The scientific analysis of ancient ceramics: a review

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1 Introduction

Although the scientific analysis of pottery fabrics began in the nineteenth century (e.g., Richards 1895) it is only in the last decade that work of this type has been widely undertaken. Pottery has always been of prime importance to the archaeologist, but due perhaps to archaeology having roots in classical history or in eighteenth-century antiquarianism and subsequently developing as an humanity, the emphasis has been largely upon morphology and decoration. Typological evidence has, of course, been subjected to detailed scientific analysis (e.g., Clarke 1962) but here we shall be concerned solely with the much neglected study of fabrics: the material of which ceramics are made.

The object of this paper is to draw the attention of archaeologists to the way in which studies of this type can provide information which is valuable and often essential to the correct interpretation of pottery evidence. Our museums contain vast and ever growing collections of ceramics of all types and it is high time that this store of potential information was more effectively utilized.

2 Preliminary considerations

The aims of the scientific study of ceramics can be conveniently considered under two principal headings: (1) technology, and (2) characterization. The elucidation of technology, the methods by which clays were prepared, shaped, finished and fired, has been the principal objective of many analysts (e.g., Grazhdankina 1965; Hodges 1966; Kociszewski and Kruppé 1968; Sayko 1965; Wirska 1967). This is hardly surprising since the history of technology is an important and interesting field in its own right. However, the results of such studies deserve to be more fully integrated with the findings of conventional typological examination since technological data can contribute to the interpretation of ceramic evidence. In primitive pottery, it is reasonable to suppose, for example, that the way in which the paste was mixed would be dictated by tradition in just the same way as the subsequent processes of forming and decoration. Perhaps in some cases it may be an even more reliable index of the heritage of the potter: for whereas typology may be influenced by relatively ephemeral contacts (e.g., by copying of traded articles), a rather more drastic influence may be needed to change basic technological processes such as clay preparation or firing, though the social mechanisms by which such innovations can be effected have yet to be fully assessed (cf. Shepard 1964).
We can see such a change if we compare the fabrics of the British primary series of Bronze Age Collared Urns with those of the preceding Neolithic Fengate and Mortlake pottery from which the main formative element is thought to stem (Longworth 1961). Study under a hand lens of many hundred Collared Urns from sites throughout lowland Britain shows that they are practically invariably tempered with grog (crushed pottery), but while the Fengate style sometimes contains grog, the bulk of the Neolithic pottery is tempered with crushed calcined flint. Clearly a widespread technological change has taken place and the source of the innovation would seem to be the Beaker invaders, for Hodges (1966) has shown that Beaker pottery is practically invariably grog tempered. What this technological break in the evolution of Collared Urns may mean in terms of changes in social structure is an interesting question difficult to assess at present. The new evidence need not alter Longworth's main conclusions but it does suggest that there may have been a rather stronger Beaker element than has hitherto been allowed.

It is, however, the scientific characterization of pottery that has produced the most spectacular results and it is here that the main emphasis of this review will lie. Characterization involves the examination of the properties of ceramics with a view to isolating materials of different origin and ultimately establishing their source where possible. To do this effectively and objectively recourse to scientific techniques is normally essential.

However, with the resources at present available to archaeology it is usually impossible to analyse more than a very small proportion of the vessels of any one type. If the results of scientific analysis are to be extrapolated effectively, it is essential that a system be devised for the accurate description of the macroscopic features of pottery fabrics, so that visual comparison can be facilitated. It is of course already customary for notes on fabrics to be included in pottery reports, but, whereas typology is often described in minute detail the fabric usually receives scant notice. Furthermore in the writer's experience (which is restricted to Europe in general and Britain in particular) the majority of published descriptions are of little value. Inclusions are often misidentified (e.g., felspar recorded as shell) and the terminology is vague and imprecise. The term 'gritty', for example, may be used to cover anything from sand to large inclusions of perhaps crushed flint, while the much abused term 'calcite gritted' can cover anything from pottery containing shell, through calcite (sensu stricto) to limestone fragments. Clearly a standardized terminology is urgently needed and since pottery is essentially a modified sedimentary rock it would seem reasonable to adopt the terminology long ago established by sedimentary petrologists (see, e.g., Shepard 1968). However, herein lies a difficulty for although we might reasonably expect sediments to be described by trained personnel, most of the macroscopic descriptions of pottery will have to be made by people unfamiliar with the appropriate discipline. The need therefore is for a simple system which can be rapidly and unambiguously applied. At least a partial answer may lie in the adoption of simple tests for recognizing the commoner tempering materials and the use of visual comparative charts, such as that published by Matson (1963: pl. XXIV), for determining the approximate size and quantity of inclusions. The introduction of colour-charts (e.g., by De Laet and Thoen 1969) is a useful step along these lines.
3 Scientific methods

There are many scientific techniques which can be applied to the study of ceramics and the more important ones are outlined in this section, together with a discussion of certain facets of their application which directly concern the archaeologist.

(a) Chemical methods

Chemical analysis has found considerable application in the study of ceramics, particularly in problems of characterization, for different clay deposits can be distinguished by their chemical composition. In theory at least, any analytical technique can be used. The now classical gravimetric method of silicate analysis is of little use as it is excessively laborious, but it was applied, for example, by Jenkins (1908) to show that briquetage from Iron Age saltworking on the Essex coast was made from local raw materials. It is usual, however, to restrict the work to partial analysis for minor and/or trace elements and the method normally used is optical emission spectrometry. This involves taking a very small sample of pottery (usually by drilling in an unobtrusive place), which is burnt between carbon electrodes. The light emitted is split by a system of prisms and the resulting spectrum photographed. The presence of different chemical elements is represented by lines at specific places on the photographic plate and their intensity is proportional to the percentage of the element. Thus if a sample of unknown composition is run and the intensity of different lines compared with that of a sample of known composition, the chemical composition of the unknown can be quantitatively estimated. As might be anticipated this process is not very accurate but an error of 10–30% is unimportant when considering elements present in the order of 1–2% or less.

The choice of which elements to measure tends to be somewhat arbitrary. Aluminium, magnesium, iron, titanium, manganese, chromium, calcium, sodium and nickel have been most commonly studied in this country (e.g., Richards 1959; Catling, Richards and Blin-Stoyle 1963; Hartley and Richards 1965), though Freeth (1967) has drawn attention to the dangers attendant on the postdepositional migration of such mobile elements as calcium, manganese and iron. Although this can be taken as a useful warning against placing too much emphasis on too few analyses or even on those from a single site where such changes may be taking place, in fairness it must be stated that groupings using these elements often seem to make archaeological sense.

Bouchard (1966) has made a contribution to the problem of choice of elements, based on a study of vessels taken from sites spread throughout Europe and North Africa. She suggests that iron, manganese, copper, chromium, nickel and cobalt will be most generally useful in characterizing wares made from different clays, while titanium, lead, tin and silver are of little value, but unfortunately elements other than these were not considered. Mitrichev (1965), on the other hand, lists the following elements in order of their usefulness: manganese, nickel, sodium, copper, magnesium, silicon, calcium, iron, barium and aluminium. Thus, although the method is useful, there is no general agreement about the best elements to study and resolution of this problem might help to enhance the technique's powers of archaeological differentiation. The writer is inclined to think that the optimum elements will vary from one geological province to another, and before attempting a major ceramic study it might be advisable to analyse a selection
of clays from the region in order to determine which chemical elements are likely to give optimum ceramic differentiation.

Another method of chemical analysis which is coming to the fore, is X-ray fluorescence spectrometry. When a specimen is irradiated with X-rays it emits secondary or fluorescent X-rays characteristic of the different chemical elements present in the sample. By analysing the spectrum of fluorescent X-rays it is possible to determine both qualitatively and quantitatively the elements present (see Hall 1960). Since the technique can be non-destructive it is not surprising that it found an archaeological application early in its career, when Young and Whitmore (1957) used it to distinguish oriental ceramics from different centres of production. However, the method suffers from the drawback that it only analyses the material to a depth of about 0.01 to 0.1 mm. and thus if the surface has been treated in any way or if surface enrichment in chemical elements has taken place during burial, the analysis may not be representative of the sample as a whole. This difficulty can be overcome by crushing about 2–5 g. of pot to a fine powder after removal of the outer layers. This is then made up into an artificial ‘pellet’ the surface of which can be analysed to give a true picture of the chemical composition. Although the quantity of material required is large by comparison with samples for spectrographic analysis, it is usually possible to remove this amount without unduly affecting the archaeological value of shered material, and the sacrifice is admirably compensated by the increased accuracy and by the fact that it is possible to analyse major as well as minor and trace elements with comparative ease. Furthermore, the pellets are not destroyed by analysis and can be stored for future reference. Although this technique has been little used to date, it is now becoming standard equipment in university geochemical laboratories and we can look forward to its increased application by archaeologists. The writer, for example, has used it in the study of prehistoric pottery in south-western Britain.

Neutron activation analysis is another non-destructive method which is receiving attention at present. The sample is bombarded with neutrons in a nuclear reactor, inducing weak radioactivity. Study of the gamma-ray spectrum from this enables qualitative and quantitative determination of the constituent elements. Preliminary work has been carried out on various groups of Mediterranean pottery (Sayre and Dodson 1957), on Samian ware (Emeleus 1960; Emeleus and Simpson 1960) and on pottery from a number of sites in America (Sayre, Murenhoff and Weick 1958; Bennyhoff and Heizer 1964). As Shepard (1968, 1966b) has pointed out, a drawback with this work is that only the concentrations of sodium and manganese have been studied, and although the results show promise it is difficult to put much weight on characterization based on two elements.

Aspinall, Slater and Mayes (1968) have recently begun to examine pottery from some eighty British medieval kiln sites using the neutron activation analysis to determine trace elements. In preliminary work on material from two kilns, ten elements were studied and satisfactory differentiation was obtained. Perlman and Asaro (1969) have studied an even more comprehensive range of elements, but their paper is concerned mainly with methodology, and it is difficult to assess the full archaeological value of their work from the few illustrative results quoted.
A particularly valuable method of studying ancient ceramics is by examination in thin section under the petrological microscope. This involves removal of a small fragment of pottery (c. 10 mm. \times 10 \text{ mm.}) which is fixed to a glass microscope slide and ground with a diamond lap or with abrasive powder until it is exactly 0.03 mm. thick (see, e.g., Cornwall 1958 for method). Most of the minerals are then transparent, and can be studied under the petrological microscope, an instrument equipped with optical refinements which enable the precise determination of mineral and rock inclusions. Clay minerals are too fine-grained to be identified in this way and so the study is limited to coarse inclusions, either naturally occurring in the clay or added as temper.

Thin sections are invaluable in research into ancient technology for it is usually possible to determine the way the paste was mixed (from the types and distribution of inclusions), whether the vessel was wheel or hand-made (since wheel-turning will tend to orientate long inclusions parallel to the pot walls) and the firing temperature (by observing changes in certain key minerals).

The method is, however, equally valuable in characterization, for pots made in a similar way from the same materials will appear alike under the microscope. Furthermore, when rock inclusions are present it is frequently possible to determine the source of raw materials from the types present, if the geology of the area under consideration is known. The precision that is possible will depend upon the extent of the natural outcrops of the parent rock of the inclusions. Thus if the parent rock is, for example, a limestone or sandstone which outcrops over a wide area, the provenance of the pottery will be defined only within broad limits, whereas the presence of an unusual igneous rock may enable the source to be defined within very close limits.

Unfortunately a great deal of pottery contains inclusions of quartz sand and little else. In thin section all that can be seen are grains of quartz embedded in a matrix of baked clay and it is usually impossible to say much about the provenance of such commonplace materials. Heavy mineral analysis is a useful approach in such cases (Peacock 1967). About 20–30 g. of pot are crushed and floated on a liquid with a specific gravity of 2.9. The quartz and clay float while the heavy minerals (e.g., zircon, garnet, tourmaline etc.) sink enabling them to be separated and mounted on a microscope slide. Since sands of differing geological origins can be distinguished by their heavy mineral assemblages, pots of different origin can likewise be characterized. In some parts of the world, such as Britain, a considerable amount of work has been done on the distribution of heavy minerals throughout the geological systems and in such cases it may be possible to refer to the geological literature and to discover the system with which the mineral assemblage in the pot is most closely related. From the distribution of rocks of this type it may be possible to limit the source area of the pottery. The main drawbacks are that the method involves destruction of a considerable quantity of pottery, and it is excessively laborious. It is not surprising therefore to find that it has been little used in archaeology: Peacock (1967) has reviewed some of its applications, to which should be added Wallis and Evens's (1934) study of pottery from Pant-y-Saer, Anglesey. Although not suitable as a technique for routine examination it has considerable potential in answering specific questions.
(c) Other techniques

Although the principal methods for the study of ceramics have been outlined above, a number of other techniques have been used on occasion, some of which have produced interesting results.

One of the drawbacks of thin section examination is that it does not permit study of the clay mineralogy of the pottery. Clay is not a homogeneous material but is made up of submicroscopic grains of various clay minerals of which common examples are kaolinite, illite and montmorillonite. Since clay mineralogy varies in different deposits, this can, theoretically, be used to characterize pottery. However, in practice, most clay minerals are destroyed by heating above about 500° C and hence it is applicable only to very low fired wares.

The writer has studied the clay mineralogy of certain Iron Age pots from Cornwall showing that they contain a predominance of montmorillonite. This information is useful from several points of view. Firstly, the clays, suspected as the source on other grounds, are also montmorillonitic, and secondly, the fact that this mineral is preserved at all indicates a firing temperature of less than 300° C since at this temperature the structure undergoes changes (Grim 1968: 314).

Clay mineralogy is studied by X-ray diffraction. The sample is bombarded with monochromatic X-rays, which are diffracted at different angles depending on the crystals present. Hence by studying the angles at which maximum diffraction occurs it is possible to identify the crystalline components. The sample required for this work is very small indeed.

The method is also of value in the study of wares fired at a very high temperature where new artificial minerals have developed in the fabric. Thus Bimson (1969) discusses its use in the identification of porcelain and stoneware where it is of value in distinguishing products of different centres and in detecting forgeries.

X-ray diffraction need not be limited to clay minerals and their high temperature alteration products. Since any crystalline substance can be identified in this way, the overall mineralogical composition of all types of pottery can be examined, and Young and Whitmore (1957) suggest that diffraction patterns may be an ideal way of ‘fingerprinting’ pottery of different origins. However, the method cannot be regarded as a substitute for thin sectioning, for it gives no information about the way the minerals are distributed in the paste and this is often of considerable importance. On the other hand, since the technique can be non-destructive, it is a useful source of mineralogical information when sampling is not possible.

The organic matter present in many types of pottery has received little attention. However, an interesting advance in this field has recently been made by Duma and Lengyel (1969). They investigated the causes of the black appearance of pre-Scythian pottery from Mezőcsát on the northern edge of the Great Hungarian Plain and showed that it was due to an admixture of blood in the clay. Using a method of fluorescence analysis they were able to assess this quantitatively. Their discovery is of considerable interest as it opens up a new field of study, and from an archaeological point of view it would be valuable to know more of the geographical and chronological distribution of the technique of adding blood.
Sauter (1967) has recently investigated coatings on Hallstatt ceramics by infra-red spectrometry and shown them to be lacquer-like coatings of resin.

(d) Selection of methods

It will be clear from the above survey, which is by no means exhaustive, that the archaeologist is today confronted with an impressive array of techniques with which to examine his pottery fabrics and hence the question of choice of method arises. Ideally, the methodology should be tailored to fit the case under study, though in practice it is likely to be determined by what is readily available. On the broad question of whether to analyse chemically or petrologically, the obvious answer is that both should ideally be employed, since as Shepard (1968: xi) has pointed out, interplay between the two disciplines may be valuable in assessing the results from each. When, however, selection has to be made, it is important to consider the nature of the problem, since both approaches have limitations; though if technology is to be studied, thin sectioning is essential, for much of the required information can only be obtained in this way.

The optimum method for characterization will depend largely upon the texture of the ware. Petrology has the advantage that it may be possible to pinpoint sources of raw materials, but if distinctive rock fragments are absent this may be difficult. Wares of different origin would have to be characterized on granulometric considerations (e.g., grain size, sorting, ratio of quartz grains to clay matrix etc.) and the source of the individual groups would then have to be investigated by heavy mineral analysis.

This is not practicable with the very fine-grained well levigated wares and chemical analysis is ideally suited to such cases. Although this approach is useful in grouping wares of different origin, the actual source is not easy to ascertain, and it is usual to investigate this by considering distributional evidence. However, if a study is also made of the geochemistry of the principal clay deposits in the distribution area of the pottery, there is no reason why the sources should not be limited on chemical grounds. Catling, Blin-Stoyle and Richards (1963) claim that correspondence between pots and clay is not to be expected if the clays have been refined, and that dehydration on firing will alter the composition. However, Freeth (1967) has demonstrated by practical experiment and analysis that there is no reason why clays and pots should not be directly compared. For such comparisons to be valid it is, of course essential to ascertain that no extraneous matter has been added to temper the clay, and examination under the petrological microscope is a vital prerequisite.

Even if chemical analysis is ultimately adopted as the optimum method of investigation, it would be preferable to preface such work with a limited petrological investigation, in order to enhance understanding of how chemical elements are distributed in the paste: thus it may be possible to understand why a group of pots shows a particularly high concentration of a certain element or elements, e.g., a high calcium value might prove to be a result of the addition of limestone or shell to the clay (cf. Shepard 1968: vi).

In summary, the writer would advocate the adoption of the petrological microscope for the routine investigation of ceramics to be supplemented by chemical analysis where possible, rather than vice-versa.
4 Applications

Since not all archaeologists are equally enthusiastic about the encroachment of science into a field that was once a preserve of the arts (e.g., Hawkes 1968) it is perhaps as well to follow the above methodological outline with a discussion of the archaeological aspects of this work. In this section the writer proposes to review a few of the more important contributions that have been made to archaeology by the scientific study of ceramic fabrics.

It is appropriate that a survey of this type should begin with consideration of Anna Shepard's now classical work on the Rio Grande Glaze-Paint pottery (1942, 1966). Although not the earliest work of its kind, it was one of the first to bring home to the archaeological world the full value of the petrographical approach. Shepard studied the pottery from sites in the Upper Rio Grande Valley of New Mexico with particular reference to the sequence obtained from Kidder's excavation at Pecos, a site continuously occupied from about A.D. 1300 to A.D. 1838. Archaeological thought on the area had for many years proceeded on the assumption that the pottery at each site was locally made, hence it was supposed that although there were artistic stimuli from outside, the ceramic development of each site was essentially a local matter. As a result of a thorough and painstaking study of numerous thin sections Shepard revolutionized this by showing that there was a large-scale movement of pottery suggesting the existence of a hitherto unsuspected trade. Shepard was indeed fortunate in her choice of study area, for the varied geology made it possible to distinguish the products of different regions on the basis of rock temper. Materials such as andesite, basalt, tuff or sandstone had been added to the clay according to their local availability and these became the key to the classification of the pottery. It was possible to show the way in which the ceramic sequence at Pecos was related to innovations at specific localities and to changes in trade patterns.

In view of the remarkable success of this investigation conducted over thirty years ago, it is perhaps surprising that extensive studies of this kind have been few and far between until recent years, though the situation is rapidly changing. In Britain, the pioneer work of Cornwall and Hodges (1964) on Neolithic pottery has been followed by an extensive study of pre-Roman Iron Age pottery from western England (Peacock 1968, 1969b). Study of the pottery from the Severn Valley and Welsh Borderlands, comprising vessels ornamented with stamped impressed or linear tooled decoration, points to the Malvern Hills as the abode of specialist potters serving the region (Peacock 1968). The pots do not contain rock fragments local to the find-sites, but are instead tempered with igneous and metamorphic rocks which can only be matched in the Pre-Cambrian Malverian, or with limestone or sandstone, for which there are good grounds to postulate a source in the Malvern region. The transportation of raw materials rather than pots cannot be substantiated in view of the typological homogeneity between sites and the use of iron repair rivets on some sites, suggesting that the community did not possess people competent to make replacement vessels.

A similar conclusion resulted from the study of ornate 'Glastonbury' ware found on many Iron Age sites throughout south-western England (Peacock 1969b). Six centres of production in Cornwall, Devon and Somerset were postulated and doubtless others will
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The centralized production of Iron Age pottery is a new concept, and its implications go far beyond the light it throws on the social organization of the time. For the past forty years thought on the British Iron Age has proceeded within Hawkes’s ABC framework (Hawkes 1931, 1959). In the scheme put forward in 1959 Hawkes sought to explain the Iron Age in terms of a series of regional immigrations, the intrusive peoples ultimately merging with the indigenous population to produce new distinctive insular cultures. However, this scheme is based largely on a consideration of pottery since this is the only find common to the majority of Iron Age sites. Underlying the use of pottery evidence in this way is the assumption that it is made in the home so that the distribution of differently ornamented styles will represent the areas of settlement and influence of peoples of different cultural background (see Brailsford 1960). In the west of England, pottery studied can now be seen as a traded product, and the distribution of different styles may represent nothing more than the marketing areas of different groups of potters. Whether these correspond to the homes of different groups of people remains to be demonstrated. The evidence available so far does not favour this, for the pottery distributions cut across zones based, for example, on hill-fort architecture (e.g. Fox 1964: fig. 37). Thus in this case petrological study provides information which appears to cut at the basis of the accepted structure of the British Iron Age, and it is clearly desirable that pottery from the rest of lowland Britain should be investigated. Here the problems are greater, mainly because of lack of variation in the geology, a factor which greatly facilitated study in the west and south-west.

Most of the early work in Britain concerned with Neolithic pottery has recently been reviewed with a reassessment of the problem of the fine ‘Hembury’ ware, which was distributed through south-western and southern Britain in about 3300–3000 B.C. (Peacock 1969a). It was suggested that the fabric of this can be matched petrologically with the clay which is found above the gabbro outcrop on the Lizard peninsula in south Cornwall. Since the distribution of this pottery corresponds broadly with that of Cornish stone axes it was postulated that it may have been a trade ware. The movement of Neolithic pottery was, of course, demonstrated long ago when Obenauer (1936) isolated petrologically five imported groups from the settlement at Köln-Lindenthal. In one case, (Import II), the presence of basaltic hornblende, augite, plagioclase and biotite led him to postulate a source in the volcanic areas to the south of Cologne. It has been customary (Clark 1952: 251) to equate these imports with occasional visits of people from another area, but if a trade hypothesis is accepted for the fine Hembury ware, it might also apply to the Cologne material.

It would, however, be wrong to give the impression that petrological study is only of value when the long-distance movement of pottery can be demonstrated. It is always valuable to have scientific confirmation of a local source and this at least puts subsequent ceramic discussion on a sound basis. Krug (1965), for example, has studied the ceramics from the kingdom of the Cimmerian Bosphorus (between the sea of Azov and the Black Sea) demonstrating production at Panticapaeum, Phanagoria and Hermonassa. The local origin was confirmed by careful comparison with clays from the Kerch and Taman peninsulas involving separation and study of heavy and light fractions and differential
thermal analysis. The latter was used in comparison of clay from Phanagoria with pottery. On applying heat at a steady increasing rate, clays display endothermic and exothermic reactions at different temperatures depending upon their composition, and the Phanagorian clays and pottery displayed similar characteristics.

Krug (1965) also made an extensive study of the pottery of the Cherniakov culture, produced over wide areas of the Ukraine in second to fourth centuries A.D. The coarse wares varied petrologically from site to site, and sometimes within a single site, as a result of the use of different local raw materials. However, the contemporary fine black polished ware with inclusions principally of quartz, 0.1-0.3 mm. across, displayed a remarkable homogeneity in microtexture throughout the area studied. It appears that potters, working at different centres, were producing a remarkably consistent paste regardless of variations in the local clay available, and Krug suggests there must have been a single widely used technological recipe in circulation throughout the area.

Space does not permit further discussion of the application of petrology to ceramics but other examples are the works of De Angelis (1960), Farnsworth (1964), Felts (1942), Gladwin (1937), Guerreschi (1966), Reyman (1959), Sundius (1955) and Williams (1967), while more references to the Russian literature are to be found in papers by Krug (1965) and Petrun (1966).

Spectrographic analysis has produced much valuable information about the movement of ancient pottery. An important study of Mycenaean and Minoan pottery, involving the analysis of over 500 sherds, has been published by Catling, Richards and Blin-Stoyle (1963), but this will not be discussed here as it has already been criticized in detail by Shepard (1968: iv) who suggests that the results might have been clarified by study of thin sections. This deficiency has now apparently been rectified (Millett and Catling 1967) but the results have not yet been published. The spectrographic work has continued since 1965 when Shepard wrote her review (Catling and Millett 1965 a and b, 1966, 1969) and more data are awaiting publication. This study which now involves more than a thousand samples from over fifty sites is of considerable importance and interest.

Another useful spectrographic investigation is the study by Hartley and Richards (1965) of 270 sherds of Romano-British mortaria. These, trituration grits apart, are often fine-grained and may not be so amenable to microscopic examination. The study was largely restricted to kiln finds with the objective of setting up reference standards to facilitate the recognition of the products of different centres. Although extreme differentiation was exceptional, the results clearly demonstrate the feasibility of chemical characterization of mortaria. Used in conjunction with archaeological evidence, the results are of particular value in, for example, tracing the movements of potters such as C. ATTIVS MARINVS who appears to have worked at three widely separated places – Colchester, Radlett (Hertfordshire) and Hartshill (Warwickshire).

As further examples of the application of spectrographic analysis we may cite papers by Musty and Thomas (1962) and Payne (1966).
5 Conclusions

Although the above survey is of necessity brief and by no means comprehensive, it should be evident that the scientific analysis of pottery fabrics has an important role in archaeological research. It is perhaps not too much of an exaggeration to claim that studies which consider typology alone are based on about half of the available data. Admittedly, the two classes of information are not always of equal importance: in some cases study of fabric may add little to what can be deduced on typological grounds, but frequently knowledge of the composition is essential if the evidence is to be correctly assessed. This applies particularly to primitive ceramics, which often have an exaggerated place in archaeological thought because of the lack of other evidence. We can no longer assume that hand-made pottery is of necessity home made, nor can we deduce the organization of pottery production by analogy with the activities of present-day primitive potters. Objective scientific methods are available for assessing such questions and the need is for their application.

However, this is not to claim that the technique is perfect. The chemical approach would benefit from more work on the selection of elements for study, while in petrology one of the most pressing needs is for the adoption and application of suitable granulometric methods for characterizing the ubiquitous sandy wares in thin section. At present the comparison of such sherds tends to be somewhat subjective, the petrologist pronouncing whether the fabrics 'look' alike under the microscope. In practice these comparisons have limited value, for the texture of a sandy potsherd is an extremely complex matter, depending on factors such as the proportion of sand to clay, roundness of the grains, their sphericity and the properties of the size distribution. If each of these were isolated, measured, and expressed in terms of mathematical parameters as is customary with sedimentary rocks, it would put the study of such wares on a much more objective basis. The writer is engaged in research into this question and a report will be published in due course.

The last decade has seen impressive advances in instrumentation and doubtless this trend will continue. A particularly interesting and very recent development is the use of a portable X-ray fluorescent spectrometer for on-site analysis of ceramics (Frierman et al. 1969). The advantage of this approach is that it enables problems thrown up by the analysis to be investigated on the site, and could prove of considerable importance, particularly on sites of difficult access.

In general, the most successful analyses appear to be those carried out on a large scale, drawing on contemporary pottery from sites throughout a wide geographical region. By contrast the writer knows of a number of references, which need not be cited, where geologists of repute have come to the wrong conclusion about the source of a sherd simply because they were asked to pronounce upon a single piece which they were unable to see in its true distributional perspective.

If we are to see an increase in the scope of analyses in the future as seems desirable, it will soon be necessary to introduce objective methods to sort and classify the mass of scientific data obtained. The computer has already been used in typological work (Clarke 1962) and there is every reason for applying it to fabric studies. The problem of grouping chemical analyses of ceramics is analogous to that of metal analyses and the methods
discussed by, for example, Hodson (1969) could apply to this field also. Furthermore, petrological data can easily be coded in a manner suitable for computer analysis and Krug and Krug (1965) have already pioneered a statistical method for classifying pottery on the basis of thin sections. The development of such approaches may well be the most important aspect of ceramic analysis in the next few years.

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References


