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Comments Concerning Recent Fieldwork on Roman Maritime Concrete

In recent years the most important advance in underwater archaeology *vis-à-vis* hydraulic concrete structures for Roman maritime installations has been made by the Roman Maritime Concrete Study (ROMACONS) project, directed by Brandon, Hohlfelder, and Oleson, dedicated to analysing the composition and manner of use of the elements making up the concrete mixtures (Oleson *et al*., 2004a; Oleson *et al*., 2004b; Brandon *et al*., 2005; Hohlfelder *et al*., 2007; Gotti *et al*., 2008). In many cases *pulvis puteolanus* was present as an essential element. This, the construction material recommended by Vitruvius and found on the Phlegrean and Neapolitan coastline of Campania, was transported as far as Caesarea Maritima (Branton and Oleson, 1992).

With a view to verifying how widely pozzolana was used (for example, we would expect it to have been used in Mauretania in the port of Jol-Chercell under Juba II), or to analyse and evaluate structures created with other combinations of materials, samples of conglomerate for analysis have been taken by means of drilling. The sites studied so far are: Cosa, Santa Liberata, Portus, Antium, Baiae, and Gnathia. Similar research has also been carried out at Chersonesos in Crete (Oleson *et al*., 2004b: 206; Brandon *et al*., 2005). The results, which have mostly already been published, provide useful information. Among the most obvious, the presence of pozzolana has been confirmed on many sites, and one of the structures of the port of Cosa has been dated by C14 to the mid-1st century (57–33) BC, which is almost a century later than had been previously supposed (McCann, 1987; McCann, 1998: 43; see also Oleson *et al*., 2004b: 217ff.).

The general purpose of this paper, stimulated by the results produced by the ROMACONS project, is to review the chronology for the early use of *opus caementicium* for building structures in the sea. In addition, a review of supposed structures at Carthago Nova indicates that they do not relate to the harbour, but very probably to a temple, while the *pilae* at Tarraco and Ampurias are also not definitely maritime structures.

Identifying the earliest example

The structure at Cosa had been thought to be the oldest identified example of maritime construction using hydraulic concrete. Another potentially early site, roughly contemporary with the *Porticus Aemilia,* which is thought to be the first large-scale use of concrete at Rome (Liv. XL, 51, 4), is the mole built by M. Aemilius Lepidus on his properties at Terracina in 179 BC (D'Arms, 1981: 36). Now, however, the revised date for Cosa perhaps makes such an early instance of the use of pozzolana much less likely.

The application of this technique in the sea, due primarily to the use of *pulvis puteolanus* in the mixture making up the *caementicium*, is indirectly attested only at a later date. The first instance of the creation of *piscinae* for fish-farming, built in the sea by Sergius Orata in the first years of the 1st century BC, occurred in precisely the area which Vitruvius (II, 6, 1 and V, 12, 2–3) notes as having pozzolana of the best quality; all the more effective if, Pliny adds, '*Cumano misceatur caemento*' (*NH* XXXV, 166, see also Strabo V.4.6; Sen., *Nat. Quaest*. 3.20.3). There is, therefore, no reason for doubting that the technique was invented and applied extensively along the whole littoral of the Phlegrean Fields during the construction boom of the late Republic and early Principate. This was a time when other daring experiments were also conducted on land, as can be seen, for example, in the vaults of the Baths of Baiae.

The previous chronology for the mole at Cosa slightly anticipated this scheme, but nevertheless constituted a useful reference-point for the study of other ports. Now, however, some of them must be reconsidered in the light of the new dating. This is the case with Carthago Nova, to which an inscription (*CIL* I, 2:2271 (= I,1477) and 3:1104; *CIL* II, 3434 (suppl. 5927) and p.952; *ILLRP* 778) mentioning the construction of concrete piles refers. Since this inscription is dated to the late-2nd or first half of the 1st century BC (Abascal Palazón and Ramallo Asensio, 1997: 71–7, n.1, pl.1; Gianfrotta, 2008a: 73f.), the associated port would replace Cosa as the oldest known example of construction with hydraulic concrete in the sea. After listing at length the *magistri* who dedicated it, the

text ends: '*mag(istri) . pilas . III et / fundament(a) . ex / caement(o, -icio) . faci(undas) / coerauere*'.

Therefore, this inscription would document the new technique, adding the detail '*ex caement*(*o*)' which is all the more remarkable in view of the great distance between the area of experimentation in northern Campania and of this putative first instance. True, entrepreneurs from that region had been active at CarthagoNova for some time. Many names are documented on lead ingots (Domergue, 1990: 229–70, 322) and in the city's inscriptions (Abascal Palazón and Ramallo Asensio, 1997: 76f.). On this reading, the dedicators listed in the inscription, who can all be linked to Campania and central Italy (especially Minturnum and Capua, but also Delos) on onomastic grounds, would have financed the construction of the harbour as public work linked to their commercial activities, and from which they themselves would have benefited.

For some time now this construction work has been connected to the harbour (*RE* III, 2, 1899 (1970, 2), 1625; for a detailed discussion see Abascal Palazón and Ramallo Asensio, 1997: 70; Berrocal Caparrós, 1998: 110–12). However, the absence of archaeological remains that might clarify matters, and the topography of Carthago Nova, whose deep bay is well provided with safe areas and vast zones of standing water, make it doubtful whether this inscription in fact refers to a *maritime* construction. In addition, three piles alone would have been insufficient to provide effective protection for a mole, even if they had been situated at the innermost part of the harbour.

Even more to the point, however, is the fact that other dedications referring to the construction of piles are known at Capua, to which the names of some of the dedicants of the inscription of Carthago Nova lead us, which are analogous in terms of chronology, form, social composition of the dedicants, formulary and perhaps palaeography (*CIL* II suppl. 5927: 952; Abascal Palazón and Ramallo Asensio, 1997: 76f.). In two of these inscriptions, reference is made to a '[*muru*]*m et pilas IIII*' (ILLRP, n.706 = CIL I, 2.673 = X3774) of 112/111 BC and to a '*murum coniungendum et pilam faciendam et teatrum / terra exaggerandum locavere*' (*ILLRP*, 708) of 108 BC. From this it emerges that the piles are in fact connected with building within the city, serving as buttressing pilasters (Frederiksen, 1984: app., 281).

As for the structure to which the inscription of Carthago Nova refers, everything points to its being a building used for religious purposes, which is to be identified among the constructions built between the late-2nd and early-1st century BC, probably in that part of the city where there was a pronounced slope and where (perhaps) the theatre was later built in the time of Augustus. The inscriptions of Capua, it is to be remembered, refer to cult sites and indicate that the work being done was intended to provide a venue for spectacles. They mention an imposing curved wall with concrete foundations and buttresses so it could contain the large volume of earth that had been amassed (in all likelihood) for the *cavea*. Examples can be seen in the 'sanctuary-theatres' of the late Republic: Tibur (*Hercules victor*), Gabii, Praeneste, Teanum, Pietrabbondante, Fregellae and elsewhere. This architectural format of a structure connected to a theatre-shaped sacred building ('Roman theatre-temples') was particularly widespread in the late Republic, especially in the regions of Latium and Campania-Samnium whence derived the dedicants listed in the inscription of Carthago Nova (Hanson, 1959; Tagliamonte, 2007: 54ff.).

On the basis of analogy with what was believed to be the case at Carthago Nova, it has been suggested that a concrete mole built on piles to protect the harbour of Tarraco should be dated to the end of the 2nd century BC (Domingo *et al*., 2004: 119–20). It is now no longer possible to inspect the material evidence, but following the arguments above such a date is no longer tenable. At Ampurias, exiguous remains of a composition hard to determine (concrete or natural conglomerate?) have been identified in the sea (Nieto and Raurich, 1998).

Why was pozzolana transported so far?

The research done by the ROMACONS project has provided information on the materials used, which is linked to questions whose significance justifies and goes beyond the technical results. Aside from the Phlegrean region, where its use was widespread, we now know not only that this technique of pouring concrete under water was employed in the neighbouring areas (Ponza, Circeii, Antium, Astura, Portus, Cetara, Punta Licosa, Sapri and of course Cosa and Santa Liberata) (Gianfrotta, 2002: 72ff.; Benini, 2006; Felici, 2006; Scognamiglio, 2008), but also that it was exported to distant places, sometimes together with specific materials and expertise. Such was the case with the *pulvis puteolanus* used in the immense harbour of Caesarea Maritima, in Judaea, which king Herod the Great built between 22 and 9/8 BC (between 22 and 15 BC (Votruba, 2007: 325) or between 22/21 and 12/9, Branton and Oleson, 1992; Raban, 1998). The first notice about the use of similar materials for the moles of the harbour of Chersonesos in Crete forces us to rethink whether the case of Caesarea was as exceptional as it once seemed.

Initially the presence of *pulvis puteolanus* at Caesarea was surprising and seemed 'odd' from an economic viewpoint, since there were other solutions possible. A convincing explanation for its use can be found if it is remembered that its characteristics assure the best possible result. Craftsmen specializing in the new technique could be expected to work best if they operated according to their experience. In other words, best results were to be had from a respect for the materials and methods which had already been tested. Substitution of a similar material for the *pulvis puteolanus*

would have necessitated relying on local experience, which probably did not exist, and the inability to exercise complete control over the effects of a process that was delicate, slow, and costly. Flavius Josephus, it is worth noting, highlights both the absence of local resources and the immense expense involved in the construction of the harbour of Caesarea (*AJ* XV, 332).

As far as expense is concerned, moreover, we have already had occasion to remark that long-distance transportation cost less if performed by returning grain-ships, which often made the voyage back to Alexandria without cargo for that half of the route (Plinius, *Panegyr.* 31, 4; Gianfrotta, 1996: 75f.; Hohlfelder, 1999: 158f.). New information has recently been forthcoming regarding the nature and quantity of materials imported—*pulvis puteolanus*, wood for the forms, and stones for the conglomerate. These stones were medium-sized, came from various areas, and were picked with a view to their eventual function. The amount of pozzolana used must have been *c*.24,000 m^3 (*c*.52,000 tons) (Hohlfelder *et al*., 2007: 414). As for the wood, some 8 or 9 species, from the central and northern Mediterranean, have been recognized and it is estimated that some 11,400 m^3 (*c*.6000 tons) of wood were transported overall (Votruba, 2007: 328–9).

The quantity of material involved is impressive, especially in the case of the pozzolana. A noteworthy amount of material might readily be transported through the use of *naves annonariae*, which were available since they served routes otherwise left uncovered. Documentation is lacking, but it is likely that something similar occurred when the harbour was systematized, together with a vast project of urban design at Jol-Caesarea in Mauretania, which was another extensive vassal-kingdom (Reddé, 1986: 244ff.). There, too, use was made of the new technique and expertise that came at least in part from Italy (as was the case with the main marble monuments from Luna, Gianfrotta, 2008b: 84f.).

There are close parallels between the two Caesareas. Herod the Great and Juba II were *reges socii et amici populi Romani*, client-kings whose privileged position meant that they did not pay tribute to the Roman state, but implicitly required that they spend money in their own kingdoms and in friendly cities, especially on public works which reproduced Roman models (Gabba, 1979; 1980: 99). Herod did this on an ample scale, both within and without Judaea. Aside from his projects at Caesarea, he created imposing works in Syria, Lebanon, Libya, Rhodes, and Greece (Fl. Joseph., *B.J.* I, 21, 11–12; see also Gleason, 1996). Josephus adds that he sometimes even went so far as to send grain to those requesting it (*B.J.* I, 21, 11, 424f.). This information is to be linked to the never-ending need to have grain reserves available for dealing with potential shortages, which were due in part to unfavourable winds and made worse by the high customs duties levied by the ports of Joppe and Dor (thus did he resolve the problem of the coast's lack of good ports, which was aggravated by the Libyan wind, Fl. Joseph., *B.J.* I 409; Beebe, 1983: 204; Hohlfelder, 2000). The immense size of the new harbour at Caesarea can be justified in part by its role in the provision of grain. Serving also military needs, the harbour was a part of the overall supply and fiscal strategy making up the Augustan renewal of commerce with the East (aside from copper from Cyprus and the customs dues levied on goods from the Far East, Judaean exports (balsam, glass, cosmetics, porphyry) were of noteworthy significance).

As regards models for Herod's public works, especially the harbour, his many visits to Rome gave him abundant opportunity to see monuments there, as well as probably discussing them with both Octavian and Agrippa. Octavian, it will be remembered, dealt with a dire food-supply crisis in the capital in 23 BC, and assumed oversight of the *annona* in the following year (Dio LIV, 1, 3–4). Moreover, he saved Palestine from famine by allowing Herod to buy grain in Egypt and by facilitating its transport by sea between 24 and 21 BC (Fl. Joseph., *A.J.* XV, 305–7; Roddaz, 1984, 451ff.). But even more significant is the fact that Herod met Agrippa at Mytilene in 23 BC (*A.J.* XV, 251). Significantly, Agrippa had recently been engaged in constructing near Puteoli the new Portus Iulius, which was much admired by contemporaries (in his *laudes Italiae* (*Georg*. II, 161–4) Virgil refers clearly to this and the '*addita claustra*'; for the underwater remains, see Gianfrotta, 1993 and 1996; Scognamiglio, 2009).

In order to reach Rome, Herod had travelled by sea despite the risks involved. On occasion he made landfall at Brundisium (in 40, for example, when he came to receive his kingdom), and at other times he almost certainly used the port of Puteoli, which was perhaps still growing at the time of his first voyage as king (between 23 and 18/17 BC). In the Augustan reorganization of the *annona* system, the ability of the harbour of Puteoli efficiently to accommodate shipping arriving from Egypt was fundamental. Portus Iulius, which had been established 15 years previously near to Puteoli, became the hub of this system, going from military to commercial use (Fig. 1). The whole coastline of that region witnessed a concrete building boom. There were even private proprietors who vied with each other in ostentatious display. Even official documents offer a vivid glimpse of the shock and moral outrage aroused by the rush to construct luxurious maritime villas (Hor., *Carmina* II, 18, 20–22; III, 1, 33–7; III, 24, 1–4; Verg., *Aen.*, 9, 710–16; Sen, *Contr.* 2, 1, 13; *De ira* 1, 21, 1). This is also true for the creation of fish-ponds (Conta, 1972).

During this period, Herod's children by his second wife were educated at Rome, probably entrusted to the care of Vedius Pollio (Syme, 1961: 30; Gleason, 1996: 227; Roller, 1998; D'Arms, 2003: 217), who reckoned among his properties the famous Pausylipon villa situated on the Neapolitan coast near the Phlegrean Fields. Aside from its renowned fish-ponds, this villa

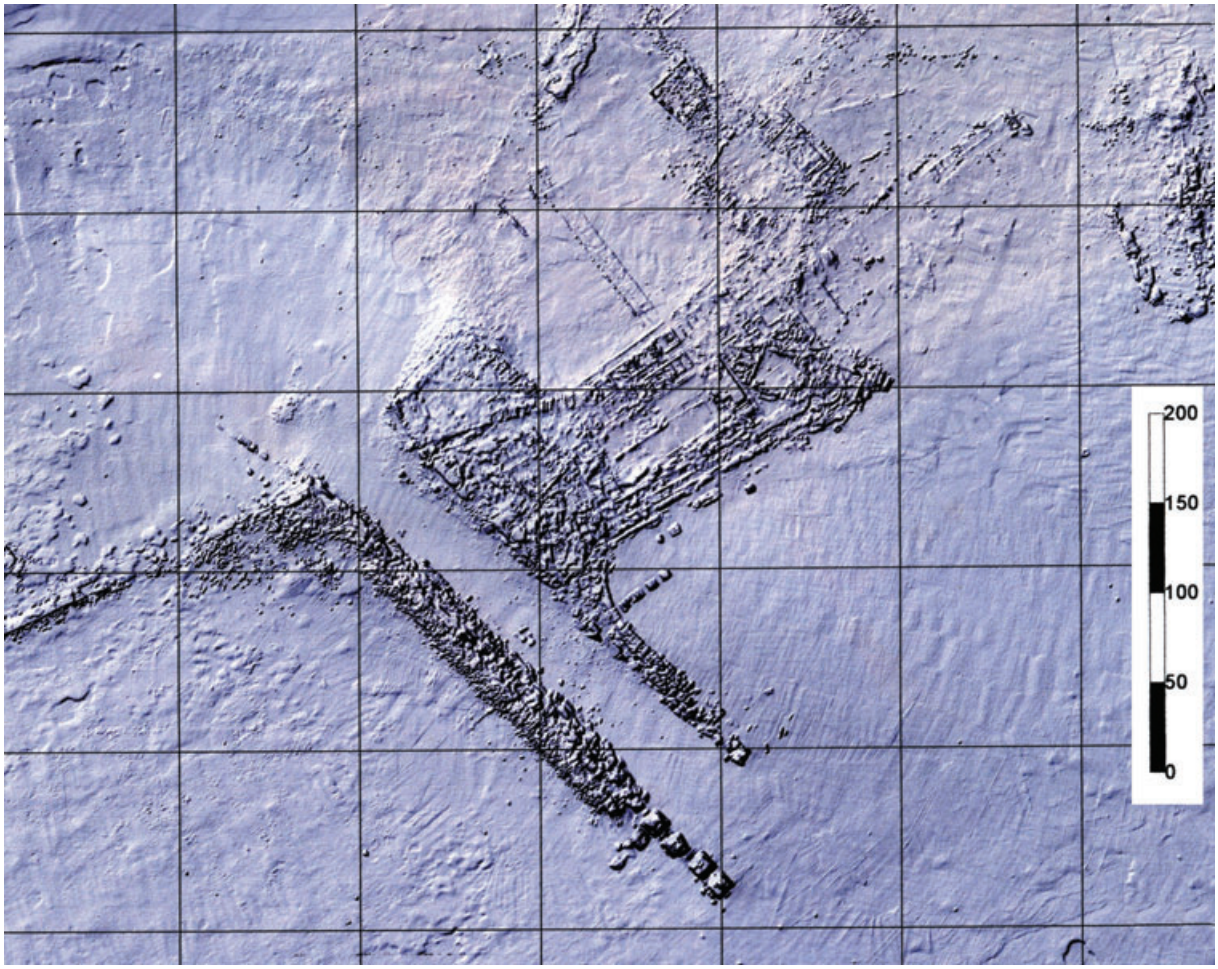

Figure 1. Sunken remains of Portus Iulius, detected with multibeam sonar. (courtesy of Teknomar)

had a maritime concrete structure, a mole and some piles which are today under water, but can be seen in aerial photographs near the islet of Gaiola (Pagano, 1984: 246; Felici, 2006: 77; very close, on the Nisida side, stood even more substantial moles supported by piles, Gianfrotta, 1996: 68ff.; Gianfrotta, 1998: 154ff.; Severino, 2005).

Caesarea Maritima therefore, more or less contemporary with the ports near the Phlegrean Fields, was created through an impressive transfer of technology and materials. With a surface area of 100,000 m^2, it was one of the first large Roman ports, if not in fact the largest then existing. However, while the return-voyages of the grain transports provide an economically rational explanation for the transportation of pozzolana to Caesarea, the increase in archaeological evidence from other areas raises further questions.

Far-flung examples of pozzolana use

In the case of the northern coast of Crete (Oleson *et al*., 2004b: 206), study of the concrete conglomerate in the moles of the small port of Chersonesos has revealed the presence not only of pozzolana but of pumices whose geological characteristics point to their deriving from Italy (Brandon *et al*., 2005: 28–9, 'the key raw material for the concrete was imported from the Bay of Naples'). Even in the case of Chersonesos, however, the explanation is to be found in political and economic circumstances which are well documented. There were strong maritime links and routes uniting Crete with Capua (just inland from the Phlegrean coast, the source of pozzolana). At the time of Augustus, ownership of part of Cretan territory in the area of Knossos had been attributed to the Capuans (*CIL* X 3938 = *ILS* 6317). That overseas possession annually produced goods said to be worth at least HS 1,200,000 (Vell., II, 81.2; Dio, XLIX, 14.5). These products included wine from the mountains of Lyttos, near Knossos, which was exported in 'Cretan' amphoras throughout the whole of the Mediterranean, but is noteworthy for the massive quantities which arrived in Campania as well as at Rome and elsewhere in Italy (Zevi, 1989: 11–12; Marangou and Lerat, 1995). One of these amphoras, found in fragmentary condition at Santa Maria Capua Vetere, has on its exterior a

Figure 2. S. Maria Capua Vetere, Cretan amphora. (after De Caro 1992–3)

painted inscription documenting that it was a part of the produce of this territory: '(οινου) επιτυγχανοντος / (των) Καμπανων, (τα κεραμια) βου' (belonging to the wine of the Campanians, 472 amphoras) (De Caro, 1993: 307 ff.; for commerce between Crete and Campania see Tchernia, 2008: 61ff.) (Fig. 2).

The port of Chersonesos is not far from Knossos. Indeed, its structures were probably augmented during the reign of Augustus, perhaps at the same time as others in the area, to accommodate the increase in maritime trade. Therefore, it is plausible that *pulvis puteolanus* was transported during numerous voyages from Campania to Crete in the initial phase of this new relationship with Capua. The quantities involved, however, were far less than those at Caesarea, for the port of Chersonesos had rather modest dimensions (270 × 150 m). When the need arose, the northern side of the island could be used for the return voyages. On the other hand, from the moment the summer Etesian winds began, the island was approached by the Alexandrian ships, and probably more than one port of call was used for the long journey from Alexandria to Italy (Arnaud, 2005: 56–7, 212ff., 222; St Paul's voyage to Rome by means of an Alexandrian ship is an excellent example (*Acta Ap.* 27, 7–15); the immense *Isis* described by Lucian (*Navigium*, 9) would likewise have passed close to Crete, if it had not ended in shipwreck).

Conclusion

It is clear, therefore, that the transport of pozzolana was part of a wider system of trade and transport, and of personal networking. Further work by the ROMACONS project will almost certainly offer far more that the analysis of materials and construction methods, and shed further light on a range of aspects of political and social history within the Roman empire.

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