Roman ports and Mediterranean connectivity

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INTRODUCTION

This paper examines several interrelated aspects of maritime connectivity within the Roman Mediterranean. First, it considers Fulford's suggestion of a divide between eastern and western trading zones along the north African coast in the light of new evidence discovered in the twenty years since he wrote; second, it considers the glass industry as a case-study illustrating the geographical integration of the Roman economy through maritime networks between ports; and third, it examines how port structures, capacities and facilities might relate to the patterns of maritime trade in antiquity.

AN EAST–WEST DIVIDE IN NORTH AFRICAN MARITIME TRADE?

In two seminal papers in the late 1980s, Fulford drew attention to the high degree of economic interdependence between cities of the Roman Mediterranean that was suggested by quantified and provenanced analysis of the ceramic assemblages at several port sites, chiefly Carthage, Berenice (Benghazi) and Ostia (Fulford 1987; 1989). At these sites, between 20% and 40% of the pottery was imported from outside the local region or province during the first to fourth centuries AD; and at Ostia the proportion of imports rose sharply during the second century from 20% to over 85%. Fulford argued that the pottery assemblage might be representative of general trading patterns in other, perishable, goods and therefore could be used to provide a rough picture of trading connections. In his 1989 paper he pursued this approach further, looking at the different patterns of connections exhibited by ports along the north African coast to the west and east of the Gulf of Sirte. Carthage, to the west, looked mainly to Italy for its imports; so (with a smaller sample size) did Sabratha; Cyrenaica to the east (represented by Berenice) looked to Crete and the Aegean, with some imports from Italy. But there seems to have been relatively little traffic east–west along the north African shoreline, as — he argued — north African imported amphorae at Berenice are of minor significance in the assemblage there. Fulford explained the marked differences between the import patterns of Africa Proconsularis and Tripolitania, on the one hand, and Cyrenaica, on the other, by a combination of currents, prevailing winds and the treacherous waters of the Gulf of Sirte.

Despite the enormous potential of the comparison of port ceramic assemblages to which Fulford drew attention, twenty years further on relatively little has changed. Although new fieldwork has been done at several ports between Carthage and Berenice that might help fill out the picture — for example Leptiminus, Meninx, Lepcis Magna —, only the amphora assemblage from Meninx is published so far in a quantified form that enables such comparative analysis (Fontana, Ben Tahar and Capelli 2009). New data are becoming available for some ports in other regions, but for north Africa we are still reliant on the reports for Carthage, Sabratha, Berenice and now Meninx. Moreover, Fulford's 1987 comparisons aggregated the sherd counts for fine-wares, coarse-/cooking-wares and amphorae, although we might suspect that the distribution of these categories need not respond to the same economic logic; disaggregation of the figures by ceramic category (below) enables more detailed patterns to be detected.

CYRENAICA AND THE ADRIATIC

In some respects, the picture sketched by Fulford still seems to hold good some two decades later, and has even been reinforced by new evidence. His picture of Cyrenaica's northward links was based on

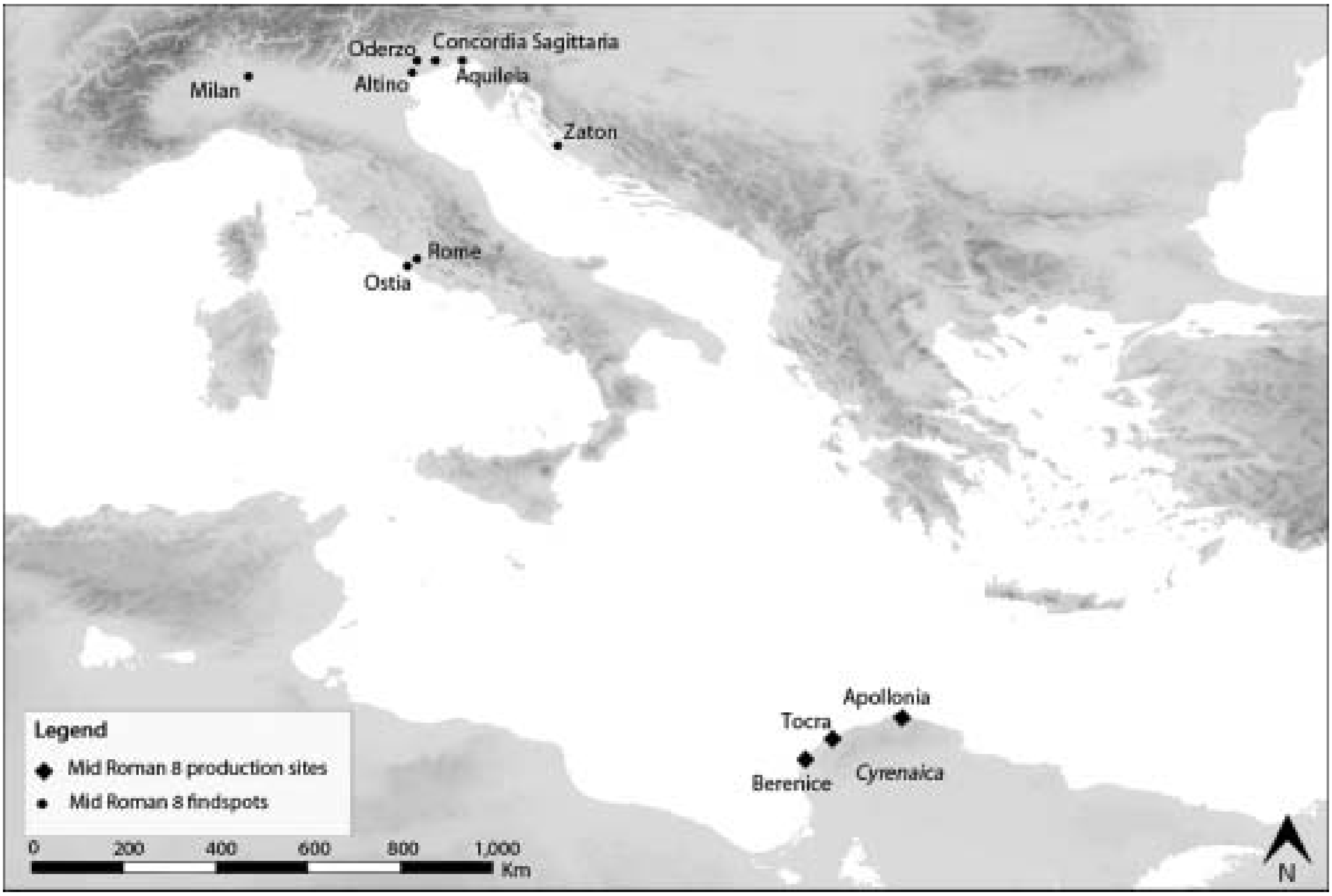

FIG. 20.1. **Distribution of Cyrenaican Mid Roman 8 amphorae.** *(A. Wilson/K. Schörle.)*

imports alone, but since he wrote we can now distinguish one Roman-period type of Cyrenaican amphora — and one only — that seems to have been exported outside Cyrenaica, albeit in limited quantities, and its distribution supports his view that Cyrenaica traded primarily with regions to the north rather than to the west. Riley's Mid Roman 8 amphora was produced during the first half of the third century AD in at least three of the Cyrenaican port cities — Berenice (Benghazi), Taucheira (Tocra) and Apollonia (Marsa Souza).[1] On grounds of morphology, with its wide mouth, the Mid Roman 8 is probably to be seen as an olive-oil amphora, although it could have carried salted fish — no residue tests have been performed yet. The limited distribution of this type includes the expected sites of Ostia and Rome, of course, but is otherwise confined to the Adriatic and northern Italy — it is found at Aquileia, at Milan, and at Altino, Oderzo and Concordia Sagittaria in the Veneto region, and also at Zaton near Zadar in Dalmatia (Fig. 20.1).[2] The export of Cyrenaican olive oil to the Adriatic is confirmed in fact by a passage of the late second-/early third-century jurist Scaevola in the *Digest* (19.2.61.1), broadly contemporary with the period of Mid Roman 8 amphora production, which refers to a contract for shipping 3,000 *metretai* of olive oil and 8,000 *modii* of wheat from Cyrenaica to Aquileia. This suggests some north–south axis of trade between Cyrenaica and the Adriatic, although Cyrenaica had other links as well, to which we shall return. Although the Cyrenaican exports are not well recognized yet and their distribution elsewhere may be under-reported, the scale of exports from Cyrenaica was limited by comparison with, for example, olive-oil exports from Tripolitania, which may suggest differences also in the intensity between eastern and western connections from these two regions.

RETURN CARGOES: DISTRIBUTION OF BRICKS AND BUILDING MATERIALS

The distribution of Italian stamped bricks also supports the idea of a closer relationship between Italy and Africa west of the Gulf of Sirte than between Italy

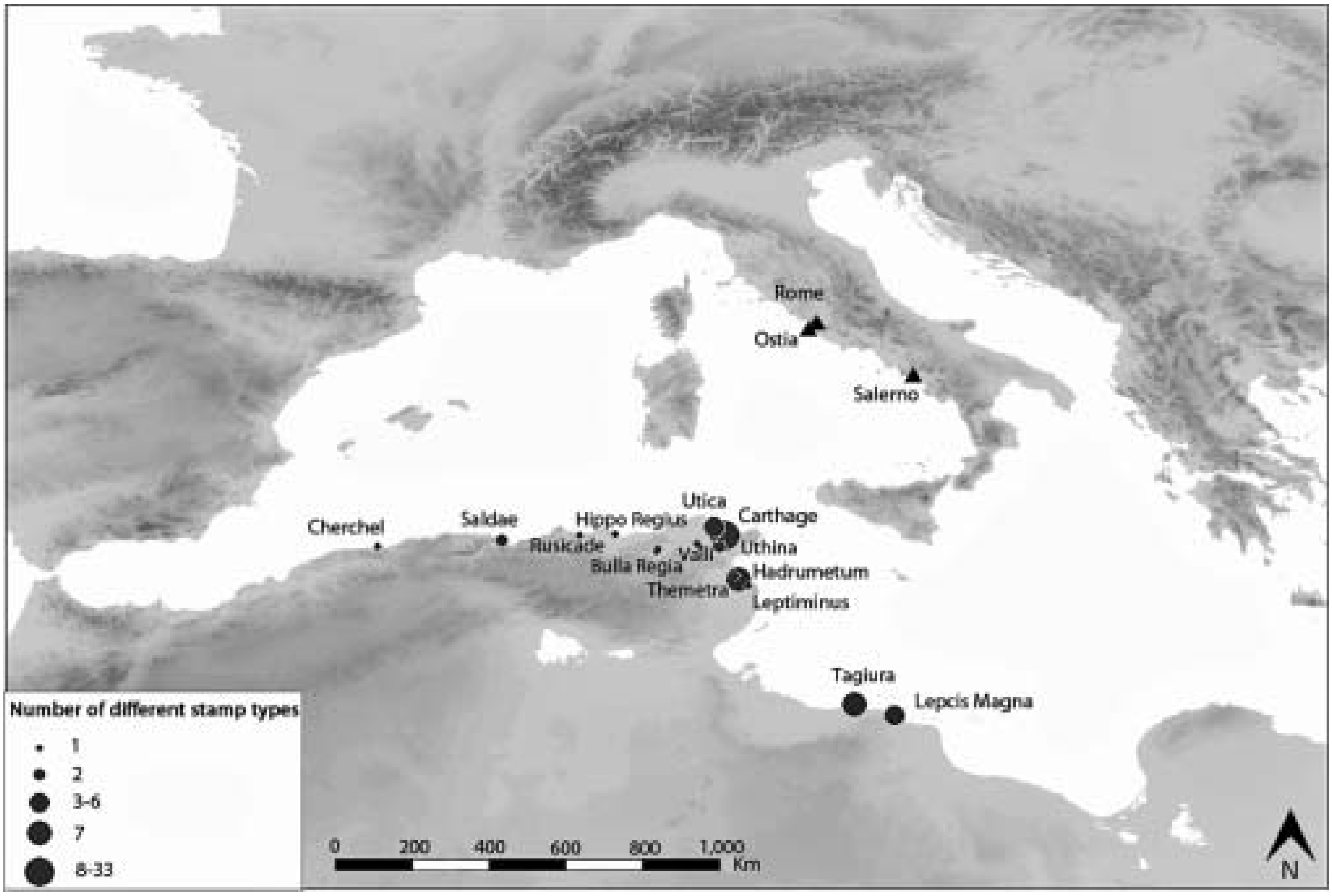

FIG. 20.2. **Distribution of Italian stamped bricks in north Africa.** *(A. Wilson/K. Schörle.)*

and Cyrenaica (**Fig. 20.2**).[3] Bricks whose stamps identify them as products of Rome or the Tiber valley are found at most major north African ports between Cherchel and Lepcis Magna, but not further east. These are interpreted as return cargoes carried on ships that had sailed from Africa to Portus with exports of grain, olive oil and fish products, for example. Most of the Italian bricks at these sites are found in bath-houses or related large reservoir cisterns; we do not know whether they arrived as products sold on the open market or as specially commissioned loads because a magistrate involved in the construction of a bath-house at a north African town had lands in Italy, or had a close connection with a landowner with a brickworks there. Either way, it does not affect our model; the important point is that the export trade from Africa Proconsularis to Portus/Rome subsidized the return carriage of bulk cheap goods in a way that the trade between, for example, Cyrenaica and Rome could not. The same point can be made for Campania; bricks of T. Claudius Felix, a Campanian producer with *figlinae* at Salerno, are found at Hippo Regius, Leptiminus and Thapsus (Wilson 2001a). The baths at Leptiminus also used imported pumice from Pantelleria (Lancaster *et al.* 2010), presumably picked up on a return voyage from Italy or Sicily. But while Italian bricks are found also in Sardinia and southern Gaul (Parker 2008), at a few ports around the mouth of the Rhône, they are not found in Cyrenaica, or anywhere else in the eastern Mediterranean.

Fulford's model of the separation of trade to east and west applies principally to communications along the southern shore of the Mediterranean, because of winds and currents. Of course, there were trading connections between the eastern and western basins of the Mediterranean, but much of this took more northerly routes, between the Aegean and southern Italy rather than along the African coast. The *annona* traffic between Alexandria and Rome took routes up the Levantine coast via Cyprus and southern Turkey, then across to Italy, often returning by a more direct open-water route (cf. Arnaud 2007). Trace element analysis has shown that the concrete breakwaters of Herod's harbour at Caesarea Maritima in Judaea were built with *pozzolana* imported from the bay of Naples, presumably as part of Roman technical assistance to its client king (Oleson and Brandon 1992: 56–60). The export of the large quantities of *pozzolana* necessary would have been greatly facilitated by the fact that the Alexandrian grain ships of several hundred tons' burden returning from Puteoli (since they could not dock at Portus, which had not yet been constructed at this date) would have had vast amounts of spare cargo capacity and, indeed, the need for some kind of return cargo if they were not to make the return voyage in ballast. *Pozzolana* from the Puteoli region has been identified in harbour works at Chersonesos on Crete also, presumably another of these targeted shipments for a particular project facilitated by the grain fleet's need for return cargoes (Hohlfelder 1999: 158–9; Votruba 2007: 326–7). But it is likely that there was also a trade in *pozzolana* outside these routes — in addition to its main cargo of Italian wine amphorae, the Madrague de Giens wreck (*c.* 60–50 BC) was carrying a complementary cargo of volcanic sand (Liou and Pomey 1985: 562) that may have been intended for sale, perhaps for use in a harbour construction project, rather than simply as ballast.

EAST–WEST CONNECTIONS ALONG THE NORTH AFRICAN COAST

POTTERY ASSEMBLAGES AT MAJOR PORTS

But if these data largely seem to support Fulford's view of a divide in exports between east and west, there are some new complicating factors that point to a level of trade along the north African coastline.[4] The first is provided by the recent excavations at Euesperides, the predecessor to the site of Berenice (Sidi Khrebish, Benghazi), which provided one of Fulford's key datasets. Here, the quantification of the early Hellenistic pottery (325–250 BC) indicates considerable east–west trade across the Gulf of Sirte, between Hellenistic Cyrenaica and Punic north Africa. Of the cooking wares, *c.* 35% are imported, and 15% of the total are Punic imports from what is now Tunisia or Tripolitania (Wilson 2005; Swift 2006; Wilson forthcoming). Punic amphorae constitute about 5% of the total amphora assemblage (Göransson 2007). Moreover, Cyrenaican amphorae can now be recognized in the published material from Punic levels at Sabratha. This might be taken to indicate that the physical discouragements to east–west trade along the African coast — winds, currents, the lethal shallows of the Gulf of Sirte — have been overstated, and that if any east–west divide existed in the Roman period it was not so much determined by sailing conditions as by different cultural or economic factors.

Indeed, Kenrick's analysis of the fine-wares at Berenice casts some doubt on the notion of an east–west divide for the Roman period as well (Kenrick 1985; 1987). To deal with problems of residuality, his figures relate not to particular assemblages, some of which were highly residual, but to datable forms, which were then aggregated within broad periods (Table 20.1). At Berenice, in the early Imperial period, from *c.* 25 BC to *c.* AD 100, some 60% of imported fine-ware (by sherd count) was Italian *terra sigillata* (ITS) (including the Campanian production once referred to as Tripolitanian *sigillata*); apart from a further 1% Campanian black gloss and less than 1% South Gaulish wares, the remainder is from the eastern Mediterranean. By the early second century AD, the Italian contribution has shrunk to 13%, and 55% is now accounted for by African red slip ware (ARS); by the third century ARS dominates the assemblage to the virtual exclusion of everything else. Fulford suggested that perhaps the ARS came to Berenice 'through established networks in the Aegean area' (Fulford 1989: 180); however, if this were the case, we might expect to find considerably more Aegean fine-wares. Moreover, if one wanted to argue for an indirect source, one might prefer the idea of redistribution back from major Italian emporia such as Portus or Puteoli.[5] However, we certainly cannot rule out some

TABLE 20.1. Quantification by period of the fine-wares from Berenice (Benghazi). Total sherds per period: 25 BC–AD 100: 3,824; second century AD: 1,574; early third century AD: 3,811. Based on the data provided by Kenrick (1985; 1987).

	ITS	ESA	ESB	ARS	Çandarli ware	Misc.	Total
25 BC–AD 100	61%	27%	3%	0%	1%	8%	100%
Second century AD	13%	2%	14%	55%	11%	5%	100%
Early third century AD	0%	0%	0%	98%	0%	2%	100%

TABLE 20.2. Quantification by period of the amphorae from Berenice (Benghazi). Total sherds per period: Augustan: 101; early to mid-first century AD: 154; mid- to late first century AD: 481; early to mid-second century AD: 556; late second century AD: 148; early third century AD: 615; late third century AD: 613. Based on the data provided by Riley (1979: 402–42).

	Local	Italian	Spanish	North African	Aegean	Misc. imports	Total
Augustan	31%	6%	0%	5%	4%	54%	100%
Early to mid-first century AD	7%	9%	0%	1%	12%	71%	100%
Mid- to late first century AD	11%	5%	2%	2%	10%	70%	100%
Early to mid-second century AD	13%	2%	2%	3%	24%	56%	100%
Late second century AD	8%	0%	1%	6%	21%	64%	100%
Early third century AD	5%	2%	0%	8%	41%	44%	100%
Late third century AD	7%	0%	0%	12%	26%	55%	100%

more direct contact between Tripolitania and Cyrenaica of the sort that appears to be attested for the third century BC at Euesperides.

The amphorae, which formed a major part of Fulford's argument, tell a less clear-cut story, as between 44% and 70% in any one period are largely unidentified imports, thus potentially masking other trends (Table 20.2). Moreover, Riley's quantified tabulation of them by period does not attempt to deal with the problems of residuality highlighted by Kenrick for the fine-wares, although they come from the same contexts (Riley 1979: 402–42). Nevertheless, they suggest an increasing reliance on imports over local production, with Aegean imports growing over time to reach 41% by the early third century; the early Italian contribution is perhaps replaced by examples from north Africa, but these only achieve 6–8% in the late second/early third century. The proportions of Aegean to African amphorae are now the opposite of those for the fine-wares.

The pottery from the Circular Harbour at Carthage also shows clear differences in the composition of the amphora and fine-ware assemblages (Tables 20.3 and 20.4) (Fulford 1994). These were analysed by phased contexts, not by datable sherds as Kenrick did for Berenice, and residuality is clearly a problem, as shown by the high percentages of Republican black-gloss wares in contexts of the first and second centuries AD. In an attempt to lessen this effect, several contexts that clearly contained a superabundance of residual material have been removed from consideration.[6] In the late first century BC, Italian fine-ware is dominant, followed by Eastern *sigillata* A (ESA) (with 30%); thereafter ESA dropped out and ARS became progressively more important (Table 20.3). Its apparent failure to reach the dominant levels seen at Berenice is probably a result of the highly residual nature of the contexts examined (note residual Punic, black-gloss, thin-walled and probably residual ITS accounting in total for almost half of the second-century figures).

By contrast the amphorae are overwhelmingly African at all periods (Table 20.4) — though this is likely to include imports from all along the Tunisian coast —, but with 7% identifiable Italian imports in the late first century BC and the first/early second century AD, and 10% Spanish in the period AD 1–125. The sample size for the amphorae is very large, but

TABLE 20.3. Quantification by period of the fine-wares from the Circular Harbour at Carthage. Total sherds per period: first century BC: 906; AD 1–125: 428; AD 125–200: 1,378. Based on the data provided by Fulford (1994).

	Black gloss	ITS	ESA	ARS	Black gloss unknown	Thin walled ware	Punic	Misc.	Total
First century BC	25%	2%	30%	0%	40%	1%	1%	1%	100%
AD 1–125	4%	49%	0%	10%	14%	14%	0%	9%	100%
AD 125–200	0%	20%	0%	43%	17%	5%	4%	11%	100%

TABLE 20.4. Quantification by period of the amphorae from the Circular Harbour at Carthage. Total sherds per period: first century BC: 73,195; AD 1–125: 13,937; AD 125–200: 11,122. Based on the data provided by Fulford (1994).

	Italian	Spanish	North African	Misc. imports	Total
First century BC	7%	1%	81%	11%	100%
AD 1–125	7%	10%	74%	9%	100%
AD 125–200	0%	0%	81%	19%	100%

likely to suffer from the same problems of residuality identified for the fine-wares, making it difficult to draw detailed conclusions. What is clear, though, is that fine-ware distribution was driven by different economic considerations from that of amphora-borne commodities. This casts some doubt on the degree to which either type of pottery distribution on its own — or even both together — can be used as a simple proxy of trading connections.

The recently published data from excavations at Meninx again show that the amphora assemblage there is dominated by African amphorae, mostly locally produced (Table 20.5).[7] The imports are predominantly western rather than eastern. In the second and first centuries BC, 30% of the amphorae are imports, mainly from Italy; imports drop to under 25% in the first century AD, although are still dominated by Italian material, and then to a maximum of 9% in the early second century, and a maximum of *c.* 10% in the later second to mid-fourth centuries. There is uncertainty over the provenance of the Benghazi Mid Roman 1 amphorae in the sample; production sites are attested on the Tunisian coast, for example at Thaenae, but fabric analysis of samples in the assemblage suggests that the examples found at Meninx were produced in Sicily. Only three sherds from the Aegean region are present in the second- to fourth-century assemblages. The overall picture for Meninx must be seen against a general pattern of declining imports of amphora-borne goods to the island of Jerba as the region developed its own export-oriented production of wine and olive oil; but its overseas links clearly were mainly with Italy and the central Mediterranean, and not with the east.

The amphorae from the Terme del Nuotatore at Ostia show a wide variety of sources (Table 20.6).[8] Initially substantial contributions from Italy and Spain shrank after the middle of the second century, to be replaced by greater imports from first Gaul (24% in the early second century) and then north Africa (38% in the mid- to late second century), and then the Aegean (41% in the early third century), with Africa in second rank at 30%. The prevalence of north African imports (55%) is shown also in the late third- to late fourth-century destruction level.

We do not have the fine-ware quantification for these deposits, and are not told anything about residuality; but it is interesting to note that there were more Aegean than African amphorae in the century when ARS exports peaked.

More recent amphora evidence from the Deutsches Archäologisches Institut–American Academy in Rome (DAI–AAR) excavations at Ostia complements and enhances the picture.[9] As in the Terme del Nuotatore, Spanish and Italian products dominate the assemblage between AD 50 and 100. The second century varies between the two excavation areas; whereas Gallic and Spanish amphorae are present in relatively similar quantities from the Terme del Nuotatore, Spanish amphorae solidly dominate the assemblage from the DAI–AAR excavations (44% of the amphorae). Mid-second to mid-third-century levels

TABLE 20.5. Quantification by period of the amphorae from the excavations at Meninx, Jerba. Total sherds per period: 150–1 BC: 40; AD 1–100: 111; AD 100–50: 146; AD 150–350: 108. Based on the data provided by Fontana and his colleagues (2009: tables 16.15, 16.18 and 16.19).

	Italian	Spanish	Sicilian?	North African	Aegean	Total
150–1 BC	27%	0%	0%	70%	3%	100%
AD 1–100	18%	3%	3%	76%	0%	100%
AD 100–150	3%	1%	3%	92%	1%	100%
AD 150–350	0%	0%	6%	91%	3%	100%

TABLE 20.6. Quantification by period of the amphorae from Ostia, Terme del Nuotatore. Total sherds per period: AD 80–90: 430; AD 90–155/60: 419; AD 155/60–190: 379; AD 190–235/40: 2,228; late third century to late fourth century AD: 1,129. Based on the data provided in: Carandini and Panella 1973: 463–619; Carandini and Panella 1977: 116–262, 359–83.

	Italian	Gallic	Spanish	North African	Aegean	Misc. imports	Total
AD 80–90	23%	16%	25%	7%	2%	27%	100%
AD 90–155/60	12%	24%	21%	9%	6%	28%	100%
AD 155/60–90	5%	12%	12%	38%	15%	18%	100%
AD 190–235/40	3%	10%	4%	30%	41%	12%	100%
Late third century AD to late fourth century AD	6%	7%	6%	55%	20%	6%	100%

were absent from the DAI–AAR excavations, missing the peak in Aegean amphorae visible in the baths. The DAI–AAR excavations have produced more substantial evidence on the later levels at Ostia. From AD 280 onwards, north African imports dominate (50% of imports AD 280–300; 61% AD 350–475). Eastern Mediterranean amphorae do, however, account for 64% and 55% of all wine amphorae respectively in these two phases.

CONNECTIONS BETWEEN COMMUNITIES

If elements of the more detailed ceramic analysis, notably the fine-ware analysis from Berenice, undercut the notion of an east–west divide along the north African coast, some other evidence does the same. At Carthage, a group of Greek-speaking worshippers of Sarapis was formed probably of resident Alexandrian merchants. The cult of Sarapis was, of course, of Alexandrian origin, and the worshippers at Carthage appear to have comprised a distinct group of people; the known dedicators all had Greek *cognomina* and the dedicatory inscriptions are either in Greek or bilingual in Greek and Latin (Rives 1995: 212–14). Several dedications show clear Alexandrian connections, most importantly a bust of the Egyptian priest Manetho, who Plutarch says assisted in the foundation of the cult in Alexandria (Plutarch, *De Iside et Osiride* 28). The presence of a group of Alexandrians at Carthage is certainly plausible and even to be expected.

It is possible that a similar situation existed at Lepcis Magna. A group of 30 dedications to Sarapis in Greek (still unpublished) were found inside the temple to Sarapis. These are apparently similar to five inscriptions published in *IRT* (310, 310a, 311, 312, 313), three of which bear the names of men with the Latin *nomen* Aurelios with Greek *cognomina*. Out of the group of 30 unpublished inscriptions, twelve apparently have the *nomen* Aurelios, suggesting a date after Caracalla's grant of universal citizenship in AD 212. Thirteen different dedicators are mentioned in total, but all are reported as having Greek *cognomina* (Brouquier-Reddé 1992: 103).

While monuments to Sarapis are fairly common in north Africa, there are only four cities that have verifiable temples or sanctuaries: Carthage, Sabratha, Lepcis and Lambaesis, with a possible fifth at the port city of Gigthis in southern Tunisia (Kater-Sibbes 1973: 136).[10] Whereas the sanctuaries at Carthage and Lepcis contained Greek dedications, the dedications at Lambaesis, in inland Numidia, are primarily in Latin. Indeed, the presence of Greek inscriptions in north Africa west of Cyrenaica is extremely slight before the Byzantine reconquest of north Africa. The two cities with the greatest concentration of Greek inscriptions are Lepcis Magna and Carthage; other cities that contain more than a few are Oea, Sousse and Cherchel, all major port cities.[11] These communities of Greek speakers, probably merchants, further illustrate east–west trading connections.

Lepcis Magna also may have had resident communities of other groups of merchants; as a former Phoenician colony, the city retained links with its mother-city of Tyre, and dedicated at Tyre a statue personifying that city with a bilingual Greek and Latin inscription at some time between the reign of Trajan and AD 198, possibly close to that later date (Rey-Coquais 1987). In the reign of Septimius Severus, after AD 198, a statue-base was dedicated to Geta in the Forum Vetus at Lepcis Magna by *Septimia Tyros colonia metropolis Phoenices et aliarum civitatium* (*IRT* 437). Whether or not these examples can be taken also to suggest communities of traders at Lepcis and Tyre, they may provide some evidence for continued east–west connective links between two former Phoenician emporia.

Trading communities of residents of other cities are of course known at other large port cities; the Piazzale delle Corporazioni at Ostia provides a very familiar example, but there was also a community of Tyrians at Puteoli, who were having difficulty paying rent on their *statio* in AD 174, perhaps as a result of a decline in their numbers due to the Antonine plague (Mommsen 1843: 57–62; *CIG* III 5853; *IG* XIV 830). Puteoli had also acquired a sanctuary of Sarapis as early as 105 BC, and a temple of Dusares, a Nabataean god, by the mid-first century BC; both cults doubtless were imported by traders from Alexandria and Arabia respectively (Tchernia 1997: 128–9).

MARITIME NETWORKS AND THE INTEGRATION OF THE ROMAN ECONOMY

Such trading communities at major ports suggest regular mercantile connections on established routes, with knowledge about general market demand (if not actual price levels) at distant ports, and sometimes contacts between known trading partners. Direct maritime trading connections between emporia with major port facilities helped enable a considerable degree of geographical integration of the Roman economy, at least as far as the availability of goods in the Mediterranean provinces was concerned. It is less clear that prices for the same commodities in different regions were closely integrated,[12] but it can be shown that the intensity and regularity of maritime export flows affected and even determined the articulation of production in certain goods, which is particularly clear in the glass industry. Primary production of raw glass took place often at a very considerable distance from the centres that transformed that raw glass into vessels; the different stages of production were linked by long-distance maritime trade-routes.

THE ROLE OF MARITIME NETWORKS IN THE ROMAN GLASS INDUSTRY

It is now recognized that, before the widespread (re)-introduction of soda-rich plant ash as an alkali flux in the ninth century AD, the Roman and Byzantine production of blown glass was a two-stage business (Foy and Nenna 2001).[13] The first stage was the primary production of raw glass in large kilns by heating sand with natron as a flux. The principal sources of natron in the whole empire were the Wadi Natrun, south of Alexandria, and the Beheria region of Egypt; Lake Pikrolimni in northern Greece seems to have been the source of what Pliny calls 'Chalestricum' natron, and there may have been some lesser sources elsewhere but they do not seem to have been significant in antiquity (Dotsika *et al.* 2009; Pliny, *Naturalis Historia* 31.46.106–9).[14] Raw glass was produced in slabs weighing perhaps 8–10 tons each, and sometimes up to 25 tons, as in the case of the first- to second-century AD furnace excavated at Beni Salama in the Wadi Natrun, close to the source of the natron flux (Nenna 2007: 127–8). These massive slabs were then smashed up into ingots or chunks of raw glass, which were used by secondary production centres where the raw glass was heated and blown into vessels.

Although secondary production centres (glass-blowing workshops) are found all over the Roman world, there were only a few primary production centres (Table 20.7). Chemical analyses have shown that Roman glass — oddly, and in contrast to glass of earlier and later periods — is remarkably homogeneous in composition, implying a very limited range of geographical sources for the sand used for primary production, located chiefly in the southeastern Mediterranean (Foy and Nenna 2001). Primary production centres have been identified archaeologically in Egypt in the Wadi Natrun for the early Imperial period and to the south of Lake Mareotis for the late Roman period, and in the Levant — for example Bet Eli'ezer in Israel, where a battery of seventeen Byzantine furnaces of the sixth to seventh centuries AD was found (Foy and Nenna 2001: 34–9). Although no early Roman primary furnaces have been found yet in the Levant, most Roman glass has a chemical signature matching the sand from the Syro-Palestinian coast, which was especially well suited to glass-making with a natron flux; this region must have been the overwhelmingly dominant supplier of raw glass for the secondary production centres all over the Roman world (Foy 2003b: 26).

By contrast, chemical analysis suggests that material from the primary production centres in Egypt was not on the whole exported across the Mediterranean, but used at secondary production centres within Egypt (Foy and Nenna 2001: 37). Primary production also seems to be indicated at Carthage by the find of large quantities of raw glass in a cistern reused as a primary furnace (as in the Levant), but the discovery was made by a bulldozer in the 1970s and details are scant; it is

TABLE 20.7. Primary glass production centres.

Site	Country	Date	Reference
Bir Hooker (Wadi Natrun)	Egypt	Early Imperial	Foy and Nenna 2001: 36; Nenna 2003
Zakik (Wadi Natrun)	Egypt	Early Imperial	Foy and Nenna 2001: 36; Nenna 2003
Beni Salama (Wadi Natrun)	Egypt	First–second centuries AD	Foy and Nenna 2001: 35–6; Nenna 2003
Taposiris Magna	Egypt	Late Roman	Foy and Nenna 2001: 34
Philoxénité	Egypt	Fifth–eighth centuries AD	Foy and Nenna 2001: 39
Hermoupolis	Egypt	Eighth–ninth centuries AD	Foy and Nenna 2001: 39
Apollonia/Arsuf	Israel	Late Roman?	Foy and Nenna 2001: 38
Beth Eli'ezer (Hadera)	Israel	Sixth–seventh centuries AD	Foy and Nenna 2001: 37–8; Foy 2003a
Beth She'arim	Israel	Ninth century AD	Foy and Nenna 2001: 38–9
Tyre	Israel	Early medieval	Kingsley 2004: 21
Carthage	Tunisia	Roman or late Roman	Foy 2003c
Hambach (near Cologne)	Germany	Roman	Foy 2003c: 35

assumed to date before *c.* AD 800 (Foy 2003c: 35). If this is the case, it also implies the import of natron to Carthage from Egypt, which would be consistent with the suggestion of Alexandrian merchants at Carthage, and further undercuts the idea of an east–west divide in north African trade. Primary production is also suspected in Italy, Spain and Gaul on the basis of remarks in Pliny (*Naturalis Historia* 36.66), and receives some support from recent chemical analysis of the strontium and neodymium signatures of a number of Roman vessel-glass samples from Maastricht and Bocholtz (Netherlands), Tienen (Belgium) and Kelemantia (Slovakia), which do not match eastern Mediterranean signatures and therefore indicate a source in the western empire (Degryse and Schneider 2008). Chemical analysis has proved production of raw glass also from sands at Cologne in the first and second centuries AD and in the nearby Hambach forest to the west in the third to fifth centuries AD (Fremersdorf 1965–6; Rottländer 1990; Gaitzsch *et al.* 2000; Wedepohl and Baumann 2000).[15] The magnesium and potassium concentrations in glass produced here are too low for potash fluxes and seem to imply the importation of natron to the German provinces (Wedepohl and Baumann 2000: 130). However, no primary furnaces have been located yet elsewhere in the western Mediterranean, and the dominance of chemical signatures typical of Syro-Palestinian glass in most of the Roman glass samples that have been analysed indicates that most of it was produced in the Levant. Such primary production centres as did exist in the west were less important, and shorter-lived, than the Levantine centres that produced the great majority of the empire's raw glass (Foy and Nenna 2001: 37).

Although glass could also be, and was, recycled, the implication of the limited number of primary production centres is that the Roman glass-making industry was massively dependent on the efficient long-distance movement of raw materials: firstly, of the natron flux from Wadi Natrun in Egypt (the main source in antiquity) to the primary production centres in Wadi Natrun, the Levant, and, to a much lesser extent, in the western Mediterranean; and secondly, of the raw glass chunks or ingots from the Levant to nearly all the secondary production centres around the empire (Fig. 20.3). This large, bulk transport of raw glass was essentially a maritime phenomenon.

The maritime transport of raw glass ingots between ports is attested amply in several wrecks dating between the third century BC and the fifth century AD (Table 20.8; Fig. 20.3), such as Les Sanguinaires A and the Jeaune-Garde, Mljet, Bourse, Mellieha, Ognina and Port Vendres 1 shipwrecks; the most substantial glass cargo comes from the Embiez Ouest wreck, which contained at least 18 tons of raw glass ingots (Foy and Nenna 2001: 101–12; Nenna 2007: 131). These are also present in several port

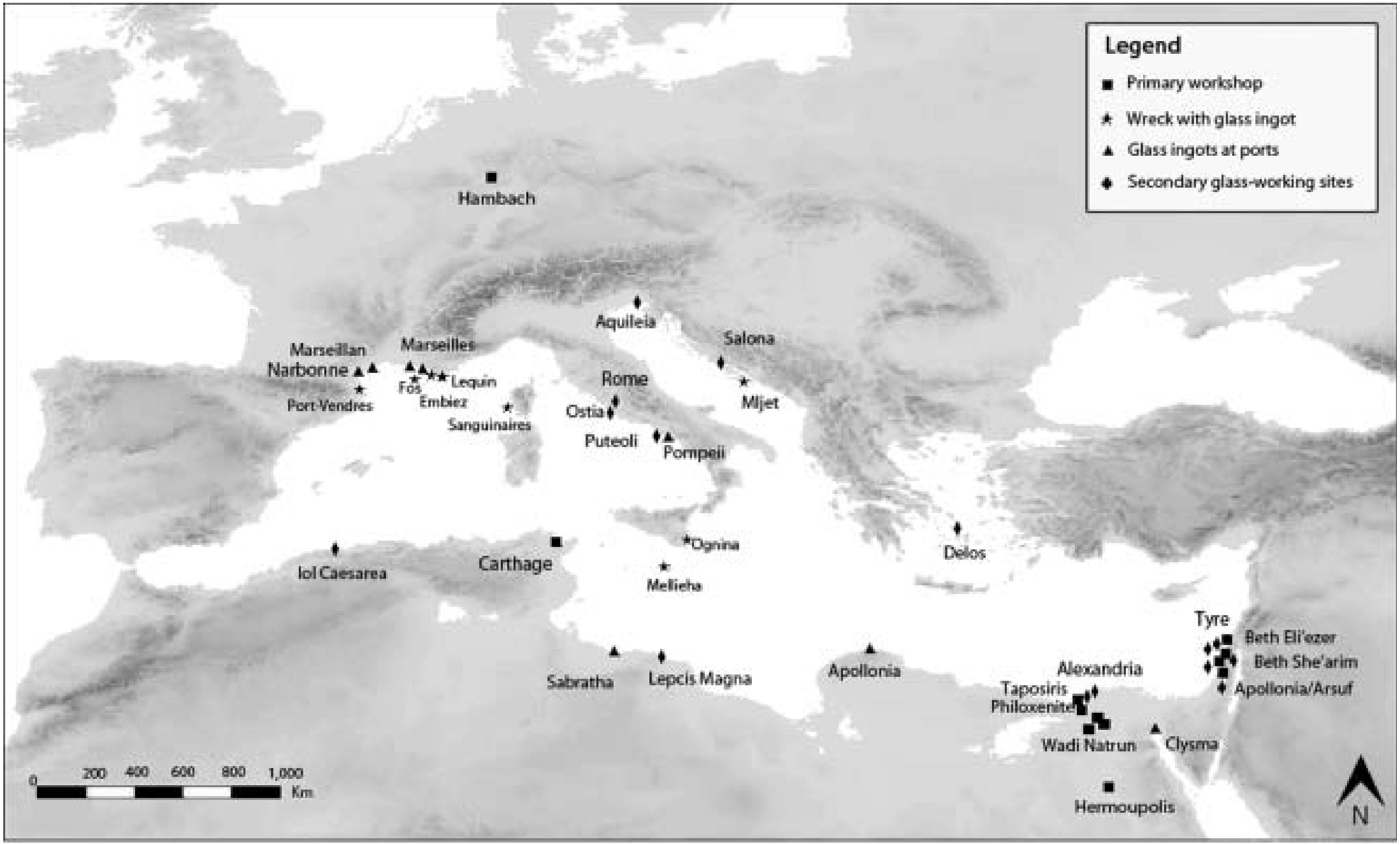

FIG. 20.3. **Roman primary and coastal secondary glass production sites, with the distribution of raw glass in wrecks and at ports.** *(A. Wilson/K. Schörle.)*

TABLE 20.8. Raw glass in wrecks.

Site	Country	Date	Reference
Les Sanguinaires A	France	Second half of the third century BC	Foy and Nenna 2001: 102
Lequin 2	France	Late third/early second century BC	Foy and Nenna 2001: 102
La Jeaune-Garde A	France	c. 100–25 BC	Foy and Nenna 2001: 103
Mljet	Croatia	Late first century AD	Foy and Nenna 2001: 109
Embiez-Ouest	France	Second half of the second century AD	Foy and Nenna 2001: 110
Marseilles (Bourse)	France	AD 190–220	Foy and Nenna 2001: 110
Mellieha	Malta	First half of the third century AD	Foy and Nenna 2001: 111
Ognina	Italy (Sicily)	First half of the third century AD	Foy and Nenna 2001: 112
Port Vendres 1	France	Early fifth century AD	Foy and Nenna 2001: 112

assemblages, where they may suggest the existence of secondary workshops (Table 20.9; Fig. 20.3). Raw glass has been found at the exporting port of Apollonia/Arsuf in Israel (close to the primary production centres of the Near East), and at Apollonia in Cyrenaica, Sabratha in Libya, Carthage in Tunisia, Pompeii in Italy,[16] and in France at Marseilles, Marseillan, Narbonne and the Golfe du Fos. Outside the Mediterranean, glass ingots have been discovered at Clysma at the head of the Red Sea (Bruyère 1966: 49, 115),[17] where they presumably had been shipped down Trajan's canal and were either awaiting working in the town or further export down the Red Sea coast or even to India, as mentioned in the *Periplus Maris Erythraei* (chapters 7, 10, 49). Secondary production centres (glass-blowing workshops) might be located either at port cities or inland; Foy and Nenna's survey of French glass production centres collects abundant evidence for glass-blowing at inland sites (Foy and Nenna 2001: 40–66), and indeed it is likely that by the second century AD most Roman cities, coastal or inland, may have had glass-blowing workshops. But since the inland workshops must have imported much of their material — the raw glass from eastern Mediterranean sources, though not recycled material — via port cities, the ports must have functioned as key nodes in the organization of supply networks for the glass industry. Unsurprisingly, therefore, glass workshops also developed at a number of the major Mediterranean port cities (Table 20.10; Fig. 20.3).

TABLE 20.9. Raw glass at ports.

Site	Country	Date	Reference
Apollonia/Arsuf	Israel		Foy and Nenna 2001: 106
Apollonia	Cyrenaica		Foy and Nenna 2001: 106
Sabratha	Libya	Roman	Wilson 1999: 50
Carthage	Tunisia	Fourth century AD	Tatton-Brown 1994: 288
Pompeii	Italy	AD 79	Verità 1999
Narbonne	France	AD 30–50/60	Foy and Nenna 2001: 107
Golf de Fos	France		Foy and Nenna 2001: 108
Marseillan	France		Foy and Nenna 2001: 106
Marseilles	France	First/second century AD	Foy and Nenna 2001: 25, 106
Clysma	Egypt		Bruyère 1966

TABLE 20.10. Coastal secondary production centres (glass-blowing workshops).

Site	Country	Date	Reference
Beth She'arim	Israel		Foy and Nenna 2001: 34
Jalame	Israel	Late fourth century AD	Foy 2003a: 29
Apollonia/Arsuf	Israel		Foy and Nenna 2001: 34
Beth She'an	Israel	Late sixth century AD	Foy 2003a: 29
Caesarea Maritima	Israel	Late antique	Kingsley 2004: 136.
Philoxénité	Egypt		Foy and Nenna 2001: 34
Alexandria	Egypt		Foy and Nenna 2001: 34
Zakik (Wadi Natrun)	Egypt		Foy and Nenna 2001: 34
Delos	Greece	Late second/early first century BC	Foy and Nenna 2001: 35
Lepcis Magna	Libya	Early second century AD	Ioppolo 1969–70: 232, 234
Iol Caesarea	Algeria	Roman	*CIL* VIII 9430.
Marseilles	France	Fourth–seventh centuries AD	Foy and Nenna 2001: 43
Aquileia	Italy		
Puteoli	Italy		
Salona	Croatia		*CIL* III 9542; Clairmont and von Gonzenbach 1975: 58–63
Rome	Italy	Imperial	Wilson 2001b
Portus	Italy	Late Roman	Simon Keay, pers. comm.

Alexandria, Aquileia and Puteoli all had particularly famous glass-making industries. Besides the ports with glass ingots already mentioned, on the north African coast, there is direct evidence for secondary glass-working at Lepcis Magna, and at Iol Caesarea where an inscription mentions a *vitriarius*;[18] elsewhere, Salona[19] and Marseilles[20] have produced archaeological evidence of glass production, and recent excavations at Portus have discovered evidence for late Roman glass-working there.[21] Overall, the Roman glass industry exhibits a considerable degree of pan-Mediterranean integration, and glass ingot distribution required entrepôt as a means of articulation between the supply of raw material and secondary production. Indeed, the Embiez Ouest wreck, a small ship of 20–5 tons capacity carrying nearly 18 tons of raw glass as its primary cargo, has been interpreted as engaged in this kind of redistribution, probably from a major Italian entrepôt such as Portus or Puteoli towards a port in southern Gaul, such as Arles (Jézégou 2008).

This picture of the organization of the glass industry being dependent on maritime trade links is supported by what happens from the fifth century onwards. With the disintegration of the empire in the west, the production and usage of glass in northwest Europe, remote from the primary source regions in the Levant, drops significantly. Cologne and the surrounding region continued into late antiquity as the major source of glass in the fifth and sixth centuries, and Frankish glass was produced and traded as far as Anglo-Saxon England, but not in the mass-produced quantities that had characterized the Roman period. The reduced access to eastern Mediterranean glass sources as a result first of the disintegration of the Roman Empire and then, from the seventh century, the formation of new Islamic states, meant that glass production and consumption in the western Mediterranean and northwest Europe diminished substantially from the fifth century onwards. From the fifth century, more varied chemical compositions of glass also suggest a growing diversity of silica sources, again probably as a result of reduced access to Levantine raw glass production following the collapse of the western Roman Empire, although natron still seems to have been used as a flux (Aerts *et al.* 2003). In the ninth century, however, a technological shift towards potash fluxes, rather than natron, removed the industry's dependence on a primary source region; the potash fluxes could be produced anywhere, and worked well with a wider range of sand deposits than did natron. The result of this new flux technology was the emergence of a much more decentralized pattern of glass-making, with a wider range of sources of raw glass and with secondary glass-blowing centres closer to the primary production centres, removing the previous dependence on Egypt for natron and the Levant for the raw glass, and reducing the importance of long-distance maritime connections between primary and secondary production centres.

TRADING CONNECTIONS AND HIERARCHIES OF PORTS

The evidence of pottery assemblages and of merchant communities in port cities, and the importance of maritime trade in the organization of the glass industry, accords with recent research on patterns of trading connections argued on the basis of cargo composition from shipwrecks, which emphasize for the Roman period the predominance of direct, regular connections between ports over a pattern of casual tramping.[22] Nieto (1997) argued for a model in which direct long-distance connections between principal ports or emporia were supplemented by coastal connections, with secondary ports supplying or receiving goods from the main emporia. Boetto (Chapter 8) develops this picture by identifying five major patterns of trading voyages: direct voyages with single cargoes between principal ports (emporia or entrepôt); voyages with mixed cargoes loaded at an entrepôt and conveyed to another principal port; mixed cargoes loaded at a major entrepôt and redistributed towards a secondary port; homogeneous cargoes transported between ports as the result of a specific order; and casual tramping from port to port. While Nieto's regional collection model implies a simple two-level hierarchy of ports and harbours, with emporia in one category and secondary ports in the other, the more complex set of possibilities argued for by Boetto might lead us rather to suspect the existence of a multi-level hierarchy, with small ports serving as the central place for several anchorages and coastal villas, and feeding in turn into a regional emporium. These questions have yet to be addressed by research on ancient ports, but we offer some thoughts as to how one might proceed in constructing regional hierarchies, based on an analysis of harbours, mainly along Italy's western *façade maritime*.[23]

RECONSTRUCTING PORT HIERARCHIES

At a basic level, one could compare ports on the basis of their enclosed harbour area, length of wharfage and depth. Figures for wharfage length and depth are available for only a few Roman ports, and since most Roman ships could be accommodated in a depth of 3 m or so, the latter variable may not be very indicative. Rough harbour areas more often can be obtained or estimated from published plans; these should be considered a rough indication of scale rather than scientifically accurate data.[24]

Figure 20.4 plots the available data for harbour areas along the Italian coast from Cosa to the bay of Naples (cf. Table 20.11). Several points are immediately apparent: the dominance of Portus and Puteoli, which comes as no surprise; the existence of a second rank that includes Nero's harbour at Antium (Anzio) and the Trajanic harbour at Centumcellae; and a host of much smaller harbours for lesser towns and villas. In particular, we should note that the port of Cosa, at 2.5 ha, is smaller than the harbours of the villas at Torre Astura (7.8 ha) and Torre Valdaliga, although the recent identification of what appears to be a second port for Cosa on the western side of the headland, associated with kilns for Dressel 1 amphorae (Fentress 2009), may more or less double Cosa's total port capacity. When we consider that by the Imperial period the port of Cosa appears to have become the port for a coastal villa, and that the town itself had declined, this is less surprising. It is possible that the eastern port is now to be seen as associated with the export of fish products from the fishery, and the western port with the export of wine, bottled in the amphorae produced at the adjacent kilns. Nevertheless, the example of Cosa highlights the fact that a maritime villa of the first or second century AD might possess better and larger harbour facilities than some towns of the second century BC. While both ostentation and utility were probably factors in the development of such villa harbours, their size, together with other aspects of export-oriented villa production, is easier to reconcile with the model of export-directed trade through the medium of emporia than with the world of casual cabotage. Such exports from villa harbours might go to secondary ports for regional collection, or even directly to distant emporia, or to other ports as

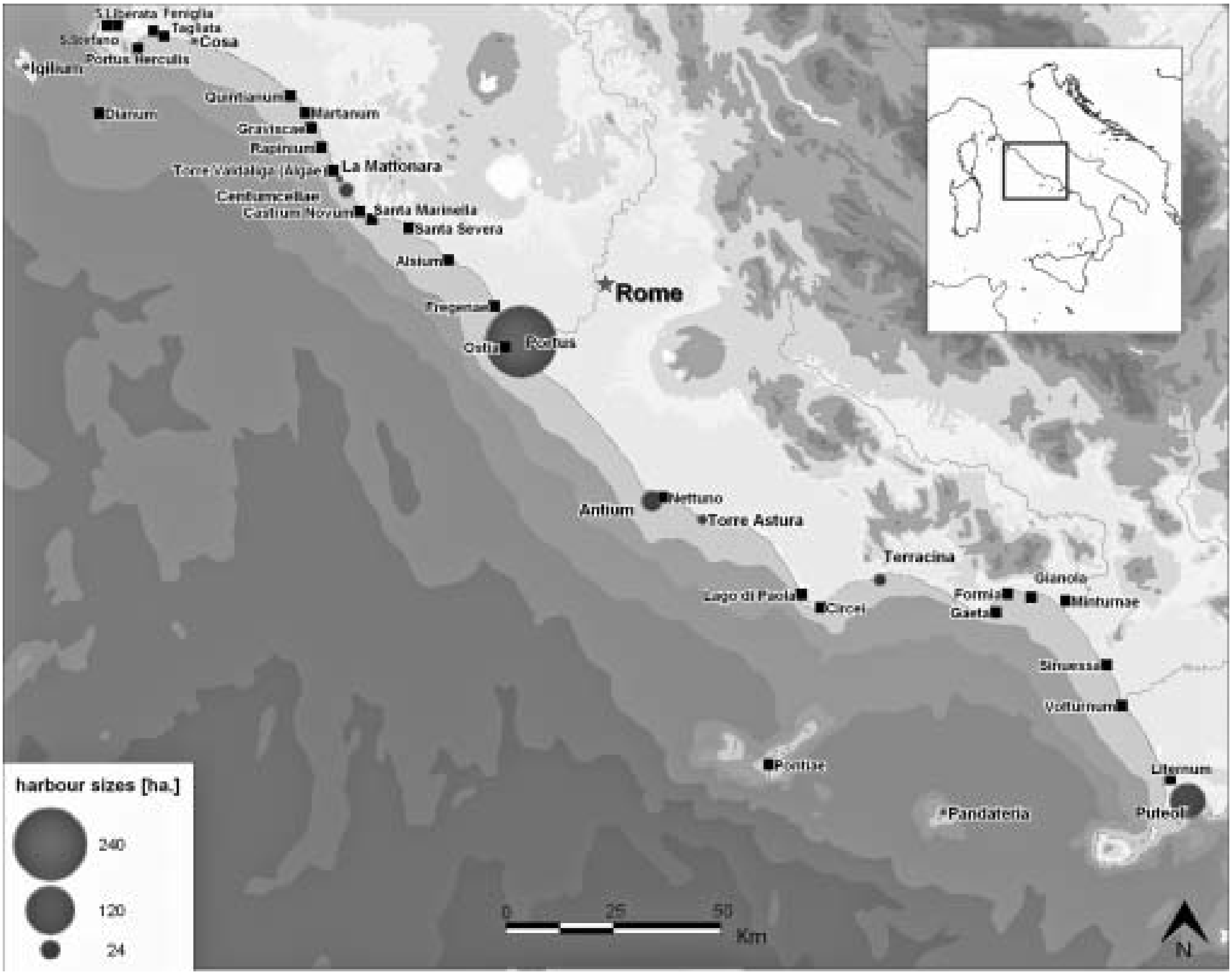

FIG. 20.4. **Roman harbours along the Italian coast from Cosa to the bay of Naples, with relative sizes where known.** *(K. Schörle.)*

directly ordered cargoes. This perhaps can be exemplified by the port on Giglio associated with the granite quarries from which columns were exported; both may have been linked originally with the nearby villa, which belonged to the Domitii Ahenobarbi before becoming imperial property (Bruno 1998: esp. p. 128; Ciampoltrini and Rendini 2004: 137–42). To put these Roman villa harbours into perspective by comparison with earlier periods, the Punic cothon harbour of Motya (Sicily) encloses just 0.18 ha (with less than 170 m of wharf space), and the cothon of Mahdia (Tunisia) encloses 0.78 ha (with less than 370 m wharf space).

One could also try to move beyond the simple quantification of harbour basin sizes to a more nuanced analysis of the relative importance of harbours in a region by considering other factors — the size of the associated port city, its legal status and range of public buildings — to come up with a kind of Central Place Theory ranking of functions and services, with larger centres providing a greater variety of goods and services over a larger geographical range.[25] Figure 20.5 represents an impressionistic attempt to do this for the Minturnae region, where harbour size data are not available, but there is other information on settlements, public buildings and inscriptions documenting trading connections, which enables a crude ranking of the importance of the ports (Ruegg 1988; Schörle 2011). The colony of Minturnae had a large sheltered river port, where fifteen Roman ship-sheds have been discovered, and it appears also to have been a centre for shipbuilding, especially for dolia ships used in the wine trade (Schörle 2011).[26] Minturnae may have played a role as a subsidiary

TABLE 20.11. Sizes of selected harbour basins.

Site	Harbour area (ha)	Wharfage length (m)	Reference
Portus (total)	234	*c.* 13,890	Keay (Chapter 2: n. 64); Morelli, Marinucci and Arnoldus-Huyzendveld 2011
Claudian basin	*c.* 200	*c.* 2,860	Wharfage figure includes various canals
Trajanic hexagon	33.3	2,100	Keay (Chapter 2, this volume)
Darsena	1.08		
Alexandria, Portus Magnus	>226	12,380	Calculated from plan in Goddio and Fabre 2008: 38
Puteoli (total)	67.9		Calculated from plan in Brandon, Hohlfelder and Oleson 2008: 376 fig. 1
Portus Iulius	53.9		Calculated from plan in Brandon, Hohlfelder and Oleson 2008: 376 fig. 1
Portus Baianus	14		Calculated from plan in Brandon, Hohlfelder and Oleson 2008: 376 fig. 1
Antium	25–30		Felici 1995: 61
Ephesus	*c.* 18–24		Calculated from Google Earth
Caesarea Maritima (outer basin)	20		Oleson 1988: 152
Hadrumetum	20		Bartoccini 1958: 12
Centumcellae	14	No more than 2,000	Calculated from plan in Caruso, Gallavotti and Aiello 1991
Carthage (circular and rectangular harbours)	14		Romanelli 1925: 92
Terracina	11		Calculated from plan in De Rossi 1980: 100, fig. 25
Lepcis Magna	10.2	1,200	Bartoccini 1958: 12–13
Torre Astura	7.8		Calculated from Marzano 2007: 49, fig. 5
Kenchreae (Corinth)	3		Kingsley 2004: 140
Cosa	2.5		Gazda 1987: 75
Giglio Porto	*c.* 2		Calculated from plan in Ciampoltrini and Rendini 2004: 138 fig. 6*
La Mattonara	1.24		Calculated from plan in Higginbotham 1997: 94 fig. 18
Villa port at San Simone	0.84		Degrassi 1955: 136
Ventotene (Pandateria)	0.7		Franco 1996: 297

*The units of the scale bar of this plan are not specified and the plan has clearly been greatly reduced from the stated 1:20,000 scale; checking against Google Earth indicates that the scale bar must represent 30 m in 2 m and 10 m units.

hub via which cargoes from larger emporia (Naples, Puteoli) might be redistributed to local smaller ports (Formia and Gaeta) and maritime villas (Gianola). Nevertheless, Minturnae's replacement of Sinuessa as the main port for the export of wine from the Ager Falernus, and its role as the home port for dolia ships trading wine between Italy, Gaul and Spain in the first century AD, also suggest that it had direct long-distance links that bypassed the emporia of the bay of Naples (Schörle 2011).

In some instances we may be able to deduce something about a port's role in wider trading networks

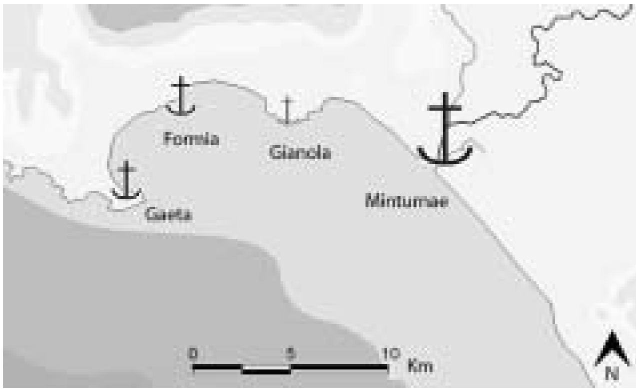

FIG. 20.5. Roman harbours in the Minturnae region, with a rough estimate of relative importance expressed by the size of the anchor symbol. *(K. Schörle.)*

even when there is no archaeological evidence of port facilities. The case of Baelo Claudia (Bolonia, Cádiz) is instructive here — a coastal town, with several fish-salting factories implying export production, although no port facilities have been found yet. One possibility would be the existence of wooden jetties, or perhaps ships were loaded and unloaded by stevedores wading through the shallows (Rickman 1985: 111), as shown on a third-century mosaic from Sousse apparently depicting the unloading of firewood on a beach.[27] In either case, though, Baelo can only have been frequented by small ships, which presumably collected the export produce into, for example, Gades (Cádiz) or Iulia Traducta in Algeciras Bay for transshipment and re-export.

The fourth-century ostraca recording shipments of olive oil into Carthage show this process of regional collection at work. An official describing himself as the *mensor olearius* at Carthage recorded a series of consignments of 200–20 amphorae each, arriving on ships, which he then inspected for quality, and weighed (Peña 1998). This was part of a state-directed operation and seems to reflect the collection of oil at Carthage before onward shipment to Rome as part of the oil *annona*. The ships arriving into Carthage were coming from ports along the northern Tunisian coast, and the ships themselves must have been pretty small — the second-century Grado wreck, a 20- to 25-tonner, was carrying three times as many amphorae.

CAPACITIES OF HARBOURS AT MAJOR EMPORIA

Ideally, we want to estimate harbour capacities not simply in terms of area, but of ships, for which we need to know figures on wharf length and constraints on ship sizes.[28] Table 20.11 lists some Mediterranean harbour sizes and, where they can be measured, wharf lengths. As expected, Alexandria and Portus top the list, far larger than other major harbours; but some of the other well-known harbours, such as Carthage and Lepcis Magna, look relatively small. The harbour at Lepcis Magna, so well preserved because it was silted up and abandoned, is about half the area of the harbours of Caesarea Maritima and Hadrumetum. The area figure for Carthage, 14 ha as reported by Romanelli (1925: 92), looks small by comparison with several other large harbours in Tunisia and Italy, but it refers only to the Punic circular and rectangular harbour basins (which were reused in the Roman period), and cannot represent the full extent of Carthage's harbour facilities. Indeed, recent work by Hurst (2010) suggests that the stretch of coastline between Falbe's Quadrilateral and the Bordj Djedid hill, some 2,000 m, was developed in the Roman period with warehouses that must have been fronted by continuous wharfage, and that much of the merchant shipping for Carthage may have docked here.[29] Indeed, if Hurst's hypothesis is correct, it would be logical to see the Roman development of the natural spring known as the *Fontaine aux mille amphores* at the foot of the Bordj Djedid hill as connected with the need to supply water to ships along this stretch of docks. In addition, Saint Augustine (*Confessions* 5.8) departed from Carthage by ship from a point near the *memoria* of Saint Cyprian, usually identified with a basilica overlooking the bay of Dar Saniat (the site of the modern Hotel Amilcar) to the north of the city; Augustine's ship presumably left from this bay.

Nevertheless, comparison of the columns for area and wharf length shows that area only gives a very rough guide to harbour capacity; a more directly relevant (but often less easily available) figure is wharf length, and this bears no constant ratio to area. The Claudian harbour at Portus is now estimated to have enclosed an area of *c.* 200 ha with perhaps 2,860 m of wharf length (Morelli, Marinucci and Arnoldus-Huyzendveld 2011; Keay, Chapter 2: n. 64); the Trajanic hexagonal basin, 33.3 ha in size, added another 2,100 m of wharfage (Keay, Chapter 2: n. 64) — seven-tenths as much, but for only a sixth of the surface area, reflecting the more efficient design of the Trajanic harbour. The wharfage length is our best indicator of how many ships could dock; in the Mediterranean, ships traditionally moor perpendicular to the quayside, in the so-called 'Mediterranean moor'.[30] That similar arrangements were also standard in antiquity is indicated both by the alignment of seven sunken fifth- or fourth-century BC wrecks at Heracleion-Thonis, found parallel to each other and apparently moored end-on to a wooden jetty (Goddio 2007: 111, 113 fig. 3.83, 114), and of fifteen fifth-century AD wrecks burnt while moored in the harbour at Olbia, bow to the shore between wooden jetties (D'Oriano and Riccardi 2004). We therefore need to divide the length of available wharfage by the amount of space required for a ship to moor — its beam, plus extra room for clearance between ships (although see below for the suggestion of broadside-on mooring in the canals at Portus). Fortunately, evidence from Portus helps here: the sides of the Trajanic hexagon each measure 358 m and had mooring blocks every 14–15 m (on side V at least), which would accommodate ships of 10 m beam with 4–5 m clearance between pairs of ships (Testaguzza 1970: 162–3). This would allow up to 24 or 25 ships on a side, but in order to avoid interference between ships at the angles where two sides met this maximum number may not have been reached, and indeed a column at the angle of sides III and IV, inscribed with the numeral XXIII (Testaguzza 1970: 163), presumably indicating the numbering of individual berths, suggests that we should imagine 23 ships for each of the five sides I–IV and VI. With a further sixteen ships for side V (which includes the entrance), the Trajanic hexagon therefore might have provided docking space for 130 large merchant ships each of several hundred tons.[31] A ship of 10 m beam might be some 40 m long (at a breadth:length ratio of 1:4); for comparison, the Madrague de Giens wreck of 300–400 tons was 9 m in the beam and *c.* 40 m long (Pomey 1982: 145).[32]

To the figure for the Trajanic hexagon, we need to add the Claudian harbour. Testaguzza assumed that the 2,500 m of quayside there allowed for the docking of 250 ships, evidently calculating only 10 m per ship (including clearance). New coring work in the Claudian basin shows that it was larger than Testaguzza thought, and Keay estimates the wharfage at 2,860 m (Morelli, Marinucci and Arnoldus-Huyzendveld 2011; Keay, Chapter 2: n. 64); but if we assume the same arrangements as for the Trajanic hexagon (we have no direct evidence for the spacing of mooring stones in the Claudian basin), we would need to revise this figure downwards to berths for *c.* 190–205 ships of the same size. Both basins, however, provided (relatively) sheltered anchorage for more ships that could wait at anchor in the harbour awaiting their turn to dock at the quays. The protection thus offered was not total, however — Tacitus records the loss of nearly 200 ships at anchor in the Claudian harbour of Portus in AD 62 (*Annals* 15.18), much the same figure as our estimate for the docking capacity. It is unlikely that every ship in the harbour was wrecked in this storm, and there were probably therefore over 200 ships in port at the time, which is entirely conceivable if there were *c.* 200 docked at the quays and others at anchor in the basin awaiting their turn to dock.

Besides the two main harbour basins at Portus, there were other quays too — Testaguzza estimated the available wharfage of the Darsena basin and the connecting canal between the Claudian and Trajanic basins at a total of 1,950 m (Testaguzza 1970: 161). The connecting canal had perhaps 1,425 m of quay space,[33] but mooring here might have impeded through traffic. The Darsena must have accommodated smaller ships than in the main basins; it measured 240 × 45 m (1.08 ha) (Testaguzza 1970: 173), and its 9 m wide entrance will have limited the ships that could enter it. Since it is only 45 m wide it is difficult to imagine vessels more than 15 m long mooring opposite each other; this area was most probably used to load up barges taking goods up the Tiber to Rome. If we allowed 9 m mooring per vessel (for a beam of 5 m plus 4 m clearance), 26 ships could be accommodated along each of the long sides (240 m long), making 52 in total (assuming that none was moored against the short sides, as most of the space here would be taken up by the endmost ships moored on the long sides). But vessels may have moored broadside-on in this more restricted basin, which would have reduced the number substantially.[34]

There was at least a further 3,710 m of available wharfage along the Fossa Traiana (50 m wide),[35] but here we probably need to imagine vessels mooring broadside-on to the quays. The marble yards of Portus were located along the southern side of this canal, and column shafts, blocks and other items of cargo weighing several tons must have been regularly offloaded from sea-going ships and loaded onto vessels heading upstream to Rome, operations that must have involved the use of cranes. This could hardly have been done across the forequarters of ships docked prow-on to the quay, and must have necessitated broadside-on mooring, with ships tethered at bow and stern. Indeed, it was probably the opportunities offered by the Fossa Traiana for broadside-on mooring that determined the location of the marble yards here. Large ships with cargoes of marble could enter the Fossa

Traiana without having to pass through the Claudian basin or the connecting canal by the Darsena, and dock side-on in the canal so that their cargoes could be unloaded by cranes. Allowing 50 m length per ship (including space for manoeuvering), in theory up to 74 large ships could have been accommodated on the southern side of the Fossa Traiana by the marble yards. Was the other side of the canal used for barges loading up for Rome with goods from the warehouses by the Trajanic hexagon immediately to the north?

Including other canals and basins, the total wharfage of Portus after the Trajanic improvements may have been as much as 13,900 m (Keay, Chapter 2: n. 64), sufficient for some 330 large ships in the two main basins and several hundred small to medium vessels berthed at the quays, as well as dozens of others waiting at anchor in the main harbour basins.

For comparison, the Severan harbour at Lepcis Magna had *c.* 1,200 m of wharfage, which Bartoccini classified into 590 m of major wharfage (on the north and east sides of the harbour basin) and 610 m of minor wharfage (on the south and west sides) (Bartoccini 1958: 12–13). On the west side, there are flights of steps 3 m wide at intervals with 9 m between each set; if each set of steps corresponded to one berth, this would allow 12 m per ship in the minor wharfage area: *c.* 50 ships on the south and west sides, and perhaps another 50, or rather fewer if the ships in the major wharfage area were bigger, on the north and east, for a maximum total of around 100 ships.

At Alexandria, the eastern port, or 'Portus Magnus' enclosed over 226 ha (precise measurement is impossible because the modern city covers the southwest part of the basin by the heptastadion). Ongoing underwater topographical research by Goddio's team has started to reveal the extent of moles and jetties that projected into this basin to provide sheltered subharbours and extend the available wharfage length, which may be estimated at at least 12,380 m.[36] The Eunostos and Kibotos harbours would have provided further docking space, increasing this figure considerably for the amount of shipping that could use Alexandria's Mediterranean-facing harbours.

The very large emporia of the Roman world thus provided purpose-built facilities for the simultaneous loading and unloading of scores or even hundreds of large ships at a time, with dockside warehouses providing entrepôt storage. These emporia were linked directly to each other by regular shipping routes, and often by established trading arrangements between groups of merchants. But they played a no less important role in articulating between the long-distance shipment of goods and local collection from and redistribution to lesser ports in their foreland regions.

CONCLUSION

The amphora imports to ports along the north African coast do indeed support Fulford's idea of two largely separate trading zones with little direct interaction along the north African coast, but this is undercut to some extent both by the fine-ware evidence (ARS at Berenice in the third century; Aegean wares at Carthage) and by the evidence for eastern trading communities at ports in Tripolitania and Africa Proconsularis. The analysis of the ceramic assemblages of major north African ports suggests both that amphorae and fine-wares were distributed through different trading mechanisms, and that there was rather more connection between Africa Proconsularis and Cyrenaica than Fulford's argument allowed. Although some of the ARS in Cyrenaica may be explained as return cargoes from major entrepôt in Italy, the evidence for Alexandrian and other eastern trading communities at some of the north African ports supports the idea of some trading connections along the north African coastline, even though the major sources of amphora-borne goods in Tripolitania and Cyrenaica were in the western and eastern Mediterranean respectively. The evidence for primary production of glass at Carthage also implies the import of natron from Egypt.

The widespread distribution of relatively low-value ceramics such as ARS or African cook-wares is explained by the patterns of maritime trade based on connections between major emporia and local redistribution. We see the virtual capitulation of some regional fine-ware networks in the face of overwhelming competition from productions that are both organized on a large scale and have exceptionally good access to distribution networks through major ports. The wide pan-Mediterranean distribution and even market dominance of a few ceramic types is explained by large-scale flows of trade into key emporia, and the redistribution from these both as return cargoes to other emporia and locally along coastal hinterlands. In the case of ARS, the pan-Mediterranean distribution may be explained first by its travelling as part-cargoes into key Italian ports such as Portus, and then back to all parts of the Roman world as part of a return cargo to almost any region with which Portus was in regular contact (Fentress and Perkins 1988: 213; Bonifay 2003; Fentress *et al.* 2004: 157–8). Direct trading links between emporia, with local coastal redistribution, also explains the distribution of Cyrenaican Mid Roman 8 amphorae up the Adriatic, and it, or specially commissioned orders, also accounts for the distribution of Italian bricks in north Africa.

Analysis of harbour capacities and facilities sheds some interesting light on trading connections, and helps flesh out the picture of voyaging patterns suggested by Boetto's analysis of wreck cargoes in Chapter 8, to give a fuller image of the nature of Mediterranean connectivity. The bigger Roman harbours and large port cities, in their infrastructure — which in north Africa as at Thapsus may include 500 m long or more jetties to enable large ships to dock on the shallow shelving coast — and their market and warehousing facilities, are entrepôt or emporia rather than just another stop in a succession of ports of call in a world of cabotage tramping. We may begin to construct hierarchies of harbour sizes and facilities, although data on both basin size and wharfage length are often incomplete. They do suggest, for example, that some of the traffic from villa harbours like Gianola or small ports such as Formia fed into regional ports like Minturnae, which might in turn form part of the network feeding major hubs like the emporia of Naples or Puteoli. But it would be false to assume that all trading voyages need necessarily work through all the steps of this hierarchy; the apparent production of dolia ships at Minturnae and its connection with the wine trade to Gaul and Spain suggest that a middling regional port like Minturnae might see voyages departing for and returning from distant emporia or indeed distant smaller ports (Schörle 2011), and the fact that villa harbours of the Roman Imperial period might compete with or even exceed in size the harbours of some cities suggests that they were capable of accommodating not just coasters but also large sea-going shipping that could trade directly with distant emporia via voyages across open water.

Morley concluded his recent survey of trade in classical antiquity with the sentence: 'The 'decline' of late antique trade can also be seen as a return to the normality of small-scale, short-haul *cabotage* after the exceptional level of activity, and exceptional degree of dependence on traded goods, in classical antiquity' (Morley 2007: 102). The Classical, Hellenistic and, particularly, the Roman periods were marked especially by long-distance maritime trade between entrepôt, and it was this coordinated access to remote and larger markets that helped stimulate high levels of urban production at port sites, not only in marine products (salt, fish products, *Murex* purple dye), but also amphorae, cook-ware production and metalworking, either geared to an export market or reliant on the import of raw materials (Wilson 2002). The geographical separation of primary and secondary production in the glass industry, and the consequent need for integration by trading networks, seems to confirm this relationship.

NOTES

1. For production at Tocra, see: Riley 1974–5; 1976–7; 1979–80. Berenice: Riley 1979: 193. Apollonia: personal observation (A. Wilson) of a sherd dump by the shore of the harbour.
2. Distribution compiled from data in: Ferrarini 1993: 157–61; Cipriano, Mazzocchin and Paspore 1997. For Zaton: Smiljan Gluščević pers. comm. (email of 13.02.2007).
3. Compiled from data in *CIL* XV and in: Bloch 1947; plus: Foucher 1958; Foucher 1965; Di Vita 1966; Hirschland and Hammond 1968; *AE* 2000, 1711 and 1712; Wilson 2001a. Cf. Hartley 1973; Tomber 1987.
4. The comparison of pottery quantifications from Berenice, Carthage and Ostia presented here is explored in more detail elsewhere (Rice 2011).
5. Indeed, for an earlier period, Kenrick (1985: 251) noted that 20–30% of the ITS at Berenice came from Puteoli.
6. The second period, that of AD 1–125, as analysed here, consists of deposits 4.4, 4.7a, 4.7b, 4.7c, 4.7e, 4.8, 4.10, 4.12a and 4.12b. Deposits 4.6, 4.14a and 4.15c, dated to this period stratigraphically, have been removed from consideration owing to the high degree of residual pottery. The contexts from AD 125–200 analysed here are deposits 4.16a, 4.16b and 4.18. Deposits 4.12a, 4.14b and 4.17 were removed because of residual contents.
7. The figures are based on Fontana's quantification of amphorae from excavated contexts at Meninx: Fontana, Ben Tahar and Capelli 2009: tables 16.15, 16.18, 16.19.
8. The amphorae figures are taken from: Carandini and Panella 1973. See also the analysis of Antonine deposits at Ostia by Rizzo in Chapter 4.
9. The results are published in detail by Martin (2008).
10. A head of Sarapis found in the forum at Gigthis beside the main forum temple, and a relief of scenes possibly connected with the cult of Isis and Sarapis on the podium of the temple, led to the suggestion that the main temple there also may have been dedicated to Sarapis (Constans 1916: 29–32).
11. For some other evidence for the use of Greek by communities in port cities of north Africa, see: Desanges 1999.
12. Kessler and Temin (2008) have argued that grain prices at Rome reflected those in the provinces plus the costs of transport, but cf.: Bowman and Wilson 2009: 24–7.
13. Analysis of prehistoric glass may suggest the use of sodium salts and potash as a flux in iron age Europe (Henderson 1985).
14. Other sources of natron are known today in England, Hungary, Switzerland, Italy (Campania) and Sicily (http://www.mindat.org/min–2858.html [last accessed 26.04.2011]), but there is no evidence for their exploitation in antiquity.
15. We thank Tyler Franconi for these references.
16. Cf. raw ingot SAP inv. 13111 (cat. no. 259): Ciarallo and De Carolis 1999: 202, no. 259; Verità 1999: 109; De Carolis 2004: 72.
17. The identification of a supposed glass-blowing works with nine furnaces (p. 62) is, however, dubious.
18. Lepcis Magna: Ioppolo 1969–70: 232, 234; Pisani Sartorio 1969–70: 250–5. Carthage: Tatton-Brown 1994: 288; Freestone 1994. Sabratha: Wilson 1999: 50. Caesarea: *CIL* VIII 9430 = *ILS* 7649.
19. *CIL* III 9542 for a *vitriarius* working at Salona; Clairmont and von Gonzenbach (1975: 58–63) for the excavation of the glass workshop and furnace at Salona.
20. See: Foy and Nenna 2001: 107 — four workshops dated between the fourth and seventh centuries AD.
21. Simon Keay, pers. comm.; excavations by the Portus Project of the University of Southampton and the British School at Rome (www.portusproject.org).
22. See: Parker 1990a: 342–3; Parker 1990b; Parker 1992: 20–2; Nieto 1997; Tchernia 1997: 124–7; Arnaud 2005; Arnaud 2007; Boetto (Chapter 8); Bonifay and Tchernia (Chapter 16). These evidence-based studies contradict the assumption of Horden and Purcell (2000: 143–52, 365–70) that coastal tramping ('cabotage' in their terms) was as or more important than direct connections ('le grand commerce maritime'). Bang's view (2008: 141) that cabotage tramping was the norm is uninformed by the archaeological reality.
23. These ideas are explored in greater depth by Schörle (2011).
24. We used the program TakeOff Live, which enables the measurement of areas of irregular polygons from any digitized plan with a scale; harbour size estimates are therefore reliant on the accuracy of previously published maps.
25. For Central Place Theory, see: Christaller 1933; cf. Evans and Gould 1982.
26. *CIL* X 5371, from Interamna Lirenas 10 km upstream from Minturnae, is the tombstone of an *architectus navalis* who may have practised his trade at Minturnae or Interamna (or both).
27. Sousse mosaic: Du Coudray la Blanchère and Gauckler 1897, 10, pl. I.6. Bardo Museum, A.6; Foucher 1960: 77–8 no. 57.169 and pl. XLIa. Foucher interpreted the mosaic as representing the unloading of lead ingots, but the objects being carried off the boat and weighed on shore in fact look nothing like Roman lead ingots in either size or shape. On the original mosaic they are yellowish brown in colour, and even in Foucher's black-and-white photograph it is clear that they have knobbly projections. They are better understood as logs, perhaps intended for firewood, sold by weight, as Gauckler (Du Coudray la Blanchère and Gauckler 1897: 10) and Meiggs (1982: 529–30) recognized. For a colour picture, see: Fantar *et al.* 1994: foldout picture at 115–18.
28. See Boetto (2010) for a first attempt to do this for Portus, but she assumes side-on mooring rather than end-on mooring (see below). Cf. also Heinzelmann (2010: 5–6) for estimates of the capacity of the river port at Ostia.
29. For some of the concrete structures (without interpretation of their function), see: Yorke and Davidson 1985.
30. Boetto (2010: 122 fig. 11) assumes broadside-on mooring only; the berth capacity in the Trajanic hexagon implied by this figure should be increased considerably.
31. This is fewer than the 200+ ships estimated by Testaguzza (1970: 161), who seems simply to have divided his figure

(2,028 m) for the total wharfage length for the hexagon by 10 m per ship.
32. The original total length of *c.* 40 m is estimated from the preserved length of 35.1 m.
33. 1,950 m less the 525 m calculated for the Darsena.
34. Cf. Boetto 2010: 122, fig. 11.
35. Keay, Chapter 2: n. 64, revising Testaguzza's lower estimate (1970: 179) of 2,000 m.
36. Calculated from the plan published by Goddio and Fabre (2008: 38).

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Abbreviations

AE = *L'Année Épigraphique*.
CIL = *Corpus Inscriptionum Latinarum* (1863–). Berlin, Georg Reimer/Walter de Gruyter.
CIG = *Corpus Inscriptionum Graecarum*.
IG = *Inscriptiones Graecae*.
IRT = Reynolds and Ward Perkins 1952.

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