Aegean amphorae
The special interest of amphorae lies in their value as a marker of economic activity, essentially the exchange of agricultural goods, such as wine, olives, and olive oil. The amphorae themselves are of no particular commercial value, as some Delian inscriptions and Egyptian papyruses attest. Their precise source and date are frequently indicated by the stamps. Thus, for example, the twin stamps with official symbols like the rose or Helios head on the amphora handle confirm a Rhodian origin, as well as the date given by the name of the eponymous magistrate and even an indication of the month.

Unstamped amphorae without a secure indication of origin occur mainly at the ‘receiving centres’. Little would be gained by attempting to quantify types of amphora at such sites without understanding their development and distribution patterns. The ‘receiving centres’ can tell us about the amphorae temporal distribution, but locating them in space requires a knowledge of the production sites.

Production sites
Research into production sites for these amphorae is already underway in Spain, France and Italy, but the picture is incomplete. During the Archaic period imports from Greece appear at the production centres in the West; in imperial Roman times they appear at Ostia and Carthage. This situation calls for coordinated research, even international effort, treating the Mediterranean as a whole. The Greek world is of crucial importance in this research since it was not only a large producing region but was sufficiently economically advanced to export its agricultural surplus.

Several approaches are possible in locating amphora production sites:

a. Regional production may be defined, as in the case of Egypt. Although it has been stated that Hellenistic Egypt lacked suitable clay to produce amphorae, the discovery of workshops in the Alexandrian Chora, in addition to those in Middle Egypt, has vividly drawn attention to the large scale of production (Fig. 20) (Empereur 1985, 76; Empereur and Picon 1986a, 104-5 figs. 1-5; for Middle Egypt, Empereur and Picon in press, figs. 28-30).

b. Another possibility is to consider a class of amphora and identify the area of its production. Late Roman I amphorae are distributed very widely in the Mediterranean in the 4th-7th cent. AD, and yet their production sites have been found to be restricted to geological zones that include ophiolitic rocks. Field survey has located some twenty production sites spanning an area from Antioch in the east to Rhodes in the west (Fig. 21) (Empereur and Picon in press, fig. 15-9 and text). This work revealed the existence of numerous small sites producing the same amphorae; these results contrast markedly with the well-known situation in the Greek period when each large centre was intent on emphasising the difference in appearance of its product with respect to those of its neighbours.

c. Certain amphorae are associated through their stamps with particular regions, yet the precise location of the production centres remains unknown. Naxian and Parian amphorae, whose stamps mention the ethnarchs of the respective cities, are a good example. During 1985, we located in one week two workshops on Naxos, eight on Paros and one on Antiparos (Empereur and Picon 1986b; 1986c).
There is a certain urgency about this type of field work throughout the Mediterranean because the pace of agricultural and other development is threatening small sites like workshops (Empereur and Picon in press). Several important workshop deposits at Alexandria have already been destroyed.

Field and Laboratory research

The discovery of production sites provides the laboratory with irrefutable reference material. The resulting analytical data can delineate on geological criteria areas for prospection. What is locally made can be confidently distinguished from what is not, without forgetting the existence at workshops of ‘plain domestic’ pottery, used by potters but not made by them. Finally, the data from producing and ‘receiving’ centres can be compared.

a. Field work varies greatly according to the type of work envisaged. If its purpose is to identify workshops that operated in a particular area, the identity of whose products is unknown, the laboratory’s role consists essentially of determining those areas that could have provided clays suitable for pottery-making. In the absence of relevant geological documentation, this work has to be done in situ. Experience shows, however, that discovery of the first few workshops is usually sufficient to give us a good idea of the potters’ practices, the types of clay selected and the type of location (Picon and Garlan 1986; Empereur and Picon 1986b).

On the other hand, when it is important to locate the workshops that produced a well-known ceramic type, the preliminary study is directed towards delimiting the area to be surveyed. Petrographic or mineralogical, rather than chemical, analysis is most suited to this kind of study because petrographic composition often relates more directly than chemical composition to the geology of the areas of interest. Nevertheless, sometimes chemical compositions can be assigned to a particular geological environment, as for example in the analysis of three examples of Zenon...
Map of Late Roman 1 amphorae workshops (drawn by N. Sigalas).
group A amphorae found in the Serve Limani Hellenistic ship wreck off the west coast of Turkey (Grace 1986). These amphorae, which have traditionally been thought to be from Egypt (Grace 1963), have high Cr and Ni contents (342, 359 and 348 ppm, and 321, 335 and 331 ppm respectively) which are typical of clay derived as an erosion product of ophiolitic material. Such outcrops are extremely rare in Egypt, and indeed the corresponding mean Cr and Ni contents in 300 samples of pottery and clay from Upper Egypt up to the Delta and Oasis are 141 ppm ± 30 and 67 ppm ± 19, individual values not exceeding 220 ppm and 140 ppm respectively. Egypt can surely be excluded as the source of these amphorae. In principle, the occurrence of ophiolites on Rhodes, Kos, the Datça peninsula, Lycia, Cilicia, Pieria, Cyprus, and parts of Greece makes all of them candidate as sources of the clay. In practice, this list should be narrowed down to the Datça peninsula since we have already shown that Zenon group A handles, one found at Reşadiye (see below) and the other at Fayum, have very similar chemical compositions (Empereur and Picon 1986a, fig. 33).

b. Determination of origin in the Laboratory

When confronted with pottery at a production site, there is a real problem in determining among the different ceramic classes those produced on the spot from those produced elsewhere. If classes are not well represented numerically, either because they are imports or they are from a minor centre or belong to an earlier period, they raise more problems than the more numerous surface sherds. In this case, the results of chemical analysis are very important (Picon and Garlan 1986, fig. 6; Empereur and Picon 1986b, fig. 4).

Let us examine the complex case of the amphora workshop of Reşadiye-Kiliseyani in the Datça peninsula. Apart from Hellenistic amphorae which were the principal products of the centre, other ceramics were manufactured, including stamped proto-Rhodian, Zenon group B and Roman amphorae (until the 7th cent. AD) and fine pottery. Survey also revealed many fragments of amphorae and fine pottery of the Archaic period whose status as local or imports was uncertain. To resolve this problem, we analysed chemically 44 reference samples from Reşadiye (black lozenges in Fig. 22), three examples of proto-Rhodian amphorae, five Archaic amphora (white triangles) and fine pottery (white circles) fragments, and three examples of Zenon group A amphorae from the Serve Limani shipwreck (white lozenges).

The samples were analysed by X-ray fluorescence spectrometry for the following elements: Na, K, Rb, Mg, Ca, Sr, Ba, Mn, Ni, Zn, Al, Cr, Fe, Si, Ti, Zr, La, Ce, P and V. The compositions were classified by cluster analysis (unweighted average link method 'sur variables centrees reduites relatives aux rapports à l'alumine de treze des constituants precedents'). The ratio of element to aluminium is employed to minimise the effects of sea burial on the composition, especially with respect to magnesium, of the three examples from the ship wreck. The contents of Na, Mg, Mn and P are eliminated because they are sensitive to burial conditions, whether on land or at sea; Si is also eliminated because the effects of inclusions in some wares causes significant fluctuations, while in the case of La the precision is poor.

The dendrogram (Fig. 22) reveals that the Archaic samples and the Zenon group A are close in composition to the Reşadiye production, but they tend to lie to the right of the diagram suggesting they may be somewhat atypical. However, on the basis of their Mahalanobis distance to the main reference group (44 samples), they are found to be no different from some of the reference samples. This presence of atypical or outlier compositions can be explained by particular geological conditions: the potting clays at Reşadiye were a refined form of a heterogeneous clay material extracted from different alluvial layers at and near the site. Besides the lack of uniformity of raw material, there is also the factor of the workshop's lifespan, which in this case was probably more than a millennium. The raw materials and their locations surely changed with time. It should also be borne in mind that the majority of the reference samples represent the most 'standardised' production, that is of the Hellenistic period. This point could explain why the proto-Rhodian stamped amphorae (black lozenges, Fig. 22), whose local origin cannot seriously be doubted, fall not in the centre of the dendrogram, but, like the Archaic pieces and the Zenon group A, to a rather marginal position at one side.

A difficult, but not uncommon, situation like this one does present problems in interpretation. With what confidence can we assign pottery to a reference group when, as we have seen above, the
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Fig. 22  Dendrogram of the cluster analysis of the Resadiye reference samples (without symbols, except for black lozenges representing the proto-Rhodian stamped amphorae), Archaic amphorae (white triangles), Archaic fine ware pottery (white circles) and Zenon group A amphorae (white lozenges).

Fig. 23  Dendrogram of the cluster analysis of the Resadiye reference samples, Archaic samples and Zenon group A amphorae (same symbols as in Fig. 22) and of a Rhodian group (black circles).

similarity in composition is less than perfect? Surely there are risks in making such an assignment? The pottery could have come from another workshop in the Datça, or even the neighbouring, I'oryma peninsulas, or alternatively from an area whose clay resembles that at Resadiye such as on Rhodes. It is reasonable to accept, however, that the similarity in composition in the case of the Archaic amphorae and fine ware pottery found at Resadiye is sufficiently close to suppose a priori they were made there.
But for the Zenon group A amphorae, on the other hand, found in the ship wreck, the assignment of origin must be more rigorous. We must compare their compositions more widely and especially with those of Rhodes. Fig. 23 shows effectively that these amphorae are closer to Reşadiye than to one of the Rhodian composition groups. Comparison with other Rhodian composition groups identified on the basis of analysis of more than 200 reference samples from some twenty ancient and modern sites, as well as about thirty modern clays, again allows us to exclude a Rhodian connection for the Archaic samples and the Zenon group A amphorae. A Koan origin is likewise excluded (more than one hundred samples from the island have been analysed).

Sources further afield have not been specifically considered, but they may be expected to yield larger differences in composition than those existing between the Datça peninsula, on the one hand, and Kos and Rhodes, on the other. It is for the laboratory to verify this hypothesis as and when alternative sources present themselves. Karpathos and Crete, for example, have not yet been excluded.

Ideally, we should want to extend the depth and extent of sampling coverage we had on Rhodes to the Datça and Loryma peninsulas, but unfortunately this is not possible at present. Nevertheless, the five or six workshops that have been characterized show larger differences from the test samples than those that exist between the latter and the Reşadiye workshop. Our confidence that the Archaic amphorae and fine ware pottery analysed probably came from the Reşadiye workshop would of course increase as the coverage of production sites on the two peninsulas is expanded. As far as the Zenon group A amphorae are concerned, their proposed origin in the Datça peninsula is an important finding. It is hoped that additional corroboration from the chemical data will materialise when more reference samples from production sites on and beyond the Datça and Loryma peninsulas have been examined. There may always be some doubt over those examples from the shipwreck, however, because the effects on composition of the fabrics by sea water may have been only partially corrected. But in the meantime, the writer has already shown that these amphorae can at least be placed within the sequence of Knidian amphorae.

To conclude, the process of origin assignment based on laboratory data is a complex one. It is probabilistic in nature; the confidence with which it is achieved increases with the joint efforts of archaeologists and laboratory specialists. The main problem that affects provenance determination is the small number of archaeologists who are sufficiently qualified to appreciate the value of the laboratory-based work. The complexity of this work is frequently such that it cannot be evaluated by common sense and willingness alone. The practice of archaeometry should not be determined solely by archaeologists. The proliferation of archaeometric applications carried out without any real scientific control could place research in archaeometry at risk for many years.

M.P.

References