Ceramic Petrography

The Interpretation of Archaeological Pottery & Related Artefacts in Thin Section

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Cover images

Thin section photomicrographs of archaeological ceramic samples. Grog temper in Late Prehistoric pottery from southern California (left) and secondary calcite deposition within voids in Anglo Saxon pottery from England (right). Crossed polars. Image width = 3.8 mm.

Contents

Preface

This book examines the nature of ancient ceramics in thin section under the polarizing light microscope and provides methodological and practical guidelines for their petrographic study within archaeology. By presenting colour photomicrographs of a wide range of ceramic artefacts from many of different archaeological periods and geographic regions, it can be used as a reference manual for the identification and interpretation of the compositional and microstructural phenomena that occur within ancient ceramic thin sections. The detailed accompanying text and logical chapter structure means that it may also serve as a course book for specialist training on thin section petrography and archaeological ceramic analysis, as well as for self-study at the microscope.

The book is structured according to the main steps involved in the compositional characterization, classification and interpretation of archaeological ceramics in thin section. Individual chapters are dedicated to the themes of provenance determination and technological reconstruction, that are common to petrographic studies on ancient ceramics. The main focus of the book is utilitarian, coarse, earthenware and terracotta pottery, which dominates most ancient ceramic assemblages. However, other types of ceramic wares and related materials are discussed and illustrated throughout the book, particularly in the final chapter.

It is assumed that the reader has a basic knowledge of optical mineralogy and the thin section petrography of rocks. The book should be used in conjunction with standard geological texts and identification guides dedicated to these topics, rather than as an alternative to them.

The book has drawn upon the personal research and teaching experience of the author as well as a general body of knowledge on archaeological ceramic analysis and thin section petrography. A further reading section is given at the end of each chapter. These works present relevant studies that the reader can refer to for more detail on specific topics.

Given that few publications dedicated to thin section ceramic petrography exist and the approach is undertaken in a number of different ways, this book is likely to contain some views or interpretations that divide opinion. Attempts have been made to cover a range of alternative methodologies and applications in addition to those of the author, where these are relevant to the topics being discussed. However, it is inevitable that the book contains some omissions.

1 Introduction to Archaeological Ceramic Analysis & Thin Section Petrography

Archaeological ceramics are clay-rich inorganic artefacts that were produced and used by past humans. They include pottery (Fig. 1.1), figurines, bricks, tiles, daub, crucibles, moulds, tuyères, clay smoking pipes, loom-weights, seals, stamps, clay writing tablets and a range of other functional objects. Ceramics represent some of the earliest synthetic materials that were intentionally created by human hands. In many cases they were fired by the application of heat. The discovery of the unique material properties of clay and the manipulation of these to create hard, semi-permanent objects of a desired shape was a crucial step in the development of ancient craft technology.

The widespread use of ceramics in many past societies and their relatively slow degradation in the archaeological record makes them one of the commonest types of ancient artefacts of many periods and geographic regions (Fig. 1.2). As such they represent a key resource with which to interpret the activities of past humans and reconstruct aspects of their cultures. Archaeological applications of ceramics include dating and the identification of cultural groups, the interpretation of subsistence and ceremonial activities, the detection of trade and exchange, the reconstruction of craft technology and traditions. They can also be used to speculate about deeper, less tangible aspects of past cultures such as their belief systems, their ritual activities and their identities.

In order to address the above topics, it is necessary to collect specific types of data from ancient ceramic assemblages and interpret this within their wider archaeological context, as well as an appropriate theoretical framework. Ceramics can be studied on many levels, using numerous different techniques. These range from the simple visual observations of their gross form and surface decoration to the scientific characterization of their compositional signatures and microscopic structures using sophisticated analytical equipment (Fig. 1.3).

The detailed study of the clay-rich material that ancient ceramics are made of is referred to as 'ceramic compositional analysis'. This can be roughly subdivided into geochemical and mineralogical approaches. Geochemical techniques such as instrumental neutron activation analysis (INAA), X-ray fluorescence (XRF) (Fig. 1.3) and inductively coupled plasma mass spectrometry (ICP-MS) are used to characterize the elemental signatures of ancient ceramic artefacts, often down to the level of parts per billion. Mineralogical techniques on the other hand focus on the mineral phases within which the constituent elements of a ceramic exist. This can be determined by means of X-ray diffraction (XRD) or observed under the polarizing light microscope in thin section (Fig. 1.4).

Geochemical and mineralogical techniques of ceramic compositional analysis share similar goals and theoretical assumptions and they are therefore largely complimentary. Both approaches are normally used to detect and document archaeologically meaningful compositional patterning within ancient ceramic assemblages. This reflects the types of raw materials and the techniques that were used

Fig. 1.1 Archaeological ceramics. Selected pottery vessels recovered from a Bronze Age tomb at Jericho during the 1952-1958 excavations. Photo from archive of Institute of Archaeology, London.

Fig. 1.2 Archaeological ceramics in the field. A workman sitting on a pile of discarded pottery sherds during excavations at Jericho in 1958. Photo from archive of Institute of Archaeology, London.

Fig. 1.3 Apparatus used for the instrumental analysis of archaeological ceramics. An X-ray fluorescence spectrometer (XRF) (left) and a scanning electron microscope with an energy-dispersive spectrometer (SEM-EDS) (right).

Fig. 1.4 A simple, inexpensive polarizing light microscope being used to examine an archaeological ceramic thin section. Detailed compositional analysis can be performed on such a microscope, which has several objectives, an analyser and a graticule.

in their manufacture. Data from the compositional analysis of archaeological ceramics is typically used to interpret their place of manufacture or 'provenance', thus providing evidence for the for movement of ceramics via processes such as trade and exchange, distribution and migration. In addition, thin section petrography and scanning electron microscopy (SEM) (Fig. 1.3) can be used to detect compositional and microstructural evidence for the technological steps involved in the manufacture of ceramics. This information is of value to studies ceramic production, craft tradition and the transmission of knowledge.

1.1 Thin Section Ceramic Petrography

Thin section ceramic petrography is a form of ceramic compositional analysis that is concerned with the characterization and interpretation of ancient ceramic artefacts in 'thin section' under the microscope. Thin sections are 30 μm thick slices of an artefact, fixed onto a glass microscope slide (Figs. 1.5 & 1.6) (Section 2.2). They are used in the geological disciplines of optical mineralogy and thin section petrography to analyze and classify rocks and minerals. Thin sections are studied with a 'polarizing light microscope' or 'petrographic microscope' (Fig. 1.4). This uses two types of light: plane polarized light (PPL) (Fig. 1.7), which is similar to regular transmitted light and crossed polars (XP) (Fig. 1.8), in which the light is polarized in two directions and interacts with the mineral specimens in the thin section, producing optical effects that can be used for their identifcation.

Ceramic petrography applies the techniques of optical mineralogy and thin section petrography to archaeological material in order to identify the types of mineral and rock 'inclusions' that they contain (Figs. 1.7 & 1.8) (Section 3.2). Naturally occurring clay is a form of 'argillaceous' material and thus archaeological ceramics share certain common characteristics with fine-grained clastic sediments. Ceramic petrography incorporates methodology from sedimentology and sedimentary petrography, such as the description of particle shape and texture (Sections 4.1.3.1 & 4.2). The abundant clay minerals within the 'matrix' of archaeological ceramics (Figs. 1.7 & 1.8) (Section 3.1) are too small to be studied individually in thin section. Instead, ceramic petrography draws upon principles from the microscopic study of soils or 'soil micromorphology' to describe the nature of the matrix as well as the pores or 'voids' that occur in ceramic artefacts (Figs. 1.7 & 1.8) (Section 3.3).

Despite their relationship to naturally occurring argillaceous sediment, archaeological ceramics are more than just fired clay or soil. As synthetic artefacts that have been manipulated by human hands, they bear evidence of the technologies involved in their manufacture (Chapter 6). This is an important distinction that sets ceramic petrography apart from the microscopic study of natural earthy materials such as minerals, rocks, sediments and soil. A key aspect of the approach is therefore an appreciation of the craft of ceramic manufacture. This is normally provided by ethnographic studies of traditional pottery production, historical records and basic knowledge from materials science. Experimental archaeology is also used to investigate the effects of specific manufacturing techniques on natural raw materials and is an integral part of ceramic petrography.

The main aims of ceramic petrography are compositional characterization

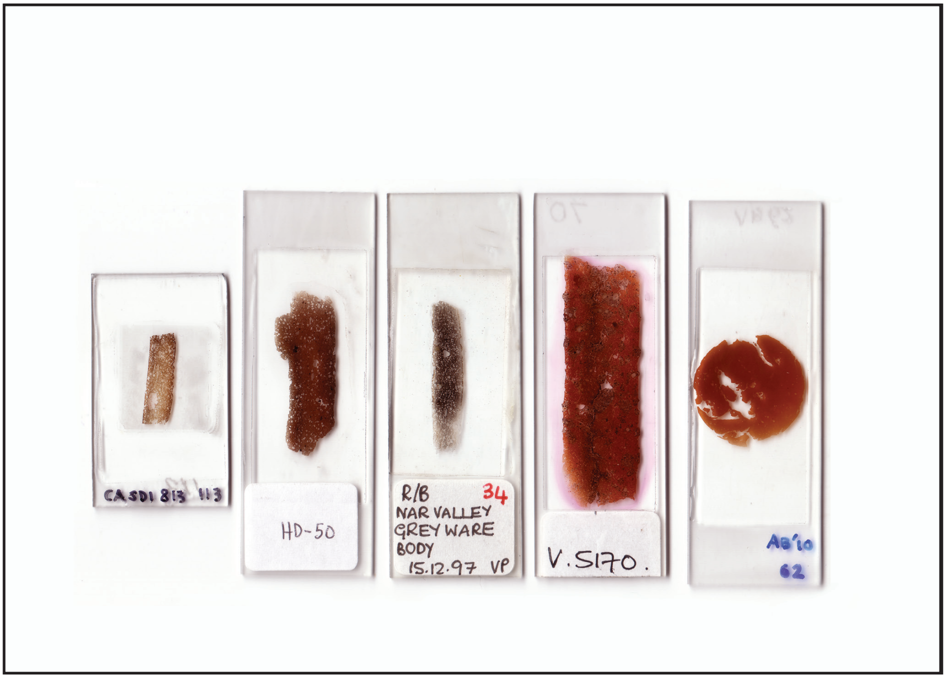
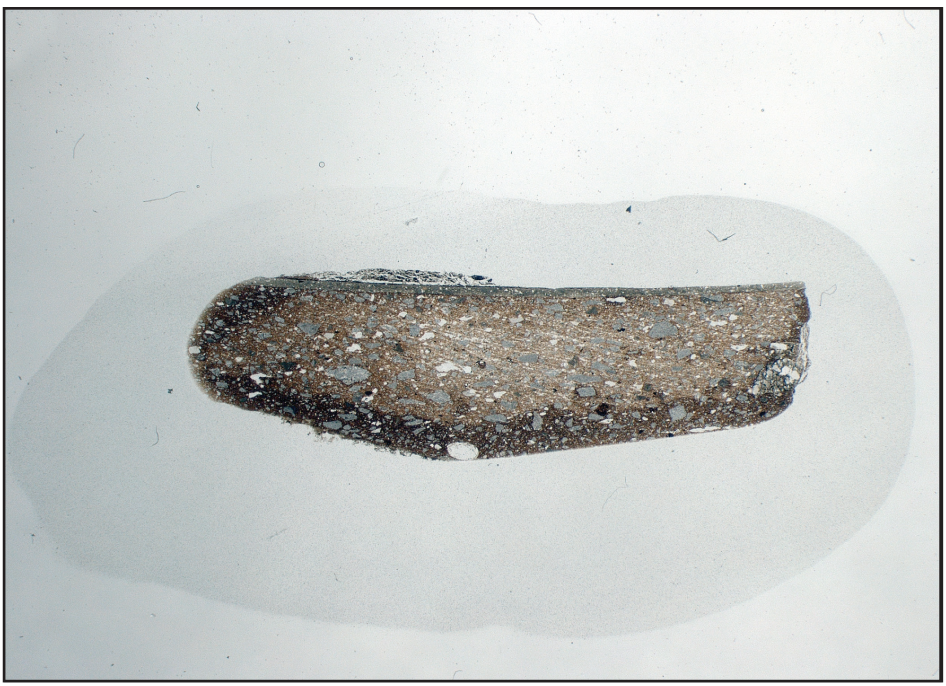


Fig. 1.5 Archaeological ceramic thin sections. These thin sections have been produced with the common 76 x 26 mm and 46 x 26 mm glass slides.

Fig. 1.6 A thin section prepared from a sherd of archaeological pottery, seen at low magnification under the polarizing light microscope. Image width = 25 mm.



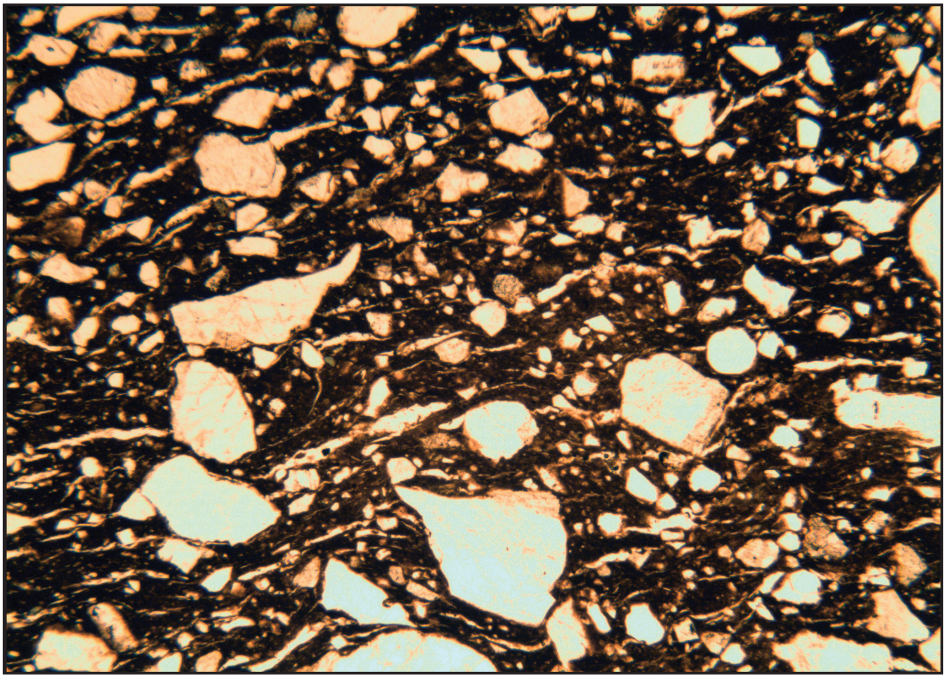
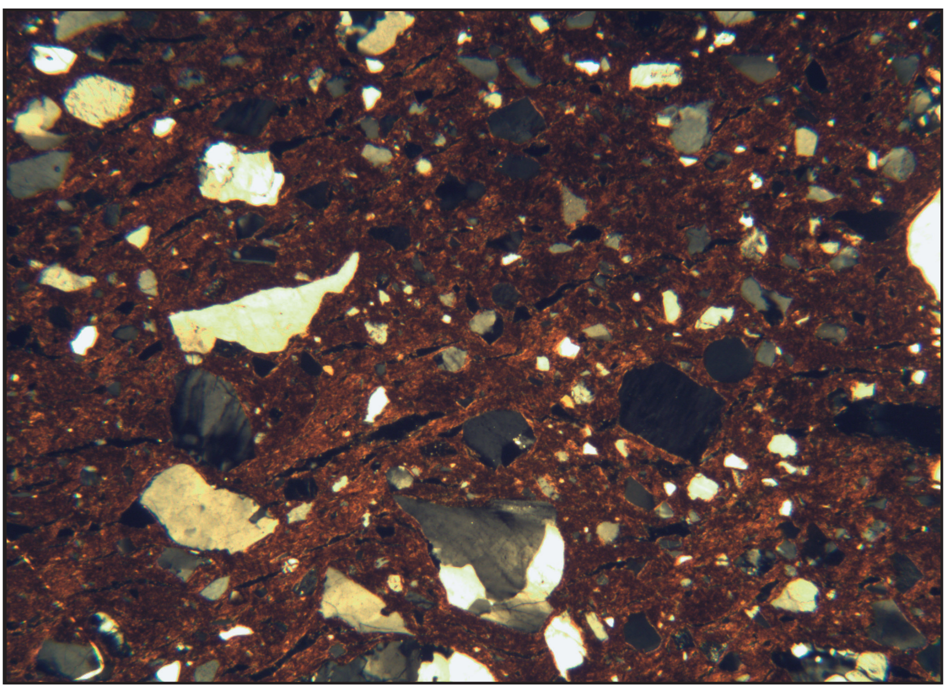


Fig. 1.7 An archaeological ceramic thin section seen at high magnification under the light microscope with plane polarized light (PPL). The white areas are particulate inclusions and pores within the brown clay rich material from which the artefact was made. Compare with figure below. Neolithic pottery, Greece. Image width = 3.8 mm.

Fig. 1.8 The same sample as above, but seen in crossed polars (XP). The white and grey quartz inclusions can be distinguished from the black pores in this image. Neolithic pottery, Greece. Image width = 3.8 mm.



(Chapters 3 & 4), classification (Chapter 4), the interpretation of provenance (Chapter 5) and the reconstruction of technology (Chapter 6). In addition, it can be applied to the conservation of ceramic artefacts and structures by documenting the nature of their original raw materials and studying aspects of their deterioration. Ceramic petrography also has a limited role to play in the field of authentication.

Ceramic petrography is most frequently performed on relatively coarse, low-fired, utilitarian pottery vessels such as earthenware and terracotta, which tend to dominate ceramic assemblages, especially in prehistoric contexts. These are well suited to thin section analysis due to their abundant inclusions as well as their perceived low importance compared to more elaborately decorated fine wares. However, ceramic petrography can in some cases provide important insights into finer, higher fired pottery vessels such as stoneware, fritware (Fig. 1.9) and sometimes porcelain (Section 7.6).

A wide range of non-pottery ceramic artefacts are also studied in thin section, including bricks and tiles (Section 7.1), daub, metallurgical tools such as crucibles, moulds and tuyères (Section 7.3), as well as clay smoking pipes, loom-weights, seals, stamps and clay writing tablets (Section 7.4). The petrographic analysis of ancient cementitious building materials including plaster and concrete (Fig. 1.10) (Section 7.5) is closely related to that of archaeological ceramics and falls loosely within the general remit of ceramic petrography. These and other building materials are also analysed in thin section within engineering materials science.

Ceramic petrography is mostly used to examine the composition of the main body or 'paste' of ceramic artefacts. However, thin sections can also provide important information about the nature of finishing layers and other types of decoration (Section 6.4), as well as deterioration effects and external deposits (Section 6.8).

Petrographic data from the study of ancient ceramics in thin section is interpreted within its archaeological context in order to answer specific questions about the sites, cultures or archaeological periods from which the artefacts came. Theoretical concerns from the field of material culture provide a framework with which to structure ceramic petrographic data. Ceramic petrography can be used on its own as a research tool for interrogating aspects of the composition, technology and provenance of ancient artefacts. However, it works best when combined with data from the traditional macroscopic study of ceramics or other compositional analytical techniques such as geochemistry and SEM, in what has been referred to as an 'integrated' approach.

There is some debate over the correct name for the technique of analysing archaeological ceramics in thin section. The terms 'ceramic petrography' and 'ceramic petrology' are both widely used, sometimes interchangeably, and may therefore be considered as synonyms. In geology, the term petrography refers more specifically to the description and classification of rocks under the microscope, whereas petrology encompasses all aspects of their study. However, as archaeological ceramics usually contain abundant isolated mineral inclusions as well as fragments of rock (Section 3.2), neither term fully describes their study in thin section. Furthermore, ceramics are composed of abundant clay minerals that are too small to be seen individually in the polarizing microscope (Section 3.1) and cannot therefore be studied via optical mineralogy. The description of the microscopic plastic clay features as well as the voids in archaeological ceramics falls outside of the scope of geological thin section petrography and has more in common with soil micromorphology (Section 4.1.3.2). If the aim of ceramic

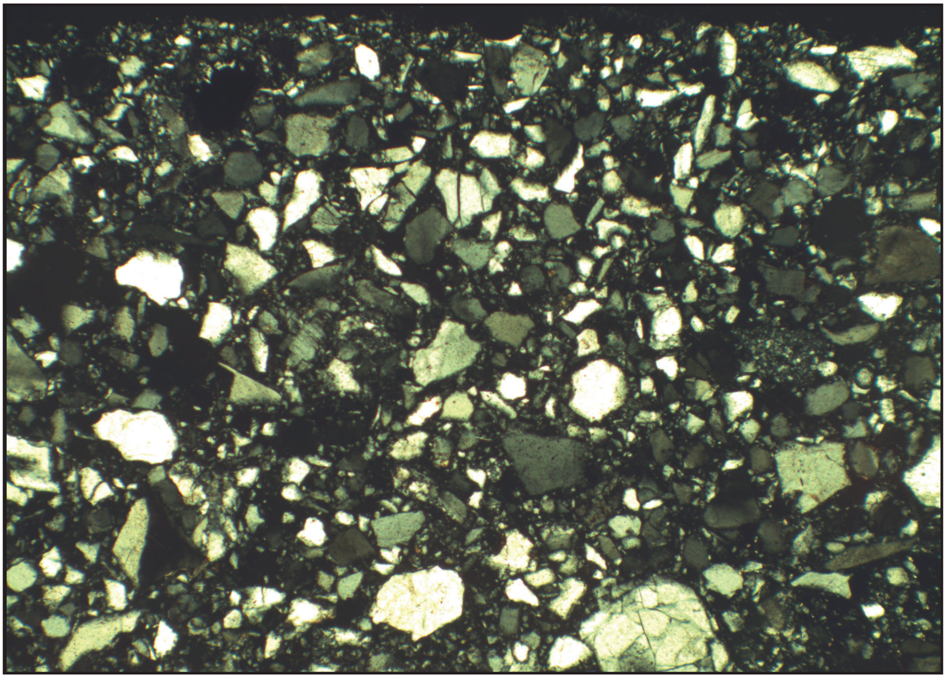
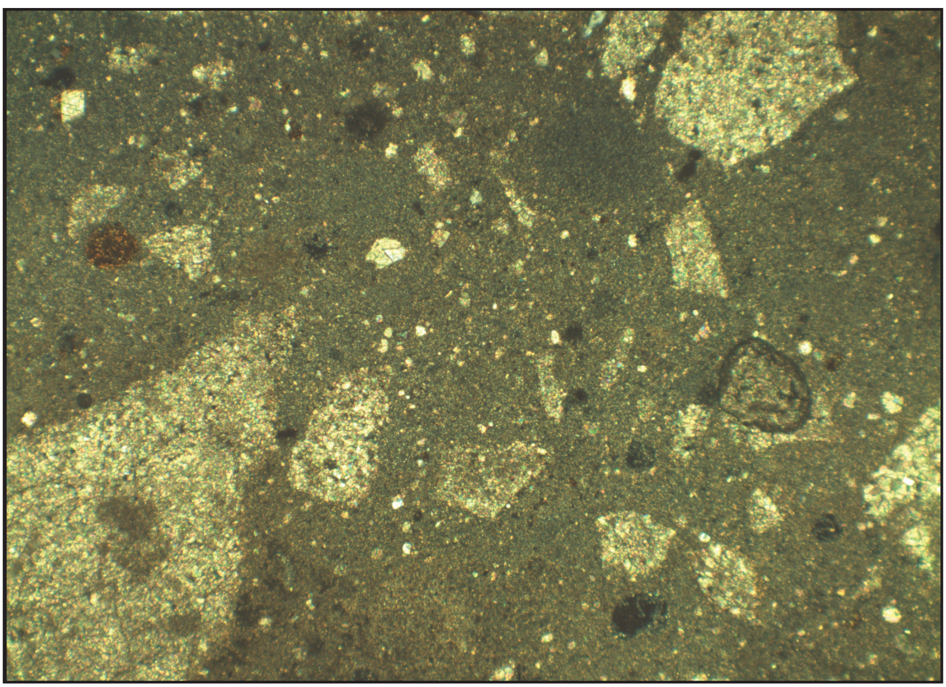


Fig. 1.9 Photomicrograph of fritware ceramic artefact in thin section. The paste of this sample contains only a relatively small amount of clay and was made from the mixture of crushed quartz and a glass frit. Islamic tile, India. XP. Image width = 2.9 mm.

Fig. 1.10 Photomicrograph of cementitious archaeological material in thin section. This is composed of a carbonated lime binder with angular limestone aggregate. Roman plaster, Greece. PPL. Image width = 2.9 mm.



petrography is to characterize and interpret the totality of ceramics in thin section under the microscope, then a more general term such as 'ceramic thin section analysis' might be more appropriate. Other labels given to the approach include 'mineralogical analysis' and 'optical microscopy', as well as abbreviations such as 'OM' and 'PE'.

The number of different names given to ceramic petrography is matched by equal diversity in methodologies by which the technique is carried out. This is perhaps a consequence of its interdisciplinary nature and a strong reliance on approaches from the earth and environmental sciences, which are sometimes applied to ceramics without sufficient modification. Archaeologists, geologists and engineering material scientists independently undertake petrographic analysis of ancient ceramics, each guided by their own experience, standpoints and biases. This situation does not encourage standardization. Indeed, the range of different types of publications in which petrographic research appears (Section 1.3), has led to much diversity in approach as well as some unnecessary repetition. As a consequence similar studies on contemporary artefacts from the same region are sometimes not easily comparable and therefore do not benefit sufficiently from one another's findings.

The beginnings of a standardized methodology for the qualitative description (Section 4.1.2) and quantitative classification (Section 4.2) of archaeological ceramics in thin section have existed for some years, but have not been universally adopted. The increasing use of on-line publication and data sharing via the Internet is likely to necessitate greater standardization in the field of ceramic petrography. This will hopefully lead to increased compatibility between studies and therefore more reliable and detailed interpretations of ancient ceramic material culture.

Ceramic petrography is normally carried out by scientifically trained archaeologists, or earth scientists with an interest in archaeology. The approach is currently taught as part of a relatively small number of specialist university modules, usually in archaeological or anthropological departments. Trained students apply the technique to ancient ceramic assemblages as part of master's dissertations or PhD theses on material from a wide range or periods and geographical origins. Whilst the majority of petrographic research into ceramics is undertaken in an academic environment, a number of professional archaeological units and independent specialists provide a dedicated commercial analytical service for larger research projects. These typically draw upon the findings of relevant academic research and vice versa.

Ceramic petrography is relatively low-tech compared to geochemical approaches of compositional analysis and SEM (Figs. 1.3 & 1.4), which require the use of more sophisticated analytical equipment and preparation techniques. The fundamentals of thin section preparation and polarizing light microscopy have changed little since their introduction in the 19th century (Sections 1.2, 2.2 & 2.3). For this reason, the technique is often regarded as somewhat old fashioned sufficiently cutting edge. Whilst it is certainly not as new or technologically sophisticated as approaches such as INAA, XRF, XRD or ICP-MS, the necessary equipment is much more affordable and easier to set up. The lower cost of thin section petrography relative to other instrumental approaches also means that larger numbers of samples can be analysed within a specific project.

The true value of thin section petrography, which sets it apart from geochemical approaches to compositional analysis, lies in its ability to investigate both the provenance and technology of ancient ceramics. Having been applied to archaeological material for over one hundred years (Section 1.2), it is both well established and widely known outside the scientific archaeological community. Despite these benefits, the approach remains somewhat under utilized in certain parts of the world or is infrequently applied to the ceramics of specific archaeological periods. The huge range of petrographic and microstructural features that can exist with archaeological ceramics in thin section means that the fundamentals of the technique are perhaps as less clear-cut and easy to grasp than instrumental analytical approaches, which deal mainly with a limited number elements and their abundances. This can make ceramic petrography seem less accessible and has led some scholars to liken it to an 'art' as well as a science.

Like all analytical techniques, thin section ceramic petrography is not without its limitations. The resolution of the polarizing light microscope means that petrography cannot be used to determine the clay mineral composition of archaeological ceramics (Section 3.1). Similarly, artefacts characterized by fine inclusions can be difficult to study in thin section and ascribe to a place of origin (Section 5.3). For these and other reasons petrography is not always applicable to all archaeological ceramic material. Wherever possible, it should be combined with and complimented by other techniques of ceramic analysis such as geochemistry, SEM and XRD.

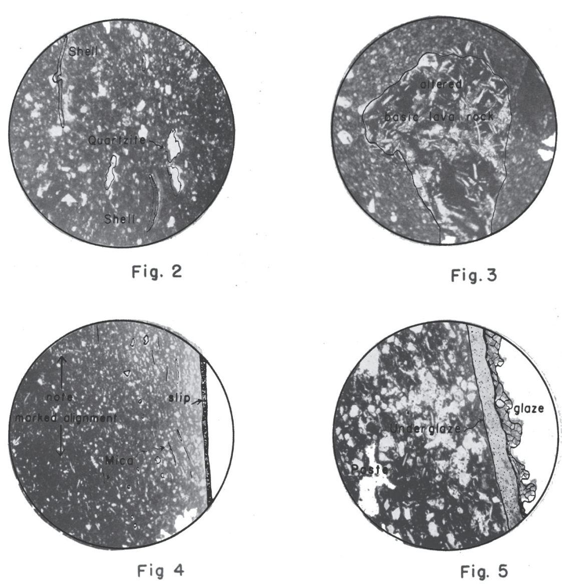
1.2 A Brief History of Ceramic Petrography

The potential of examining archaeological ceramics in thin section under the microscope was first appreciated as early as the mid-late 19th century. Henry Clifton Sorby, a British scientist who is credited with the initial development of thin section petrography as a method for studying rocks, quickly applied his new technique to archaeological specimens, including Roman and Medieval bricks and tiles from eastern England. However, the earliest published account of the petrographic character of archaeological ceramics in thin section appeared in 1879, in a geological monograph on the volcanic history of the island of Santorini, produced by Ferdinand Fouqué. Fouqué, who collaborated with noted French microscopist Auguste Michel-Lévy, identified volcanic inclusions within prehistoric Theran pottery and illustrated these by means of hand-drawn colour micrographs (Fig. 1.11). At around the same time, Anatole Bamps and Gustav Nordenskiöld both applied thin section petrography to native pottery specimens from North America. Nordenskiöld's 1893 study of sherds from Mesa Verde in Colorado highlighted the potential of mineralogical identification for the determination of pottery provenance.

Despite the pioneering research of Fouqué, Nordenskiöld and others, thin section petrography appears to have been applied to archaeological ceramics on an ad hoc basis until the work of American archaeologists Anna Shepard and Wayne Felts in 1942. Shepard undertook the first large-scale petrographic study of archaeological ceramics, thin sectioning 679 sherds of Rio Grande Glaze Paint pottery from New Mexico. She classified samples based on the petrographic composition of their temper and related these to local geology to identify several different areas of production. Felts applied petrography to pottery from Troy in western Turkey and demonstrated the technological information that is visible in ceramic thin sections under the microscope. His observations of the evidence in thin section for the forming and firing of ceramics (Fig. 1.12) were very incisive for their time.

Fig. 1.11 Hand drawn micrographs of prehistoric pottery from Santorini from the study of Ferdinand Fouqué. These illustrate volcanic inclusions deriving from the use of the local raw materials of this volcanic island. From Fouqué (1897, plate XLIV).

Fig. 1.12 Early photomicrographs of archaeological ceramics in thin section, from the work of Wayne Felts at ancient Troy. His interpretations are overlaid on the photomicrographs. From Felts (1942, plate XIV).



The 1960s saw the publication of several important petrographic studies of archaeological ceramics and the application of the approach in new geographic areas. The work of David Peacock in Britain established a tradition of ceramic petrography that continues to the present day. Peacock's 1969 study of gabbroic inclusions in Neolithic Hembury 'f' ware sherds from numerous sites in southwest Britain demonstrated long distance movement of this pottery from a restricted source in the Lizard Peninsula of Cornwall (Fig. 1.13). The suggestion that coarse, hand-made vessels had been transported and perhaps traded over significant distances in prehistoric times had far reaching implications for the view of pottery in this period. Elsewhere in Europe, Marie Farnsworth, who was trained in thin section petrography by American mineralogist Paul Kerr, investigated the provenance of cooking pottery used in Attica from the 6th-4th centuries BC. She was able to distinguish between ceramics from Athens, Corinth and Aegina based on their respective metamorphic, sedimentary and igneous inclusions. Like Peacock, Farnsworth demonstrated that there was a 'lively industry' in coarsewares in Classical Greece.

Thin section ceramic petrography was finally established as a recognized scientific approach in the 1970s and 1980s with the rise of Processual Archaeology. This saw it applied on a more routine basis in certain parts of the world, including Britain and the Mediterranean. Important proponents included researchers at University of Southampton, trained by Peacock, who applied petrography to pottery and other ceramic materials from a range of archaeological periods and geographical regions. The Southampton Aegean Project, which involved both John Riley and David Williams, used ceramic petrography on a systematic basis to study Mycenean and Minoan pottery. Riley published what may be the first petrographic fabric descriptions in his 1981 study on coarseware stirrup jars from Mycenae. In 1983 he noted the value of microfossil inclusions (Section 5.8) as a means of investigating the clay sources of Late Minoan finewares from the palace of Knossos.

In 1971 whilst studying Roman pottery from Sussex, England, Peacock applied sedimentological approaches such as textural and modal analysis (Sections 4.2.1 & 4.2.2) to ceramic thin sections for the first time. This quantitative data enabled him to define petrographic groups within these quartz-rich ceramics. Peacock and others at the time viewed archaeological ceramics as a type of sandy metamorphosed sedimentary rock, on account of their argillaceous composition and the high temperatures to which they were subjected during firing.

Though various aspects of pottery technology had been noted very early on by Felts and tested experimentally by researchers such as Henry Hodges in 1962, it was not until the work of Ian Whitbread (Fig. 1.14) that ceramics were treated as synthetic cultural materials and analysed accordingly. Working at the Fitch Laboratory of the British School at Athens, Whitbread recognized the value of descriptive terminology from soil micromorphology as a means of dealing with the plastic clay component of ceramics. He included these in his proposal for the detailed description of archaeological ceramic fabrics, which was first published in 1989. Whitbread applied this methodology to a large-scale study of the production and trade implications of Greek transport amphorae, which appeared in 1995. An important influence on petrographic studies at this time was Frederick Matson, who took an ecological approach to the study of traditional ceramic production systems and advocated the use of scientific methods to

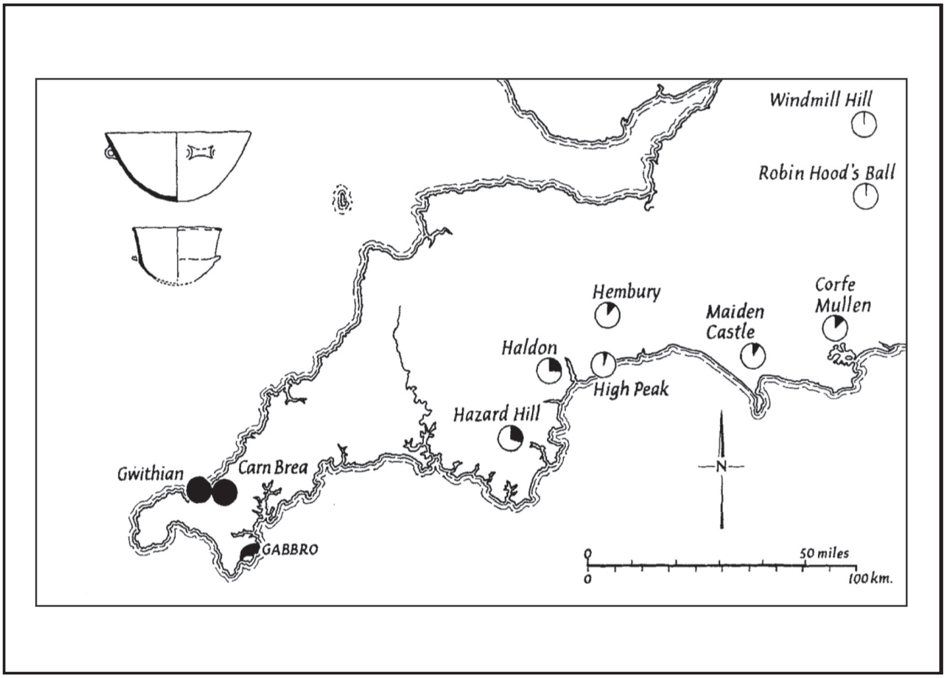


Fig. 1.13 David Peacock's classic petrographic study indicating the movement of grabbroic pottery from the Lizard Peninsular to Neolithic sites in southwest Britain. From Peacock (1969, fig. 1, p. 147).

Fig. 1.14 Dr Ian Whitbread studying sherds at Sparta, Greece. In the 1980s and 90s, while working at the Fitch Laboratory of the British School at Athens, Ian pioneered a holistic approach to the description of ceramic fabrics in thin section.

examine the technology of archaeological material.

Researchers at the British Museum's Department of Scientific Research including Andrew Middleton and Ian Freestone contributed significantly to the development and widespread application of ceramic petrography in the 1980s and 1990s. The British Museum was the venue for two important meetings in dedicated to the approach and attended by researchers from around the world. These were published in two key edited volumes that appeared in 1982 and 1990 respectively (Fig. 1.15) (Section 1.3). In 1988 Middleton, Freestone and others founded the 'Ceramic Petrology Group' (CPG) as a forum for British-based researchers examining ceramics in thin section at this time. The group, which is still active today (Fig. 1.16) and has members around the world, has encouraged several generations of ceramic analysts and published some important contributions within its newsletter 'The Old Potter's Almanack'.

Thanks to the work of Middleton and Freestone, David Williams of Southampton and the activities of Alan Vince, thin section petrography was applied on an almost routine basis to large numbers of British ceramics during the 1980s and 1990s. These appeared as petrographic appendices to site publications as well as in unpublished specialist reports. Vince, who worked at the Museum of London and later as a freelance finds analyst, applied petrography alongside techniques such as ICP to investigate the provenance of pottery from many British sites. His work on Medieval and Saxon pottery is particularly impressive and is summarized in a review published in 2005.

Since the early 1990s researchers at University of Sheffield, under the leadership of Peter Day, have applied ceramic petrography to prehistoric Aegean ceramics, mainly from Crete. In addition to contributing to the knowledge of regional pottery production and trade on the island, they have brought petrographic data to bear on key issues in Minoan archaeology such as craft specialization and consumption practices. Ceramic analyses at Sheffield have emphasized the value of combining petrographic and geochemical data, seeing them as complimentary techniques rather than alternative standpoints (Sections 4.2.4 & 5.3). The 'GEOPRO' research network, which brought together workers from five European countries, tackled these and other important issues in the determination of ceramic provenance via thin section petrography.

Whitbread's pioneering research at the British School at Athens was continued by a succession of 'Petrography Fellows' working at the Fitch Laboratory from the 1980s until the present day. The lab contains perhaps the largest collection of thin sections of Greek ceramics and remains a leader of petrographic research in this area.

Despite the pioneering work of Nordenskiöld, Shepard and others, ceramic petrography was not as widely adopted as a method of studying North American ceramics as it was in Europe, with preference given instead to more quantifiable instrumental techniques of compositional analysis such bulk geochemistry. To a large extent this situation continues to the present day, with petrographic studies of native ceramics much less common than those on Old World material. However, several exceptions exist, such as the tradition of quantitative petrographic analysis in southern Arizona. Starting with the work of Wallace Roberts in 1957, numerous researchers have used petrography to provenance the Hohokam pottery of this area, comparing sherds with sand samples collected in the field. In the late 1980s, James Lombard took the approach further by building up a quantitative database of sand composition in the Tucson basin and implementing a 'petrofacies' provenance methodology that involves detailed point

Fig. 1.15 Edited volumes dedicated to thin section ceramic petrography. All three books followed important meetings on the topic, held in England in 1980, 1987 and 2008 respectively.

Fig. 1.16 A meeting of the Ceramic Petrology Group (CPG) in Nottingham, England in 2010. The CPG and similar forums provide a means of disseminating research, exchanging ideas and getting to know other specialists in the field.

counting of ceramics (Section 4.2.3). The procedure of analysing comparative raw materials first and ceramic objects second, differed from the prevailing methodology elsewhere and proved to be particularly well suited to the largely sand-tempered material of Arizona. Lombard's efforts have been painstakingly continued by researchers at the Center for Desert Archaeology in Tucson, such as Elizabeth Miksa and James Heidke, permitting increasingly detailed provenance ascriptions of native sherds and enabling the testing of theories of ceramic production and interaction (Section 5.7). A quantitative petrographic approach based on the proportions of clay matrix, natural inclusions and temper was also developed by James Stoltman of University of Wisconsin, Madison and applied to Woodland Period ceramics from the Upper Mississippi Valley.

Notable petrographic studies of archaeological ceramics were undertaken in many parts of the world during the late 20th century. These have mostly been the work of specific individuals, including William Dickinson (Pacific Islands and Oceania), Jean-Claude Echallier (France), Yuval Goren (Levant and Near East), Marino Maggetti (Switzerland), Rob Mason (Middle East), Laurence Smith and Janine Bourriau (Egypt).

After a flourish of interest and activity during the late 20th century, particularly in Britain and Europe, ceramic petrography assumed the status of an established analytical technique, as other more novel and cutting edge approaches were introduced for the analysis of ceramic composition. However, in recent years it has experienced a renaissance in many parts of the world, such as Italy and Eastern Europe. Important research groups now exist in Padova, Palermo, Budapest and Catamarca (Argentina) among other places.

With archaeology facing a funding crisis, researchers are again appreciating the benefits of ceramic petrography, which can be carried out relatively cheaply and with only relatively modest investment in analytical equipment. More crucially, however, interest in ceramic technology, craft tradition and related topics such as identity and the transmission of knowledge, have seen archaeologists and materials analysts turn to petrographic data once more for the unique insights that it can provide (Chapter 6).

1.3 Publications & Academic Forums

Articles on the thin section petrographic analysis of archaeological ceramics can be found in a large range of published and unpublished sources. Technical research articles that use petrography, often alongside other compositional techniques, to answer focused archaeological questions are frequently presented in the pages of specialist academic journals including Archaeometry, Journal of Archaeological Science, Geoarchaeology and the short-lived Archeomaterials. These and other scientific journals such as Applied Clay Science, Journal of the European Ceramic Society, Hyperfine Interactions, Cement and Concrete Research and Construction and Building Materials are also a good source for methodological studies and applications of ceramic petrography.

Occasional articles that apply petrography to the ceramic materials of specific periods and/or geographic regions can be found in general archaeological journals including Annual of the British School at Athens for prehistoric Greek pottery, Medieval Ceramics and Journal of Roman Pottery Studies in Britain, as well Antiquity, American Antiquity, Oxford Journal of Archaeology, World Archaeology and Journal of Field Archaeology.

Petrographic studies on archaeological ceramics are frequently included in the proceedings of ceramics and archaeological science conferences. Many of these have been published as British Archaeological Reports. In addition, several dedicated collections of papers exist, namely the two British Museum volumes (Section 1.2) and the more recent book 'Interpreting Silent Artefacts' (Fig. 1.15).

A number of useful monographs exist on the petrographic analysis of ceramics from single large projects. These include Whitbread's 'Greek Transport Amphorae', Peter Wardle's 'Earlier Prehistoric Pottery Production and Ceramic Petrology in Britain', Ole Stilborg's 'Shards of Iron Age Communications', Yuval Goren and colleagues' 'Inscribed In Clay' and Linda Howie's 'Ceramic Change and the Maya Collapse'.

Very few dedicated textbooks have been published on the methodology of thin section ceramic petrography. Of these Chandra Reedy's 'Thin-Section Petrography of Stone and Ceramic Materials' is particularly notable for its breadth of coverage and extensive summaries of previous petrographic studies. Several books on the petrography of concrete, plaster and other engineering materials are also very useful for the study of cementitious archaeological samples.

Unfortunately, a great deal of petrographic research is not universally know and sometimes difficult to obtain, being buried within the appendices of site reports or published in low circulation and/or foreign language journals. For this reason, certain aspects of the ceramic petrography have been researched or reinvented numerous times by workers that were unaware of each other's work. For example, the French scientific literature contains many important contributions that are often overlooked by those publishing in English.

Petrographic research presentations feature prominently at meetings such as the International Symposium on Archaeometry (ISA) and the European Meeting on Ancient Ceramics (EMAC). Both of these forums take place biannually on alternate years. National archaeometry conferences also take place Italy, France and other countries. Petrography and ceramic analysis more generally, is frequently the subject of special sessions at large archaeology conferences such as the annual meeting of the Society for American Archaeology (SAA). Smaller, highly focussed forums are few, but include the aforementioned Ceramic Petrography Group, the Applied Petrography Group and the International Building Lime Symposia. These enable petrographic specialists to get together on a regular basis and discuss technical aspects of their field (Fig. 1.16). They are also responsible for the production of important guidelines for the petrographic analysis of archaeological materials.

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