergée, mer enterrée: une «géoarchéologie» du port antique de Marseille. In L. DE MARIA and R. TURCHETTI (eds.), *Evolución Paleoambiental de los puertos y fondaderos antiguos en el Mediterráneo occidental*, *I Seminario ANSER*, *14-15 novembre 2003, Alicante*. Soveria Mannelli, 3-29.

HESNARD A., 2004b. Vitruve, *De Architettura*, V, 12 et le port romain de Marseille. In A. GALLINA ZEVI and R. TURCHETTI (eds.), *Le strutture dei porti e degli approdi antichi, II Seminario ANSER, 16-17 aprile 2004,Roma-Ostia Antica*. Soveria Mannelli, 175-204.

KRAFT J.C., RAPP G.R., KAYAN I. and LUCE J.V., 2003. Harbor areas at ancient Troy: Sedimentology and geomorphology complement Homer's Iliad. *Geology*, 31, 163-166.

LABOREL J., MORHANGE C., LAFONT R., LE CAMPION J., LABOREL-DEGUEN F. and SARTORETTO S., 1994. Biological evidence of sea-level rise during the last 4500 years on the rocky coasts of continental southwestern France and Corsica. *Marine Geology*, 120, 203-23.

LAMBECK K. and PURCELL A., 2005. Sea-level change in the Mediterranean Sea since the LGM: model predictions for tectonically stable areas. *Quaternary Science Reviews*, 24, 1969-1988.

MARRINER N., 2007. *Géoarchéologie des ports antiques de Beyrouth, Sidon et Tyr: 5000 ans d'interactions nature-culture/ Geoarchaeology of Phoenicia's buried harbours: Beirut, Sidon and Tyre: 5000 years of human-environment interactions*, PhD thesis, Université de Provence. Aix-en-Provence.

MARRINER N., MORHANGE C., BOUDAGHER-FADEL M., BOURCIER M. and CARBONEL P., 2005. Geoarchaeology of Tyre's ancient northern harbour, Phoenicia. *Journal of Archaeological Science*, 32, 1302-1327.

MARRINER N., MORHANGE C., DOUMET-SERHAL C. and CARBONEL P., 2006a. Geoscience rediscovers Phoenicia's buried harbors. *Geology*, 3, 1-4.

MARRINER N., MORHANGE C. and DOUMET-SERHAL C., 2006b. Geoarchaeology of Sidon's ancient harbours, Phoenicia. *Journal of Archaeological Science*, 33, 1514-1535.

MARRINER N. and MORHANGE C., 2006. Geoarchaeological evidence for dredging in Tyre's ancient harbour, Levant. *Quaternary Research*, 65, 164-171.

MARRINER N. and MORHANGE C., 2007. Geoscience of ancient Mediterranean harbours. *Earth-Science Reviews*, 80, 137-194.

MORHANGE C., 1994. *La mobilité des littoraux provençaux: Eléments d'analyse géomorphologiques*, PhD Thesis, Université de Provence. Aix-en.Provence.

MORHANGE C., GOIRAN J.-P., BOURCIER M., CARBONEL P., LE CAMPION J., ROUCHY J.-M. and YON M., 2000. Recent Holocene paleo-environmental evolution and coastline changes of Kition, Larnaca, Cyprus, Mediterranean Sea. *Marine Geology*, 26, 205-230.

MORHANGE C., BLANC F., BOURCIER M., CARBONEL P., PRONE A., SCHMITT-MERCURY S., VIVENT D. and HESNARD A., 2003. Bio-sedimentology of the late Holocene deposits of the ancient harbor of Marseilles (Southern France, Mediterranean sea). *The Holocene*, 13, 593-604.

PIRAZZOLI P.A., 2005. A review of possible eustatic, isostatic and tectonic contributions in eight late-Holocene relative sea-level histories from the Mediterranean area. *Quaternary Science Reviews*, 24, 1989-2001.

POMEY P., 1995. Les épaves grecques et romaines de la place Jules Verne à Marseille, *Comptes Rendus de l'Académie des Inscriptions et Belles Lettres*, 459-484.

POMEY P. and RIETH E., 2005. *L'archéologie navale*. Paris.

REINHARDT E.G., PATTERSON R.T., BLENKINSOP J. and RABAN A., 1998. Paleoenvironmental evolution of the inner basin of the ancient harbor at Caesarea Maritima, Israel; foraminiferal and Sr isotopic evidence. *Revue de Paleobiologie*, 17, 1-21.

REINHARDT E.G. and RABAN A., 1999. Destruction of Herod the Great's harbor Caesarea Maritima, Israel, geoarchaeological evidence. *Geology*, 27, 811-814.