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Ceramic analysis in Greece

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Introduction

Scientific, analytical or 'archaeometric' techniques for investigating ceramic material have been used within archaeology for over 50 years and now constitute an indispensable tool for archaeologists in the Aegean world (see Jones 1986 for a detailed summary of early work in Greece and Italy) and beyond (Santacreu 2014). This paper provides a brief historical overview of research themes investigated by ceramic analysis in Greek archaeology along with reports on a small number of recent studies, in order to demonstrate current methodologies and results. The narrative is not chronological, either by the date of analysis or the material analysed, but instead focuses on the types of archaeological questions that ancient ceramic analysis can address in order to shed light upon who produced, distributed and consumed the ceramics under consideration. Ceramic analysis investigates both the composition and technology of fired clay vessels, evidenced most frequently in the ubiquitous broken pot sherd, which can then be used to identify provenance, production sequence and cultural tradition, as well as to provide a relative date for production, in combination with typological and seriation techniques.

There are several scales of analysis that can be performed on ancient ceramics, from the macroscopic to the elemental, though it is only by integrating these levels that archaeologists can reach the relationships between people, material and environment; in effect, the dynamic interactions involved in making, exchanging and consuming pottery. Determination of the specific *use* of ancient ceramic vessels through analysis of organic residues, including lipids, proteins and DNA, has developed in recent years into a substantial subdiscipline and is, therefore, beyond the scope of this overview. Also not discussed is the absolute dating of fired ceramic material through rehydroxlation (RHX) measurements, as the stability and reproducibility of this technique has yet to be widely accepted (Zhao *et al*. 2015) and it has yet to be applied systematically to Greek ceramic assemblages.

Defining scales of ceramic analysis

Macroscopic analysis is mostly performed through visual inspection of sherds and vessels, usually with a hand lens, either in post-excavation or survey collections of archaeological field projects or subsequently in museum and *apotheke* (storeroom) collections. Techniques at this scale include macroscopic fabric analysis (MACFA) and macrotrace analysis. The MACFA approach (Moody *et al*. 2003) aims to distinguish pottery manufactured from different raw material sources or pastes that have been deliberately processed in different ways, although this is considerably more difficult for fine wares that have few to no visible inclusions in their pastes. The visual description of the ceramic fabric, consisting of the plastic clay matrix, the non-plastic inclusions and textural features such as voids, can provide spatially and chronologically defined groups for considering the production and distribution of ancient ceramics. Macrotrace, or surface feature, analysis (Courty and Roux 1995; Roux and Courty 1998) can assist in the identification of forming technique, particularly the use of rotative energies (tournettes and potters' wheels), as well as decorative practices. This technique can help archaeologists to consider the transmission and adoption of new ceramic technologies and practices over space and time.

Microscopic analysis is perhaps best defined by the use of advanced laboratory equipment, most frequently optical or electron microscopes, to identify compositional (mineralogical) and textural features within the ceramic fabric. Physical or mechanical properties of ceramics are also investigated at this scale using a different range of laboratory techniques (Kilikoglou *et al*. 1998; Tite *et al*. 2001), though most recent work has seen integration with microscopic techniques focusing on fabric and textural features

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(Müller *et al*. 2016). Ceramic petrography with polarized light microscopy is the most commonly used technique at this level due to its relatively efficient, albeit destructive, method of sample preparation and instrument costs (Whitbread 1995; Reedy 2008; Peterson 2009; Quinn 2013; Santacreu 2014). Scanning electron microscopy (SEM) is also widely used, in order to determine compositional differences between different areas of a sample and to investigate surface topography (Tite *et al*. 1982). Both these microscopic techniques act as an important check for interpretations made at the macroscopic level, often providing additional information on paste-processing behaviours such as clay mixing, tempering, the use of rotational forces within the forming process, decoration or surface treatments and firing regimes.

The final level is elemental or, more commonly, chemical analysis, in which sophisticated instruments are used to achieve bulk or spot chemical characterization of ceramic material. Bulk chemical analysis identifies and measures the proportion of major, minor and trace elements within the whole sample under analysis using techniques such as INAA (instrumental neutron activation analysis), ICP-MS/AES (inductively coupled plasma - mass spectrometry) and XRF (x-ray fluorescence). Spot analysis is used to identify the composition of a specific target region within a sample and can target the non-plastic inclusions, the clay matrix or the surface layers of a ceramic sample, using laser ablation to convert surface molecules into plasma (LA-ICP-MS) or electron beams to excite surface x-ray emissions (scanning electron microscopy with energy dispersive x-ray spectrometry or SEM-EDS (scanning electron microscopy with energy dispersive spectrometry); see Malainey 2011 for an accessible technical guide to the methods mentioned here). As with microscopic investigations, the majority of chemical techniques are destructive in nature, requiring samples to be processed into homogeneous dusts, liquids or plasmas for energy excitation, thereby removing all textural information from the original sherd and destroying the evidence for ancient behavioural or technological choices (Sillar and Tite 2000; Cumberpatch *et al*. 2001). Some techniques are exceptions, however, as recent analysis with SEM-EDS using QEMSCAN® (automated data acquisition software) has proved to be highly valuable in providing bulk chemical characterization alongside a compositional map of minerals across the sample surface, thereby allowing both detailed compositional and textural features to be used in the interpretation of ceramic fabrics (Knappett *et al*. 2011; Hilditch *et al*. 2016).

A consequence of increasing analytical sophistication as we move from macroscopic to elemental scales of investigation is that the number of samples decreases at each successive level, due to sample preparation and instrumentation costs. In addition, certain elements of a ceramic assemblage are better suited to specific types of analysis: for instance, ceramic petrography is particularly effective for characterizing semi-fine to coarse wares by the mineralogical composition of their inclusions, whereas fine wares are often best investigated chemically and grouped on the basis of minor and trace elements within the paste. Integration of analytical scales (**Fig. 78**) is crucial for investigating entire assemblages with respect to production, distribution and consumption choices (Peacock 1970; 1977), as these choices are not mutually exclusive domains but, rather, a complex web of socio-technically constituted interactions between potter, raw material, tools, environment and consumer (Roux 2003).

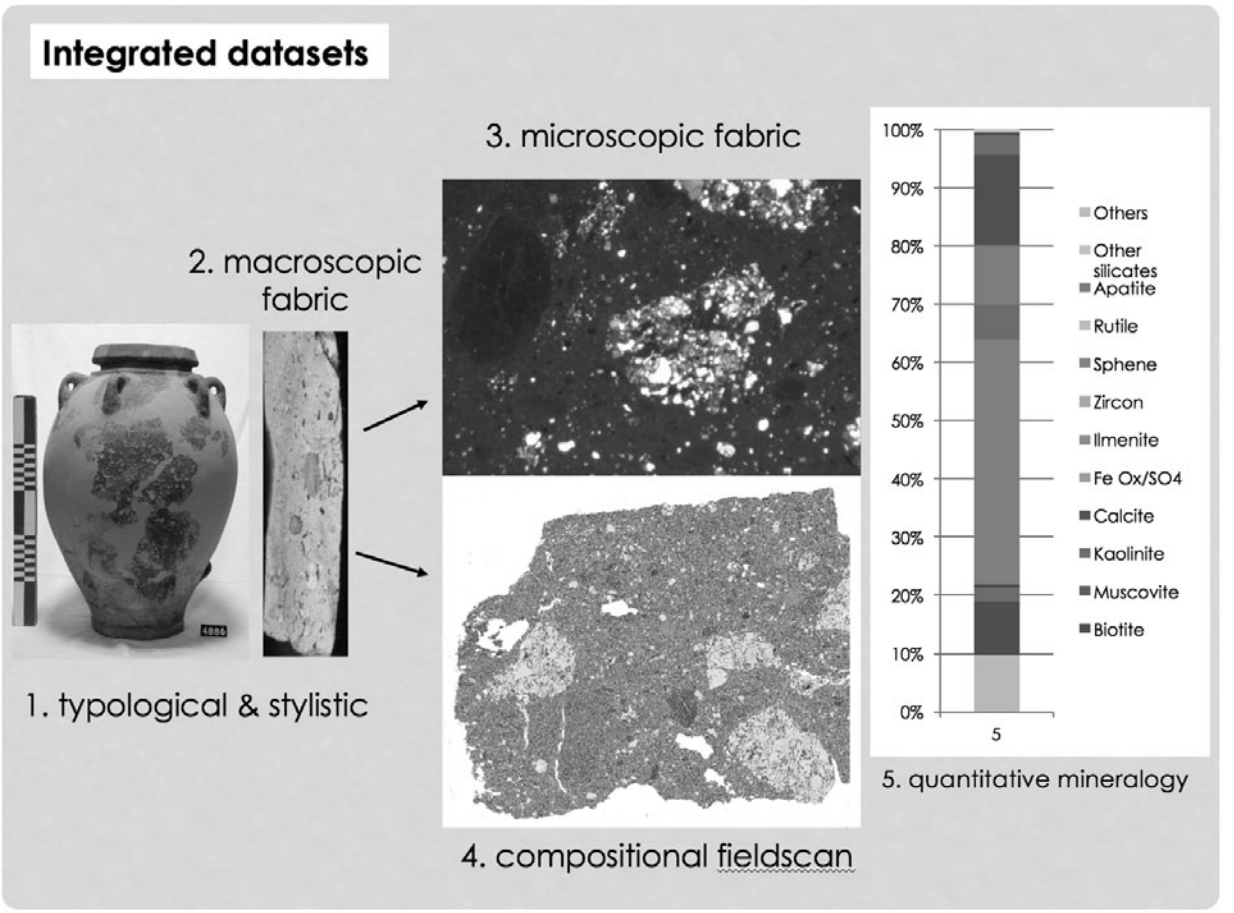
Current research themes in ancient Greek ceramic studies

The projects described below have been loosely ring-fenced within research themes for the purposes of this overview but, given the increasingly sophisticated research questions of analytical studies, it should be noted that they could easily be considered within more than one of the highlighted themes. Sites mentioned within the text are indicated on **Map 6**.

Connected communities through ceramic exchange: identifying local compatibility

The earliest case studies of ceramic analysis in Greece focused on the provenancing of diagnostic imports within an assemblage, most commonly those identified as Minoan or Mycenaean, through chemical techniques such as neutron activation analysis (NAA) and spectrographic analysis (Sayre *et al*. 1957; Catling 1961; Catling *et al*. 1963). These early attempts to identify major ceramic production centres, particularly for inscribed stirrup jars, within the Minoan and Mycenaean worlds were plagued for some years by incorrect assumptions about which sherds were locally produced and extremely small sample

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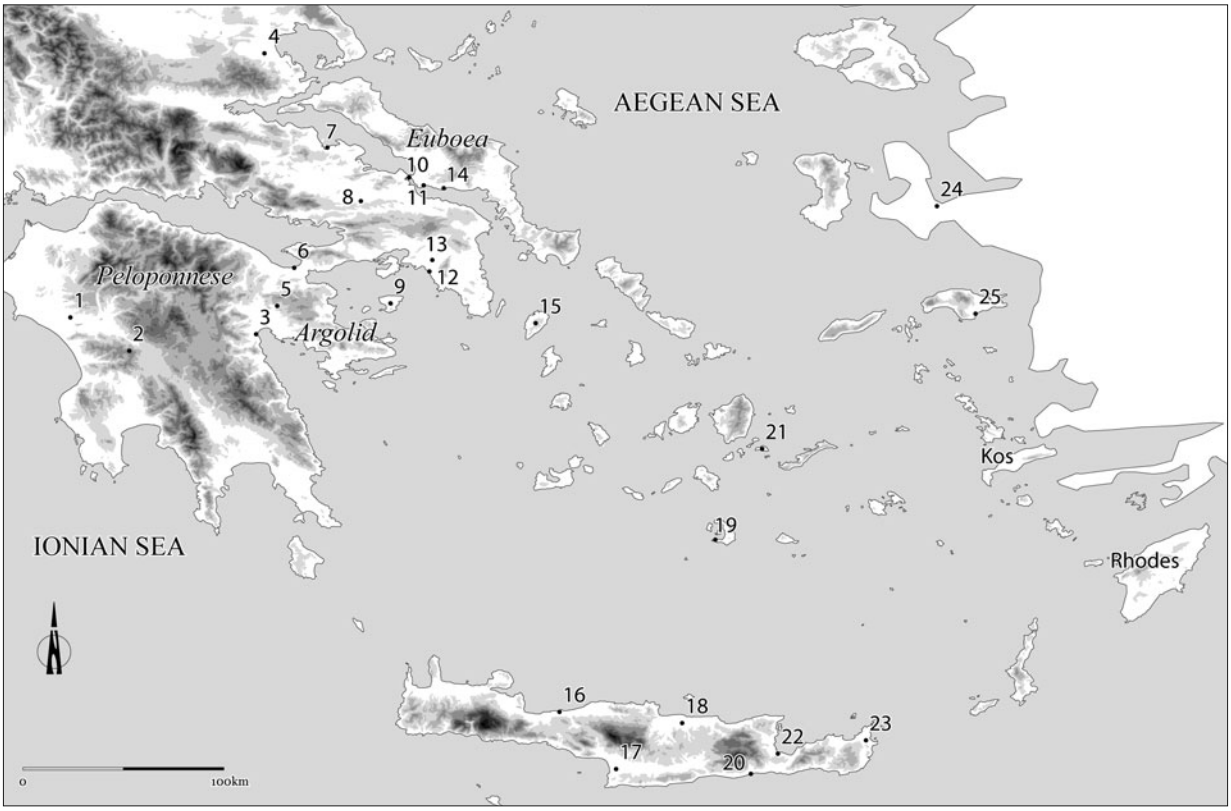


78. Integration of analytical scales, from macroscopic to microscopic and elemental analysis. © J. Hilditch.

numbers (for a valuable critique, see Shepard 1968: vi–vii), and it was only by integrating petrographic analysis with the chemical datasets that the scale of the problem became apparent (Riley 1981; 1983; Jones 1986; for a brief summary of these early investigations, see Knappett *et al*. 2011: 220) and a solution was finally reached (Haskell *et al*. 2011). Ceramic provenance studies have moved on significantly since these heady first days to incorporate analysis of coarse wares and fine wares within an assemblage and focus on the characterization of pottery products from a 'bottom-up' perspective. In effect, this methodology establishes a compositional and technological profile for the ceramic products of each site studied, allowing their identification and distribution patterns to be assessed at local, regional and supra-regional scales. Today, inter-laboratory protocols and integrated databases allow more confident grouping and attribution procedures for chemical analysis of Greek material (Mommsen 2012; Hein and Kilikoglou 2011); however, with the exception of the impending digital archive of the petrographic collection from the Fitch Laboratory (BSA), there are as yet no digital collections or databases of petrographic fabrics available for comparative study of Greek ceramic assemblages.

A 'bottom-up' methodology for characterizing local production, such as that pioneered by the Fitch Laboratory since the 1980s (see Vaughan *et al.* 1995; Whitbread 1995; Day *et al*. 1999; Kiriatzi 2003; Hilditch *et al.* 2008; Boileau and Whitley 2010; Pentedeka *et al.* 2010), involves geological prospection of locally available potting raw materials, accompanied by paste and firing replication experiments, integrated with macroscopic, petrographic fabric and chemical analyses. The key feature of this intensive approach is that compositional or technological imports are highlighted within an assemblage, even if their original provenance is not yet known. There have been few sites like **Dhaskalio-Kavos** on Keros (**ID661**, **ID 675**, **ID848**, **ID1697**, **ID1888**, **ID2906**, **ID4284**) to draw so heavily upon this premise. The

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Map. 6. Locations of sites mentioned in the text. © BSA. 1 Olympia; 2 Mount Lykaion; 3 Lerna; 4 Halos; 5 Berbati valley; 6 Corinth; 7 Mitrou; 8 Thebes; 9 Aegina; 10 Chalcis/Chalkida; 11 Lefkandi; 12 Kontopigado Alimos; 13 Athens; 14 Eretria; 15 Agia Irini; 16 Loutra, Rethymnon; 17 Phaistos; 18 Knossos; 19 Akrotiri; 20 Myrtos-Pyrgos; 21 Dhaskalio-Kavos; 22 Vrokastro, Mirabello bay; 23 Palaikastro; 24 Liman Tepe; 25 Heraion.

recent publications of the excavations on Keros, a small island centrally located in the Cyclades, have thrown the spotlight once again on the unique character of the Early Cycladic II–III settlement-sanctuary complex of Dhaskalio-Kavos (Renfrew *et al*. 2013; 2015). Investigations of survey pottery from the Special Deposit North, Kavos Promontory and the islet of Dhaskalio during the 1987-88 campaign revealed an extremely high percentage of imported pottery at the site (Renfrew *et al*. 2007). Excavations of the Special Deposit South, Kavos Middle and Dhaskalio during 2006–2008, followed by macroscopic, petrographic and chemical analyses of the ceramic assemblage, and building upon the earlier fabric study by Cyprian Broodbank (2007) and myself (Hilditch 2007), have reinforced this initial picture and led to a hypothesis that potentially all pottery found on Dhaskalio and the facing coastline of Kavos was imported to the site, with the majority coming from settlements in the neighbouring Erimonisia or the 'Keros Triangle' of Naxos, Amorgos and Ios, and a few vessels imported from more distant sources within the Cyclades, the Greek mainland and the island of Aegina (Hilditch 2013; 2015). This ceramic picture seems perhaps less unexpected when considered alongside the importation and fragmentary deposition of the iconic Cycladic marble figurines so common at the site (Renfrew 2015), as well as the importation of building materials for the construction of habitation walls on the islet of Dhaskalio (Dixon 2013).

The ceramic assemblage of the contemporary Early Bronze II–III settlement on **Samos**, **Heraion** (**ID 1296**, **ID2073**, **ID2626**, **ID3057**), has also been investigated using macroscopic and petrographic analyses to characterize the earliest pottery production at this key regional site in the eastern Aegean (Menelaou *et al*. 2016). Analysis of prehistoric sherds from domestic contexts in Heraion I–III (Early Bronze II) and IV–V (Early Bronze III) levels has provided clear indications of locally produced pottery from raw material sources in the south of the island within the vicinity of the site, and has highlighted a few known (from the western Anatolian coast at Liman Tepe: Menelaou *et al*. 2016: 485) and unknown imported vessels.

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This study provides an important first step for considering the participation of the Early Bronze Age Heraion community within the well-developed regional exchange networks of the eastern Aegean that spread from the Anatolian hinterland, through Keros and other island settlements, to the Greek mainland in this period, as well as establishing the settlement's ceramic profile for later periods of occupation, including the Sanctuary of Hera founded in the Archaic period.

The Saronic Gulf was another extremely active region in the exchange and distribution of pottery wares throughout the Bronze Age, though the similarity in vessels produced in this region during the Mycenaean period makes traditional approaches to studying ceramic production difficult. The Late Helladic IIIB–IIIC1 phases of this region are being studied by William Gilstrap and colleagues (2016), who differentiate between neighbouring pottery-producing communities through detailed reconstruction of identified ceramic *chaînes opératoires* or production sequences. By integrating petrographic and SEM analyses of three pottery wares (cooking wares, bathtubs and table wares) from the coastal site of Kontopigado Alimos, Attica, and the island of Aegina, the study found a contrasting picture. While **Aegina** (**ID99**, **ID242**, **ID1928**) attests to probably more than one community of potters working on the island, performing multiple *chaînes opératoires* of pottery production using multiple raw material sources, **Kontopigado** (**ID5265**) shows a single workshop producing a wide range of vessel types but using different recipes based on the same raw materials to produce these different wares (Gilstrap *et al*. 2016: 501–06). However, the shared practice of organic temper in paste for the production of large tubs at both sites 'appears to be a wider, chronologically specific practice' with other known examples from Corinth, Mycenae and the Vrokastro area of eastern Crete (Gilstrap *et al*. 2016: 507). Gilstrap and colleagues (2016) argue that organic tempering was a shared technological knowledge and that its study has the potential to allow a more detailed understanding of Mycenaean pottery production across local and regional contexts.

Shared regional traditions, such as that discussed above for Mycenaean ceramic repertoires, often coalesce into a single deposit at ritual or religious sites, due to the repeated dedication/deposition of pottery vessels. Just as at the prehistoric sanctuary of Dhaskalio-Kavos discussed above, later ritual centres of the protohistoric periods can hold the key to assessing the regional sphere of interaction in which a ritual centre operated and held meaning. Following this vein, an integrated programme of non-destructive analyses of the red, black, white and distinctive purple pigments on decorated pottery from the **Sanctuary of Heracles at Thebes**, Boeotia (**ID3019**) has been used to elucidate the circulation of dedicatory vessels in the Late Geometric II to the Archaic period, late eighth to sixth century BC (Mastrotheodoros *et al*. 2013). To link variations in decorative appearance to potentially different provenances, the study analysed both the surface and ceramic body using optical microscopy, SEM-EDAX (energy dispersive x-ray analyser) and XRF analysis, in addition to conducting experiments on the thermal treatment modification of iron pigments (Mastrotheodoros *et al*. 2013: 822). The resulting differences in chemical and microstructural characteristics of the pigments, assessed alongside robust archaeological standards for decorated Theban and Corinthian vessels, confirm the presence of pots from multiple production centres within the sanctuary, with imported Corinthian samples showing higher-quality black pigments and skilled manufacturing techniques (advanced furnace temperature and atmosphere) than their local Theban counterparts (Mastrotheodoros *et al*. 2013: 823). An even more recent analytical study focuses on the typical **Athenian 'Black Glaze/Gloss' (BG) wares** (Chaviara and Aloupi-Siotis 2016). Challenging old assumptions on the sourcing of raw materials for the production of these iconic decorated wares through time, Artemi Chaviara and Eleni Aloupi-Siotis analysed black-glaze sherds from Geometric to Classical contexts from Athens and Corinth *in situ* using a handheld portable x-ray fluorescence system (HH-pXRF) with subsequent SEM-EDX analyses of an experimental series of glazed samples created in collaboration with the THETIS workshop in Athens (http://www.thetis.gr/). Experimental samples made using clay deposits from the Panakton plateau and the Mount Parnes region reveal similar phenomenological features to ancient black-glaze samples. Their results also show that the Archaic sixth century BC displays the widest range of raw materials and techniques during a period characterized by experimentation, and it is likely that 'clay paint production and distribution may have constituted a separate trade that supplied the large number of pottery workshops throughout Attica' (Chaviara and Aloupi-Siotis 2016: 518).

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Petrographic analysis of pottery found in a Hellenistic kiln at **Loutra, Rethymnon** (**ID3662**), in western Crete, has shed new light on the production of amphorae (storage and transport vessels) and olive oil within regional exchange networks (Tsatsaki and Nodarou 2014). The excavation of the Loutra workshop provides a rare opportunity to supplement regional survey data with detailed information on raw material sourcing and manufacturing technology in order to investigate the relationship between pottery workshops, the range of vessels produced and their contexts (in this case, a farmstead). Although 79% of the recovered sherds within the kiln and refuse pits belong to various amphorae shapes and stands, other shapes, such as cooking pots, trays and lekanides, were also found, indicating that the workshop did not exclusively focus on amphorae production (Tsatsaki and Nodarou 2014: 290). Nearby olive-oil presses show a deliberate effort to 'bring together the containers (amphorae) and the final product (olive oil)' and also attest to the use of olive pits as fuel for the kiln (Tsatsaki and Nodarou 2014: 309). All products from the kiln were found to follow a similar clay recipe and technology of manufacture; alongside the dominant calcareous local fabric were also imported amphorae from Kos, Rhodes and Corinth, most likely imported for the products stored inside these vessels (Tsatsaki and Nodarou 2014: 300–06, 310).

Connected communities through ceramic exchange: anchoring floating fabrics

A persistent problem within archaeological ceramic analysis is the study of distinctive ceramic products that are so popular (widely distributed) and so sought after (locally imitated to satisfy demand) that they present a range of potential provenances so great as to be relatively uninformative for the reconstruction of exchange networks or social interactions of the past. The challenge for ceramic analysis, then, is to 'anchor' a distinctive ceramic ware of unknown provenance to a production unit or regional centres of production. Examples of distinctive wares that have yet to be unequivocally attributed to production centres include the soapy-feel Talc Ware vessels (Vaughan and Wilson 1993) and Urfirnis sauceboats (Wilson 1999) of the Early Bronze period and the Late Cypriot Red Lustrous Wheelmade Ware (Knappett and Kilikoglou 2007). A recent chemical study using NAA of Classical-period red-figure pottery tackles this issue (Mommsen *et al*. 2016), seeking to investigate the dispersal of ceramic artisans, potters and painters from red-figure-producing workshops in Athens during the economic and social fallout of the Peloponnesian War (431–404 BC). **Red-figure pottery** excavated at **Olympia**, Elis, was studied to characterize the 'Elean workshop' which produced vessels in the period *ca*. 425–350 BC (Mommsen *et al*. 2016: 371) and to assist in the identification of red-figure vessels from workshops in Italy, the northern Peloponnese and also possibly northwestern Greece, as well as to assess their interactions and potential stylistic impact upon one another. The results show that, despite Apulian influences in the later vessels of the Olympia assemblage, no pots were imported from an Italian production centre but were instead made locally in Elis or the northwestern Peloponnese (Mommsen *et al*. 2016: 378).

Even later historical periods, with their wealth of textual sources, can produce a 'floating ware' or fabric, as seen in the study of '**Middle Byzantine production**' (MBP) by Yona Waksman *et al*. (2014). MBP is an umbrella term for several 12th- to early 14th-century AD ceramic types, including 'Green and Brown Painted Ware', 'Fine Sgraffito' and 'Aegean Ware', found at major settlements and harbours, as well as in shipwrecks, throughout the Mediterranean from southern France to Israel (Waksman *et al*. 2014: 379–80). Chemical analyses of these predominantly fine pottery wares from a wide range of sites had suggested a single, chemically robust composition typical of 'a single, varied and long-lasting production', but no provenance had yet been identified through comparative chemical datasets (Waksman *et al*. 2014: 380). Survey investigations of rural sites around Thebes, central Boeotia and its port, Chalcis (modern-day Chalkida), had found unprecedented frequencies of MBP sherds of all types, suggesting this region as the main location of production for these important wares. In total, 77 MBP sherds from Thebes and Chalcis were analysed using WD-XRF (wavelength dispersive x-ray fluorescence), resulting in an extremely clear chemical grouping built upon reference samples from known Theban and Chalcidan production contexts, such as kiln furniture and pottery wasters (Waksman *et al*. 2014: 413–14) and establishing **Chalcis** as the 'place of origin of the MBP' (Waksman *et al*. 2014: 417). Although the precise location of the MBP workshop has yet to be identified, a raw material source in the Lelantine plain

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seems to have been used consistently for the various MBP wares. As the authors highlight, this study is an important step in reconstructing the ceramic production of medieval Greece and allowing a more detailed assessment of regional and supra-regional dynamics that affected Byzantium (Waksman *et al*. 2014: 418).

Connected communities through ceramic exchange: diachronic challenges

Ceramic variation is difficult to interpret if production at a particular centre, or within a specific region using similar raw materials, continues for several hundred, thousand or more years. On the other hand, stability or continuity in that production tradition, either with respect to raw material exploitation or production techniques, also demands explanation. As ceramic analysis has become a greater part of archaeological investigation over the years, the potential to achieve diachronic characterization for long-lived production or consumption centres has increased enormously. The relationship between ceramic change and societal development is explored in Roberta Mentesana and colleagues' diachronic study of production and consumption of pottery at prehistoric **Phaistos**, **Crete** (Mentesana *et al*. 2016). Focusing on the transition between Final Neolithic and Early Minoan I levels traditionally associated with major changes in the ceramic repertoire, the *chaînes opératoires* of three different wares – dark-on-light, dark-grey pattern burnished (DGPB) and cooking-pot wares – were reconstructed using an integrated programme of macroscopic, petrographic and microstructural analyses. Distinct choices in the Early Minoan phases, leading to changes within the raw material exploitation, processing and firing stages for each ware, were not simultaneous but instead some were shown to be grounded in later phases of the Final Neolithic assemblage. More frequent communal consumption practices in the early phases of the Early Minoan period requiring specific sets of vessels may have influenced ceramic manufacturing practices and Mentesana and colleagues highlight the shared aspects of forming by sequential slab technique and decorative syntax that link the production and consumption of ceramic wares at Early Minoan Phaistos (Mentesana *et al*. 2016: 495–96). A collaborative project investigating the use of the granodiorite resources of the central and western Mirabello area, eastern Crete, is an excellent example of a study focusing on the long-term production of pottery within a specific region (Nodarou and Moody 2014). Macroscopic, petrographic and SEM analyses of pottery with a distinctive 'salt-and-pepper' appearance, dating from Final Neolithic to modern shapes, as well as geological sediments from the Vrokastro survey area have provided a truly diachronic perspective on the use of local raw materials and manufacturing technologies, as well as intra- and inter-regional distribution of these ceramics across Crete. Two main fabric recipes had previously been established for production in this region: one for cooking vessels and another for transport and storage jars (for previous studies, see Nodarou and Moody 2014: 93). Observed continuity and variation in these fabrics, with regards to coarseness, composition and technological features, such as tempering and degree of firing, were shown to be effective tools to date more precisely survey ceramics and to trace their distribution over time (Nodarou and Moody 2014: 96–97).

Turning from Crete to Euboea, the work of Xenia Charalambidou and colleagues (2016) investigates Bronze Age to Roman **Eretria**, one of Greece's first colonial and commercial powers already by the eighth century BC. Their recent publication of the 'pre-colonial' levels of coastal Bronze Age Eretria characterizes pottery production between Early Helladic II–III, identifying locally compatible coarse, medium and fine fabrics created through different choices in the production sequence (the coarse fabric has a less calcareous base clay than the fine, with the medium forming a tempered version of the fine fabric: Charalambidou *et al*. 2016: 532). This characterization has allowed the first attested wheel-finished vessels at the site, part of the 'Anatolianizing' features of the Kastri/Lefkandi I phase of the Early Helladic IIB, to be identified as locally produced vessels rather than imports to the site, suggesting 'the reproduction of a local pottery tradition incorporating newly introduced elements into local practices' (Charalambidou *et al*. 2016: 534). Interestingly, the relocation of the coastal settlement to the summit of Kastelli Hill in the Middle Helladic corresponds to a significant change in the choice of raw materials for the local production of coarse and medium wares, despite the fine wares showing continuity over this period, as well as a significant increase in the number and range of imports in this period.

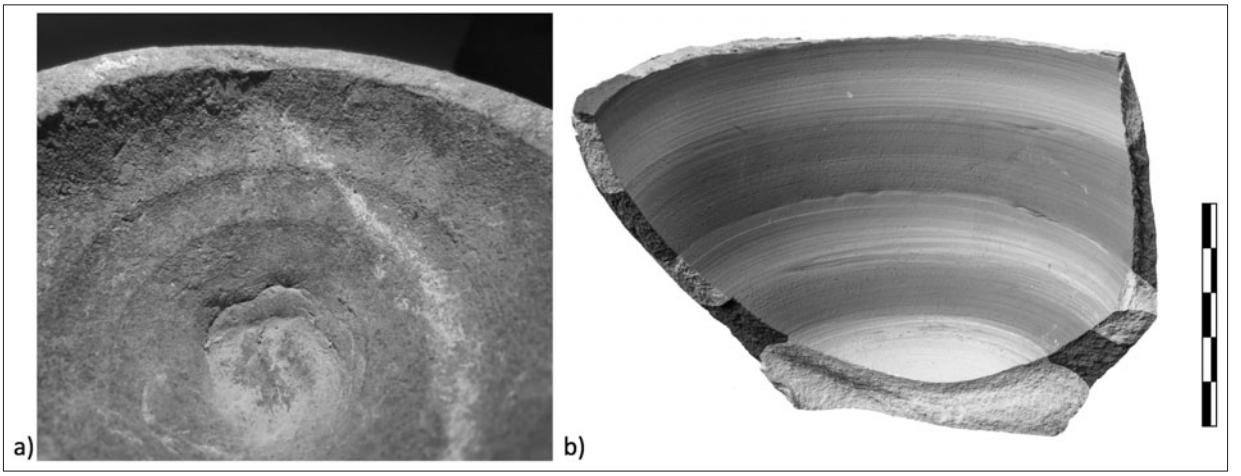
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Continuity in local religious or ritual practices has been explored at the **Sanctuary of Zeus at Mount Lykaion**, Arcadia (**ID121**, **ID305**, **ID869**, **ID1464**, **ID1879**, **ID2419**), where Neolithic to Early Iron Age sherds from the peak of the summit were sampled for petrographic and WD-XRF analyses (Kordatzaki *et al*. 2016). The earlier sherds (Neolithic to Early Helladic) reveal general continuity in the exploitation of locally available primary clays from highland areas, with minor fabric variations most probably representing small-scale production units across the landscape, but the beginnings of diversification with regards to local raw material use, first in the Middle Helladic period and then more prominently in the Late Helladic to Early Iron Age, as secondary clay sources from lower areas in the landscape become more popular (Kordatzaki *et al* 2016: 528). The authors link this development to the increased practical demands of manufacturing wheel-made skyphoi and kylikes in the Late Helladic to Early Iron Age, compared to the hand-made coarser bowls, jars and pithoi of the Neolithic to Middle Helladic periods. This changing repertoire of vessels at the summit probably corresponds to a shift in the character and use of the site over time, though it would be too simplistic to see this change as reflecting religious versus non-religious or habitational versus ceremonial uses (Kordatzaki *et al.* 2016: 529).

Technology transmission: paste preparation to potters' wheels

The integration of typological, stylistic and analytical data within ceramic studies provides an almost unparalleled ability to shed light on what and who moved, and where, within ancient interaction networks. Rather than focusing on the characterization of local production to use as a platform for provenancing ceramic vessels, this section is primarily concerned with how ceramic analysis can inform archaeologists on the movement of people, ideas and craft technologies. Several recent edited volumes address these interactions at the interfaces of cultural encounters and contain many innovative approaches and analyses of Greek ceramic material culture, including: *NOSTOI: Indigenous Culture, Migration and Integration in the Aegean Islands and Western Anatolia During the Late Bronze and Early Iron Ages* (Stampolidis *et al*. 2015); *Beyond Thalassocracies: Understanding Processes of Minoanisation and Mycenaeanisation in the Aegean* (Gorogianni *et al*. 2016) and *The Transmission of Technical Knowledge in the Production of Ancient Mediterranean Pottery* (Gauss *et al*. 2016).

Technological studies considering the transmission of technological knowledge, or know-how, within ceramic production involve detailed visual inspection of surface macrotraces, often combined with experimental approaches and petrographic analysis (**Fig. 79**). A key innovation within prehistoric Greek ceramic studies is the adoption of rotative kinetic energy (RKE) within the forming stage of the production sequence, known more commonly as the use of tournettes, potters' wheels or other rotating devices. The technology of ceramic-forming methods, including the innovation of wheel use, has been explored within



79. (a) Archaeological wheel traces (Akrotiri vessel). © J. Hilditch. (b) Experimental reproduction with wheel coiling (wheel-coiled pot). © S. Rückl and L. Jacobs; photo by A. Dekker.

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Greek assemblages for many years (Kiriatzi *et al*. 1997; Knappett 1999; 2004; Berg 2007). In 2012, Maria Choleva published an analytical reassessment of the first wheel-made pottery from prehistoric **Lerna IV** in the Argolid (**ID114**), distinguishing between wheel-made (wheel-throwing) and wheel-fashioning, with the latter corresponding to the use of RKE to modify the wall of a hand-built vessel (coiled roughout). At Lerna IV, all previously categorized wheel-made ceramics revealed typical wheel-fashioning macrotraces, suggesting that the first technique to employ RKE in the Aegean was the wheel-fashioning technique (Choleva 2012: 374). Linking this development to other studies in the Levant, Choleva demonstrates that the introduction of the potter's wheel at Lerna did not lead *directly* to use of the wheel-throwing technique. Instead, wheel-fashioning would have 'allowed for some continuity' in the craft techniques and *chaînes opératoires* of potters at Lerna, constituting a 'conservative response' or restricted adoption of a new forming technique (Choleva 2012: 376). Another study reassessing traditional trajectories of hand-building to wheel-throwing techniques in early Crete (Middle Minoan IB to Late Minoan IA) found valuable comparanda through an experimental approach to replicating specific wheel-use stages (Jeffra 2013). Using ceramic material from **Knossos**, **Palaikastro** and **Myrtos-Pyrgos**, and her own experimentally produced type-set of vessels manufactured using different stages of wheel use and modification (see Courty and Roux 1995), Caroline Jeffra revealed 'a process of gradual acquisition of combination techniques (wheels and coils)… [for which the] pattern of uptake indicates a level of cohesion across the potting community of central and eastern Crete' (Jeffra 2013: 31).

Cretan technologies, such as the use of the potter's wheel, have long been considered as part of the 'Minoanization' phenomenon in the southern Aegean during the late Middle Bronze Age period, as discussed in a recent study by Evi Gorogianni and colleagues (2016). They argue that local wheel-made vessels from House A and the Temple Complex at **Agia Irini** on Kea, one of the major Minoanized sites of the Cyclades, were, again, predominantly wheel-coiled rather than wheel-thrown. The wheel-coiling technique is not significantly less time-intensive than hand-building with coils (Roux 2003), strongly suggesting 'that adoption of this technology in the local community of practice was not tied to a desire for economic intensification and routinization' but was rather associated with increased production of Minoanizing shapes for the local community, and was later adopted to produce traditionally local shapes (Gorogianni *et al*. 2016: 216). The degree of Cretan influence within shared technological processes is also being investigated in a wider study of the ceramic *chaînes opératoires* of the Northern Sector assemblage at Agia Irini in order to allow for more detailed comparisons with other Aegean communities during a period of growing Cretan interaction and influence. A recent reappraisal of wheel-throwing techniques in post-Bronze Age pottery production has been undertaken by Štěpán Rückl and Loe Jacobs (2016). They move away from linear narratives of technological trajectories, that have traditionally assumed exclusive wheel-throwing within this later period, in order to demonstrate the presence of several methods of wheel-coiling within the Protogeometric fine ware assemblages of **Mitrou**, **Halos** and **Lefkandi**. The authors are optimistic about gaining 'insights into a large array of social and cultural phenomena of the communities of Early Iron Age Greece, namely learning networks, potters' identities and the degree of potters' mobility' (2016: 319).

Getting out of the kitchen: cook wares and coarse wares in Greece

In the world of ceramic analysis, the term 'recipe' frequently refers to a series of technological choices and behaviours, conscious or unconscious, employed by a potter to turn raw potting material(s) into a specific paste suitable for ceramic vessel production. Coarse wares are particularly well-suited to investigating such choices, as their inclusions offer greater information on the mineralogical composition of raw materials than fine wares and the processes used to alter those raw materials from their original states, including tempering (addition of non-plastics, both organic and non-organic), fining (crushing, levigation or sieving) and mixing. Coarse wares are most usually associated with utilitarian functions, such as the storage, preparation and cooking of foodstuffs, tend to display less decorative surfaces and are assumed to be produced locally to the site of deposition, which, historically, has led to the perception that these wares were less valued and, therefore, they have been less studied than their fine-ware counterparts among Greek ceramic assemblages (Whitley and Boileau 2015: 75). In the recent edited volume *Ceramics,*

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Cuisine and Culture (Spataro and Villing 2015), kitchen ware vessels produced for processing and cooking are considered nothing less than valuable material or tangible markers for the transmission and adoption of specific culinary traditions, technological practices and social interactions of the past.

Ian Whitbread's study of kitchen wares in the **Berbati** valley highlights a relationship between distinctive geologies for sourcing raw materials and the perception of quality by the consumer: '[Berbati] cooking pots reflect the engagement of people with materials properties and performance within wider social contexts of availability, priorities and expectations' (Whitbread 2015: 34). In their study of cooking pots from **Akrotiri** on Thera, Noemi Müller and colleagues investigate whether performance characteristics can explain technological choices in ceramic production; but their conclusions show that the phyllite tempering of cook ware fabrics at Akrotiri did not improve performance properties, rather, it could be interpreted as 'investment of additional effort for the production of what could be argued to have been a worse quality cooking ware' (Müller *et al*. 2015: 46; see also Müller *et al*. 2016 for a study of the influence of firing and temper on impact resistance of archaeological ceramics). Instead, they argue that phyllite tempering is derived from a Cretan practice and shows that, as Akrotiri became more engaged in southern Aegean networks during the Middle Cycladic to Late Cycladic period, the appearance of the tripod cooking pot shape and paste manipulation of local raw materials reflect the adoption of Cretan shapes and technologies, beyond mere emulation by local potters (Müller *et al*. 2015: 46–47).

Endnote

There can be no doubt that ceramic analysis continues to develop year-on-year within archaeological investigations, with advancements in analytical instrumentation providing ever more detailed means to consider the relationship between people, pottery and their socio-material worlds. Crucially, through the integration of wider material culture theory from the humanities and social sciences, analytical data are increasingly considered within robust theoretical frameworks relevant to anthropological and sociological processes of craft production and organization, meaning that our results are meaningful to both past and present communities. Lastly, if the reader has spotted a predominance of prehistoric case studies, this is most likely a symptom of the author's specialism and the popularity of analytical approaches within prehistoric investigations that have no accompanying texts to elucidate the society in which those ceramic assemblages are manufactured and distributed.

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