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TECHNOLOGY TRANSFER AT THE PERIPHERY OF THE MYCENAEAN WORLD: THE CASES OF MYCENAEAN POTTERY FOUND IN CENTRAL MACEDONIA (GREECE) AND THE PLAIN OF SYBARIS (ITALY)

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Technology transfer at the periphery of the Mycenaean world: the cases of Mycenaean pottery found in central Macedonia (Greece) and the Plain of Sybaris (Italy)

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ABSTRACT

The study of technology transfer in pottery production to the periphery of the Mycenaean world has been addressed by considering two different areas, Southern Italy and Central Macedonia. Technological features such as ceramic paste, decoration and firing, have been determined for different ceramic groups established according to provenance criteria. The studies of technology and provenance have been performed following an archaeometric approach using neutron activation analysis, petrographic analysis, x-ray diffraction and scanning electron microscopy. The results have revealed the existence of two different models. On the one hand, Southern Italy seems to exhibit a more organised pottery production, which follows a Mycenaean-like technology, while in Central Macedonia production is probably more varied, in part based on the technology of the local tradition.

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KEYWORDS: MYCENAEAN POTTERY, SOUTHERN ITALY, CENTRAL MACEDONIA, NEUTRON ACTIVATION ANALYSIS, OPTICAL MICROSCOPY, X-RAY DIFFRACTION, SCANNING ELECTRON MICROSCOPY, FIRING TECHNOLOGY, PIGMENTS

INTRODUCTION

The interaction of the Mycenaean world with its periphery has long been, and continues to be, an issue of central interest in the archaeology of the second half of the second millennium BC in the East Mediterranean. The decorated pottery finds have always formed the crucial evidence pointing to the date and nature of Mycenaean contact with the ‘periphery’. To the east and south of the Aegean, that is Cyprus, the Levant and Egypt, the traditional area of study, the combination of analysis of stylistic attributes and chemical characterisation has made substantial progress in identifying the status of the Mycenaean pottery as ‘local imitation’ or ‘import’ (Jones 1986, 542f; Mommsen *et al*. 1992). The scope of this enquiry can be extended to consider *technique* and *tradition* as well; Leonard *et al.’*s (1993) combination of Instrumental Neutron Activation Analysis (INAA) and xeroradiography on Mycenaean stirrup jars is a good example of such an approach.

During the last two decades, attention has shifted more towards Mycenaean contact with the west, that is with Italy and associated islands, and the north, principally Greek Macedonia. As a result of study of the pottery finds from these areas, and again supported by programmes of analysis, a secure picture of the process of acculturation has been built up. Whereas the Mycenaean pottery of the Shaft Grave period (17^{th}-16^{th} c. BC) found in small quantities at trading settlements in Italy (such as Vivara and the Aeolian Islands) and, for instance at Torone in the Chalkidiki in Macedonia, was in all likelihood imported from southern Greece, the status of the subsequent LH III decorated pottery has a marked chronological basis to it: as acculturation progressed during the 13^{th} and 12^{th} c. BC, so the amount of ‘local’ Mycenaean increased. The reader is referred to Vagnetti (1999), and Wardle (1993) and Andreou *et al*. (2001) respectively for the most recent accounts of the two areas. The marked technological contrast between the indigenous pottery belonging to the hand-made tradition and the kiln-fired wheel-made pottery of the Mycenaean world, technology that will be adopted in these areas, is fundamental to the discussion of the acculturation process.

This paper describes our investigation into the nature of the supposed local Mycenaean pottery in two peripheral areas, central Macedonia and southern Italy. The following questions arise: does this pottery represent centralised production in the two areas, or were there several locations of production? How readily available were suitable raw materials for building the vessels and for its silicate-based glossy decoration? What firing regimes would have been in place? What can be said about technology transfer from the Mycenaean world to its periphery? In tackling these questions, one of our aims has been to achieve a more balanced 'archaeometric' view of Mycenaean pottery which until now has been over-concerned with questions of origin to the detriment of technological issues.

The investigation is based primarily on material from two sites which have already received archaeometric attention: Assiros Toumba in Macedonia (northern Greece), and Broglio di Trebisacce in the Plain of Sybaris (southern Italy). The earlier work at these two sites is outlined below. In addition, smaller numbers of individual samples were considered from three other sites in Macedonia - Chrysavgi, Aghios Mamas and Toumba Thessaloniki - and one further site in the Plain of Sybaris, Rosa Russa (Figure 1). The first part of this paper concerns understanding better the different Mycenaean pottery types established in Macedonia on archaeological grounds, while the second one mainly concerns the understanding of technology transfer in Southern Italy.

ANALYTICAL METHODS

Chemical characterisation was carried out by INAA for 21 elements (Sm, Lu, U, Yb, As, Sb, Ca, Na, La, Ce, Th, Cr, Hf, Cs, Tb, Sc, Rb, Fe, Ta, Co and Eu) at the NCSR 'Demokritos' swimming pool reactor (Hein *et al*. 2002). Before data processing consisting of Principal Components Analysis (PCA) and cluster analysis (the former with routine 4M of the BMDP package and the latter with Clustan), the data were normalised according to the Sc content and log transformed (Aitchison 1986; Buxeda 1999). The comparability of INAA databases for the Aegean is known to have been achieved between those generated respectively at NCSR 'Demokritos', Berkeley (Asaro-Perlman database, re-evaluated by French *et al*. (forthcoming) and Tomlinson (1997; 1998) for sites throughout the Peloponnese, Perati in Attica and Thebes and Gla in Boeotia), Bonn (Mommsen *et al*. 1988; 1994: for Argolid and Achaia; Hein *et* *al*. 2002) and Manchester (Tomlinson 1997 (for Peloponnese); 1998 (for Gla); 2000 (for Boeotia)).

Petrographic analysis consisted of examination of thin sections of the pottery. The degree of sorting of inclusions and the varying proportions of inclusion size were the main factors in guiding the petrographic classification.

For the *technological* aspect of the study, Scanning Electron Microscopy (SEM) and X-Ray Diffraction (XRD) were employed. A fresh fracture, transverse to the wall and in a direction parallel to the vertical dimension of the vessel, was obtained from each sample and examined under the SEM (Kilikoglou 1994). XRD diffractograms were obtained by the powder method, using a Siemens D-500 diffractometer (Buxeda *et al*. 2001). Some experiments were also conduced on raw clays, fired as briquettes at 800 and 950°C in oxidising atmosphere at a heating rate of 200°C/h and maintaining the peak temperature for 1 hour.

RESULTS

Macedonia

To date, only two studies have tackled chemically the issue of Mycenaean pottery production in Macedonia, both of them based on material excavated in the 1970s at Assiros Toumba, in the Langadas Basin, and nearby Chrysavgi (from where several individuals classed archaeologically as Local Mycenaean type -**CLM**- were taken), (Jones 1986: 108, 494; using optical emission spectroscopy (OES)), and at Kastanas (Mommsen *et al*. 1989; using INAA), on the River Axios. In both cases, the archaeological criteria of date, style and fabric were used to provide the initial classification of the pottery, and they both used the indigenous hand-made Brown Burnished (**BB**) ware as local reference material. At Assiros, which concerns us in the present study, the Mycenaean-type pottery was divided into Local (Assiros Local Mycenaean, **ALM**), Provincial (**APM**) and Imported (**AIM**) (Wardle 1980; 1993). These terms Local, Provincial and Imported are based on practical visual distinctions applied to a broad spectrum of material found at Assiros in the first instance. At one end, Local was defined as a distinctive ware having (usually) a poorly fired pink fabric with a grey core, and often a slightly porous surface; the quantity of this category indicated that, other things being equal, it was probably made in the vicinity of Assiros. At the other end of the spectrum was a small quantity of Imported, of LH IIIA-B date, defined as pottery of outstanding quality, usually with a lustrous surface and glossy paint of the kind which would have passed without remark at Mycenae or many other southern Greek sites. In the present state of our knowledge this quality of pottery was only made outside Macedonia, perhaps in Thessaly or further south. This class was never common at Assiros and became rarer with the passage of time (Figure 2). All the rest of the Mycenaean pottery was defined as Provincial, and included a wide range of clay colours and fabrics which seemed to have come from a variety of sources, some of which may have been local to Assiros while the rest seemed likely from the quantity to have been made in other parts of Macedonia, perhaps on the coast. Almost all were uniformly fired, usually with a buff or reddish core but a dull surface. The later Mycenaean pottery, of LH IIIB and C date, belonged in the main to the Local and Provincial classes (Figure 2). The archaeometric results so far have shown the existence of local production in the Langadas Basin, and furthermore revealed that the distinction between Provincial - mostly associated with the Chalkidiki (Aghios Mamas area) - and Imported Mycenaean - not uniform but some of it being tentatively linked to Thessaly (Jones 1986: 112) - was not clear cut. At Kastanas, where the Mycenaean pottery was archaeologically divided in Local and Imported (Hänsel 1989), the results revealed twelve groups consistent with regional but perhaps not local production, including one group (G1) to which some sherds from Mesimeri and Thessaloniki belong (Mommsen and Maran 2000-2001), as well as some imports from further afield, including three linked to the Argolid. Moreover, as regards other relevant chemical data for central Macedonia, there are data sets obtained by atomic absorption spectrometry (AAS) for ProtoGeometric pottery from Mende (Kessisoglou *et al*. 1996) and Torone (Whitbread and Jones, forthcoming), and by OES for Byzantine pottery from Thessaloniki (Megaw and Jones 1983).

The samples selected for the present study, which are listed in Table 1, include some from Assiros and all those from Chrysavgi that had been previously analysed but with the addition of more examples from Assiros of the three classes of Mycenaean. A selection of samples from the excavations at Toumba, Thessaloniki (Andreou and Kotsakis 1999) belonging to the Matt-painted (**TMA**) and Mycenaean (**TMY**) types was also included that would complement those of hand-made pottery whose petrographic composition and firing temperature range have been determined by Kiriatzi *et al*. (1997). The Mycenaean from Toumba and Aghios Mamas (**AM**), the latter excavated by Heurtley (1939) and included here for petrographic analysis, were not archaeologically divided into local, provincial or imported groups, but just considered as Mycenaean. Finally, a group of decorated LH IIIB sherds from Mycenae were analysed for comparative technological purposes.

Chemical and petrographic data Classification by PCA using the covariance matrix of the INAA data (using the elements Sm, Lu, U, Yb, Na, La, Ce, Th, Cr, Hf, Cs, Rb, Fe, Ta, Co, and Eu, normalised to Sc and log transformed) for all 106 individuals from Macedonia with no rotation of axis revealed that two samples classified as outliers (**APM**104 and **TMA**16) presented extreme values in the first principal components (PCs), due to their high Cr and Co contents. Also, a group of five individuals (classified as chemical group *Local Mycenaean* 5 - *LM5* -, and basically related to Toumba Thessaloniki) were far from all other individuals, having high positive values in the second principal component, due to their high values in Cs. This situation was forcing all other individuals to a cloud of points close to the origin of the axis. On their removal and repeating PCA, the resulting plot of the first two PCs is as shown in Figure 3. PC1 and 2, accounting together for 73% of the total variance, are dominated by Cr and Co, and by Cr, Hf, Na and Co contents respectively. A broad spectrum of compositions is immediately evident, and both calcareous and low calcium compositions are represented, yet the following general trends can be discerned (Tables 2 and 3): (**1**) Assiros Brown Burnished ware forms two (chemically similar) groups (chemical groups *Brown Burnished* - *BB1* and *BB2*), which are distinguishable from, (**2**) mostly Local Mycenaean (chemical groups *LM*) from Assiros (*LM1* to *LM3*), having negative PC2 scores, and Chrysavgi (*LM4*), close to LM2, and (**3**) Provincial and Imported Mycenaean from Assiros and Mycenaean from Thessaloniki (chemical groups *Probable Imports – PI1* to *PI3*) with positive PC2 scores. It is also possible to isolate more discrete groupings of samples sharing similar compositions, as shown in Figure 3, but many samples are left unassigned.

The provenance of Brown Burnished and Local Mycenaean can be explored by turning now to the petrographic classification in Table 4 (Mitchell 1993). As can be seen, inclusion types are generally metamorphic with lesser amounts of igneous material in such a way that the variation in the composition type is less significant than the variation in texture – the inclusion size range and frequency. This picture harmonises with the sedimentary geology of the Langadas Basin and the Neogene sedimentation close to Aghios Mamas. Therefore, the geological compatibility between the chemical *BB1-2* and *LM1-4* groups and the geology of the Langadas

Basin is consistent with a local origin to the Langadas Basin. Even so, the correlation between the chemical and petrographic classifications is uneven (Figure 3): *LM1* comprises mainly Petrographic Group (PG) 2, *LM2* is less uniform but contains four examples of Petrographic Group 5, *LM4* is petrographically very heterogeneous (Petrographic Groups 1, 2, 3, 4, 5 and unassigned), *LM3* is a mix mainly of Petrographic Groups 3 and 4. Finally, *BB1* and *BB2* are made up of Petrographic Group 1 (Brown Burnished). Two superimposed effects are observed here. On the one hand, the Langadas Basin and other parts of Central Macedonia lie in a region, metamorphic in geological character, whose clays have a significant natural variation both chemically and petrographically. As a consequence, while chemical groupings can be identified, a quarter of the samples analysed are unassigned. Furthermore, chemical differences may not manifest themselves petrographically and vice versa, an example being Petrographic Group 5 with an igneous character which does not stand apart chemically.

The comparison with chemical databases for Kastanas and other sites in Macedonia shows that the one local/regional group chemically defined by Mommsen and Maran (2000-2001) at Kastanas emphatically does not match either *LM1-5* or *PI1* and *PI2*, and the same seems to apply to some of the groups from Mende and Torone. Only the group of Byzantine pottery (and modern brick) from Thessaloniki offers rough similarity. This comparison enables us to propose that groups *PI1* and *PI2* are for the present regarded as products of Central Macedonia but from different centre(s) from those of *LM*, while group *LM5* does not appear to be consistent with an origin in either Thessaloniki or elsewhere in Central Macedonia. Finally, chemical group *PI3* does not show similarities with Kastanas, and looking further afield, coastal Thessaly also looks unlikely, the Argolid is very unlikely, and yet there is some similarity with some of the available data for central Greece, such as Thebes or better Gla. Regarding the two Matt painted individuals from Thessaloniki, both of them have dissimilar compositions: one is probably local (**TMA**15), the other (**TMA**16) remains ungrouped and cannot be classified, having anomalous Th and Rb contents. In any case, as a first result, it is clear that the archaeological Local, Provincial and Imported classification based to a large extent on fabric and decorative quality is not fully upheld chemically.

Technological characterization The technological study was conducted on each chemical group in turn. The results in Table 2 summarise the general trend of each group. The firing temperatures were estimated after combining SEM examination with the results obtained by XRD. A clear division is observed in the calcium content of the clays used, and yet no correlation can be established between the calcium content and the firing temperatures estimated. Thus, there are low calcareous groups both with low firing temperatures (*LM2* and *LM4*) and high ones (*LM1* and *LM3*), as well as calcareous groups with low (*LM5*) and high firing temperatures (*PI1*, *PI2* and *PI3*). Table 2 includes the estimated firing temperatures for the comparative samples from Mycenae.

An important observation is that all the low calcareous groups fired at high temperatures exhibit a special microstructure that can be exemplified with **ALM**111. As may be observed macroscopically, the pottery archaeologically classified as Local Mycenaean has a wide, dark grey core sandwiched between two brownish-red layers. This observation extends to the microstructure: the outer areas exhibit (Figure 4 top) a typical microstructure of continuous vitrification in low calcareous clays, while the core (Figure 4 bottom) has a completely different microstructure. Here, the microstructure consists of a continuously vitrified surface containing a high concentration of fine bloating pores, with a small diameter typically below 5 μm. This kind of microstructure is typically produced by a fast firing (Maniatis and Tite 1975) and is observed basically in groups *LM1* and *LM3*. This observation raises the question of the nature of the firing structure. Taking the term kiln to denote a structure in which the pottery is separated from the fuel (in a firing chamber), it is proposed that fast firing is consistent with the use of a structure other than a kiln; such a structure could be a bonfire or a pit, but in both cases the implication is that fuel and pots are in contact with each other. Significantly, Kiriatzi *et al*. (1997) also infer fast, non-kiln firing from their SEM analysis of hand-made pottery from Toumba. It is well established that kiln firing provides a more controlled firing of longer duration and slower heating rates (Gosselain 1992; Kingery 1997).

The study with SEM-EDX of the red and black colours used to decorate Mycenaean pottery clearly indicated the general use of very fine grain size, illitic-rich clays, both in the case of low calcareous and calcareous clays. Only in the two Matt painted samples oxides were employed (iron oxides for red in **TMA**15 and manganese oxides for black in **TMA**16). Also evident was the higher quality of decoration in chemical groups *PI1*, *PI2* and *PI3*, which was inferred especially from the K_2O and Fe_2O_3 contents of the paint. Drawing in the data for Mycenae, the range of the former element was 3-5% in the body, rising to 5-11% range in the chemical *PI* groups paints, 9-11% at Mycenae, and 4-7% in the chemical *LM* groups paints; the corresponding ranges for iron were 6-14% in the body and 12-18%, 12-14% and 8-12% in the paints respectively. Moreover, the creation of a well-sintered paint layer was also dependent on the firing temperatures achieved. Thus, the best results are to be found in chemical groups *LM1* and *LM3* for low calcareous clays, and chemical groups *PI1*, *PI2* and *PI3* for calcareous ones.

The above results provide important evidence related to the use of black decoration in the Mycenaean-type pottery. The technique adopted was the same as that found elsewhere in the Mycenaean world, that is the iron reduction technique; there were no examples of carbon black or manganese oxide based paints. As regards the final colour, red or black, this was achieved through control of the firing atmosphere: the red was produced by a typical reducing-oxidising firing and oxidising cooling (RO/O), while the black was produced by the same RO/O firing but introducing a short period of reduction at the beginning of the cooling period. It is important to note that the black decoration is related to the calcareous groups, which are probably imported. In these calcareous groups, high quality black decoration can be observed, especially in chemical group *PI3* such as in Figure 5. By contrast, low calcareous chemical groups *LM1* to *LM4* present a total absence of black decoration, only red colours being observed. This could also be explained by the absence of kiln structures, as already suggested by the use of fast firing. In this case, the use of a bonfire in an open firing would make the necessary control of the firing atmosphere impossible. In such a situation, a red colour would be the natural product of a RO/O firing.

Southern Italy

During the Middle Bronze Age (17th century BC), a settlement system in the Plain of Sybaris in Northern Calabria developed, and it continued for a millennium until the Greek colonization of the Plain at the end of the 8th century BC. About thirty sites have been found, some investigated with excavation, others only by survey. Among them, Broglio di Trebisacce in Northern Calabria is a typical ‘major site’, situated on a Quaternary terrace and overlooking the sea and the Plain of Sybaris, with a remarkable continuity of settlement from the Middle Bronze Age to the Early Iron Age. Discovered in 1978, the site has been excavated continuously since 1979 by the Soprintendenza Archeologica della Calabria and the University of Rome ‘La

Sapienza' (Peroni and Trucco 1994; Peroni and Vanzetti 1998; Levi *et al.* 1998; Levi 1999; Peroni 2000; Bettelli 2002). By contrast, Rosa Russa is a 'minor' site on a small terrace investigated only by survey, occupied during the Middle Bronze Age and abandoned during the Recent Bronze Age (Bergonzi *et al*. 1982, 168-718; Peroni and Trucco 1994, 776-778).

At Broglio, the first occurrence of Mycenaean sherds (also called Aegean type regardless of their imported or local provenance) and possibly the local wheel-made Grey ware appears in some Middle Bronze Age 3 layers (equivalent to Aegean LH IIIA). The Central Hut had a high density of such wares during the Recent Bronze Age (equivalent to LH IIIB-early IIIC), and to this period the production of Aegean-derived storage jars (dolia), associated with the introduction of olive cultivation, began. The Final Bronze Age (equivalent to LH IIIC middle-late) saw an increase in building activities (also with the defensive wall and ditch) and an accumulation of goods and crucial economic activities on the acropolis (storage-rooms, iron working). The defences of the acropolis complete the picture. The settlement pattern of the Plain of Sybaris suggests that the Final Bronze Age was a period of intensive territorial competition, and the importance of the acropolis at Broglio points to a precise role of local élite groups in directing this phenomenon.

The Plain of Sybaris has been the focus of large-scale and long-term laboratory-based study of Mycenaean-type and indigenous pottery of the Late Bronze Age. It has been shown by chemical means that the large majority of the decorated Mycenaean-type pottery found at Broglio di Trebisacce was made within the Plain, if not at Broglio itself (Jones *et al*. 2002). Other pottery classes of Mycenaean derivation - Grey ware and the storage jar (dolium) - together with a later adaptation of decorated Mycenaean - Figulina, that appears in the Final Bronze Age-Early Iron Age and was slipped and decorated with red and black painted designs - were also produced there. Moreover, evidence of production of the indigenous handmade Impasto and the more specialised product, the dolium, as well as their circulation within the Plain has been decisively obtained by petrography and other means (Levi 1999). Owing to the existing chemical database for the Plain, it was decided to restrict further chemical characterisation to a small sample set and to use the resulting data in part as an inter-laboratory comparative exercise, the results of which have been reported elsewhere (Jones *et al*. 2002). On the technological front, the results presented here complement those of Levi (1999, 332-34) on the dolia and Impasto using XRD and radiography.

For the present study, 53 samples from Broglio di Trebisacce and 4 samples from Rosa Russa were analysed by the techniques shown in Table 1. The sampling covered all the pottery fabrics identified macroscopically in the area and dating to the Middle, Recent and Final Bronze Age and the Early Iron Age. The 13 Aegean-type sherds (labelled **BTA**) belong to wheel-made closed vessels, in some of which traces of painted decoration are preserved. In particular **BTA**1-2, 4 and 5 correspond to a wide-necked amphora with horizontal handles - very frequent in the Late Bronze Age layers at Broglio, having close parallels in Late Minoan III Western Crete (Vagnetti in Peroni and Trucco 1994, 402-3, 407) - and **BTA**3 belongs to a closed vessel of medium size, with a high cylindrical neck, whose surface is completely covered by black paint. All Figulina ware (labelled **BTF**) samples are closed vessels, whose surface is very often decorated with geometric matt-painted patterns, sometimes wheel-made, but more often handmade (Buffa in Peroni and Trucco 1994). The Grey wheel-made ware (labelled **BTG**) is a fabric particularly common in the Sibaritide in the local LBA. The treatment of clay and the use of the wheel are clearly of Aegean derivation, while the shape repertoire is still more linked to the local tradition (Belardelli in Peroni and Trucco 1994; Bettelli 2002). Sometimes this particular fabric is decorated with a darker grey painting (**BTG**27-28, **BTG**64). The samples of dolia (labelled **BTD**) represent well the fabric variability within this class of vessels (Tenaglia in Peroni and Trucco 1994; Tabò in Peroni and Vanzetti 1998). Impasto pottery, representing the local handmade burnished potting tradition, is represented both by samples from Broglio and Rosa Russa. Moreover, three miscellaneous ceramic materials found at Broglio (**BT**1026, daub; **BT**2005, fornello; **BT**2006, oven lining) were also examined.

Additionally, the firing properties and textural features of thirteen modern clays collected from locations around the Plain of Sybaris were examined as experimental briquettes fired at 800 and 950°C; those from Trebisacce and Marzuca close to the site and Avena and Corigliano (locations in Levi 1999: Fig. 23-24) were also examined by XRD and SEM.

Characterisation and technological data Classification by cluster analysis of the chemical data (using the elements Sm, U, Yb, Na, La, Th, Cr, Hf, Cs, and Fe, normalised to Sc and log tranformed) for 30 pottery samples indicated the presence of one large group, *A1*, and one smaller related group, *A2*, with 18 and 3 samples respectively, two other small groups, *B* and *C*, and outliers (Table 5). Chemical groups *A1* (Table 3) and *A2* both have calcareous compositions with the exception of two Impasto samples. On the basis of comparison with previously obtained chemical data for these classes (set out in full in Levi 1999: 76f), they are likely to be products of the Plain, if not Broglio itself. They comprise most of the decorated Mycenaean type, Grey and Figulina examples, and, furthermore, they separate clearly from a small group of non-calcareous Impasto (chemical group *C*), another small group of two dolia (chemical group *B*) and other four outliers. Among the outliers are two Mycenaean-type examples, **BTA**3 and **BTA**68, one Figulina and one Impasto. The former are imports to the Plain, **BTA**3 from an as yet undetermined source probably in the Aegean; **BTA**68 is from a different source.

A closer look at the technological parameters estimated for the decorated Mycenaean-type and Figulina (Table 5) reveals that the firing temperature for the group of the Plain ranges from very low firing temperatures, exhibiting a typical microstructure with no vitrification (NV), and showing in some cases calcareous fossils, which indicates temperatures below 750/800°C (Kilikoglou 1994), to high firing-overfiring temperatures, exhibiting a microstructure of a total vitrification (TV) stage which indicates temperatures over 1080°C, the atmosphere being usually RO/O. On the other hand, the likely Aegean imports, **BTA**3 and **BTA**68, the latter associated to **BTA**16 on macroscopic grounds, exhibit always high firing temperatures. All these data show that the proposed products of the Plain have a wide range of firing temperatures, indicating that control over their firing was not as good as that on the likely imports. Moreover, this also differentiates the Mycenaean at Broglio from the Mycenae reference group, because the latter is with one exception uniformly fired in the range 950-1050°C (Table 2). Turning to the decoration, the red and black decoration, of imports but also of products of the Plain, represents the finer fraction of an illitic clay, and in this respect it is very similar to the corresponding decoration on pottery from Mycenae, and thus of better quality than that of the chemical *LM* groups from Macedonia (Table 2). The white slip on the two likely imports, **BTA**68 and **BTA**16, was found to be rich in Si, Al (*c*. 10% more in the slip than in the body) and Ca, with smaller amounts of Fe and Mg. The microstructure of this slip shows clearly that it had been applied before firing, and that it had started to sinter but did not have the characteristic smooth surface expected in well vitrified materials (Figure 6, top). It is possibly a lime silicate white, as observed on some Aegean Bronze Age pottery (Noll 1982; Jones 1986: Table 9.8a).

In relation to the Grey ware, all the samples analysed by INAA are products of the Plain, unpainted with firing temperature ranging from NV to Vc+ stages. The firing was always reducing but in some cases a darker core could be observed (indicated with asterisk in Table 5). The surface treatment was restricted to polishing/burnishing, there being no slip. **BTG**24, **BTG**67 and **BTG**25, which are the high fired individuals, exhibit a characteristic shiny metallic grey colour which is attributed here to the effect of high firing temperatures. This effect is well known in calcareous clays fired under reducing conditions at high temperatures, for instance in the technological recipe of Aegean Minyan Ware (Jones 1986: 788f). By contrast, **BTG**27 and **BTG**28 (not analysed chemically) stand apart by virtue of the presence of black decoration and very high firing temperature (Figure 6 bottom), but whether these two features are related cannot be established on the basis of only two examples. In any case, the decoration is suggestive of the use of the finer fraction of an illitic clay, in common with the examples of other wares in Table 5.

The dolia exhibit a range of chemical compositions which are consistent with the use of a fine calcareous clay containing differing types and amounts of tempering material. The latter material ranges from sandstone and calcite, calcareous siltstone to crystalline rocks and mica, as already shown from petrographic analysis (Levi 1999: 145; Jones *et al*. 2002). The dolia belonging to chemical groups *A1* and *A2* also exhibit a wide range of firing temperatures, spanning NV to Vc. On the other hand, the two dolia in chemical group *B* are more consistent in their firing.

Finally, the results clearly demonstrate the contrast in technology between all the previous Aegean-influenced wares and Impasto. The latter has a low calcium content and contains a variety of materials (Impasto sample **BTI**59, found at Rosa Russa, is rich in garnet and mica; chemical group *C*, found at Broglio, sandstone, siltstone, calcite; chemical group *A1*, found at Broglio, mainly siltstone). It is fired at low temperatures, developing a soft structure that corresponds to a completely different technological tradition from the well fired Aegean products, which typically exhibit extensive vitrification. Its surfaces were burnished but not slipped. These characteristics apply even to the two samples whose compositions apart from their Ca contents, were ascribed to the *A1* group. Moreover, since all the clays included in the present study were found to be calcareous (17.8-18.6% CaO range) and not themselves compatible sources for the Impasto products; instead it is possible Impasto was made of a clay/soil mix. Two of the miscellaneous ceramic materials, **BT**1026 (daub) and **BT**2006 (oven lining), were calcareous, 19 and 22% CaO respectively, while **BT**2005 (fornello) was akin chemically to Impasto.

DISCUSSION

While the indigenous pottery of the two regions, Impasto and Brown Burnished ware, share common traits, such as the use of low calcareous clays, fired at low temperatures, decorated only by burnishing/polishing the surface, the present study has provided evidence that the Mycenaean/Aegean influence has acted in different ways in both regions.

The technology of production has been revealed to be more controlled in southern Italy than in Central Macedonia. In the former, the results of this study have, independently of the archaeological picture, indicated that potters, either Mycenaean or at least familiar with the Mycenaean tradition, were successfully producing pottery in an Aegean-influenced manner. In that sense, Mycenaean type and Aegean-influenced classes were produced, by using the wheel and calcareous clays, fired in kiln structures, and, although the firing temperature is wide, it is the relatively high proportion of the pottery that was fired typically at temperatures in the range 850-950°C that is impressive. Nevertheless, the ability to produce black decoration indicates knowledge of kiln firing and the ability to control the changes of oxidising-reducing-oxidising episodes during firing. In this case, the dichotomy between Mycenaean and indigenous traditions is more clear cut than in central Macedonia where by contrast a wide diversity of technological recipes (affecting the calcium content in the clays used), firing temperatures, duration of firing, decoration, and even the use or otherwise of kiln structures is observed. This diversity is not random but is supported by the clear correlation between chemical groups and technology used, suggesting the co-existence of different traditions that may have been in operation. Thus, some chemical groups representing local/regional production (*LM1-4* groups), in which the Mycenaean influence seems to be restricted more to style than to technology, were made from low calcareous clays even though better quality calcareous clays were available in the region and indeed were sometimes exploited. These products were not fired in a kiln, giving little control of firing atmosphere with the result that only red decoration was achieved. These firing structures could be pit-kilns, perhaps like those of Early Bronze Age date reported from Aghios Mamas

(Heurtley 1939: 5-7) and Polychrono (Pappa 1990) in the Chalkidiki and Sindos (Andreou 1996-97) near Thessaloniki. By contrast, true kilns have not yet been found in the north, the nearest ones of Mycenaean date being found at Velestino (Batziou-Efstathiou 1994) and Dimini (Adrimi-Sismani 1999) in Thessaly. Thus, the normally strict contrast between Mycenaean from calcareous clays and fired at high temperature, and handmade pottery, built from low calcareous clays and fired at low temperatures, is an over-simplification, restricted perhaps to the Mycenaean heartland, and some other areas like southern Italy.

Accepting that our two case studies are different in size, the two regions also present contrasting pictures as regards the primary materials. In Central Macedonia many fabrics are observed; there seems to be little standardisation which we believe to be the result of two superimposed phenomena, one geological - the clays in the region tend to have a broad continuous spectrum of compositions - and one archaeological - several possibly small workshops using different recipes rather than centralised production of Mycenaean pottery. The link found between several groups and sites (chemical groups *LM1-3* with Assiros; *LM4* with Chrysavgi), as well as the picture offered by the research conducted at Kastanas, seems to support the interpretation of dispersed production in this region. It is significant that the chemical evidence for imports from outside Macedonia is slim even for the three chemical groups, *PI1-PI3*, that share the features of calcareous clays and high firing temperatures with black and red decorations achieved usually from a well controlled kiln atmosphere. Especially for these groups, as well as for *LM5*, its status awaits further evaluation as the database for Macedonia expands, in the first instance in the light of results from Toumba, Thessaloniki for which INAA analyses of more examples of Mycenaean are expected to be completed in 2002. In the meantime, the terms Local, Provincial and Imported Mycenaean remain useful archaeological concepts in the Langadas Basin even if they do not accurately reflect the true situation in terms of provenance alone. By contrast, the position in the Plain of Sybaris is somewhat clearer due in the part to the larger chemical database than for central Macedonia. The chemical data for decorated Mycenaean are consistent with discrete production within the Plain, a result that seems to be paralleled elsewhere in southern Italy, for instance in the Metapontum (Termitito) and Taranto areas (Jones *et al*. 2002). It is logical to suppose there were potters working in the Mycenaean tradition either permanently based in these areas or less likely itinerant; in any case, however their operations were organised, their output had a good measure of standardisation.

Before concluding, it is important to point that, at the methodological level, this investigation has shown the merits of combining provenance with technological enquiry, the latter achieving its main impact when linked to a well-established chemical group. Returning to the questions posed at the outset of this paper, we have made progress in describing the situation and establishing that a new technology had arrived in the two regions, but we have not explained the technology transfer. For Macedonia, this will require a larger database for Mycenaean pottery in regions such as Thessaly, as well as a fuller archaeological picture with regard to production, information that is in any case going to be hard to come by. There will be no quick solutions.

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LIST OF ABBREVIATIONS

Related to analytical and statistical Techniques: AAS – Atomic Absorption Spectrometry; EDX - Energy Dispersive X-ray fluorescence; INAA - Instrumental Neutron Activation Analysis; OES - Optical Emission Spectroscopy; PC - Principal Component; PCA - Principal Component Analysis; SEM - Scanning Electron Microscopy; XRD - X-Ray Diffraction.

Analytical groups: *LM* - Local Mycenaean (Macedonia); *PI* - Probable Imports (Macedonia); *BB* - Brown Burnished (Macedonia); PG - Petrographic Group (Macedonia); *A1 and A2* Mycenaean-type pottery in the Plain of Sybaris.

Firing atmosphere: O - oxidising; R - reducing; RO/O - Reducing-oxidising firing, oxidising cooling.

Vitrification stage (firing temperature): NV, no vitrification; IV, initial vitrification; Vc, extensive vitrification (Vc- initial; Vc+ advanced); TV, total vitrification.

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Figure captions

Table captions

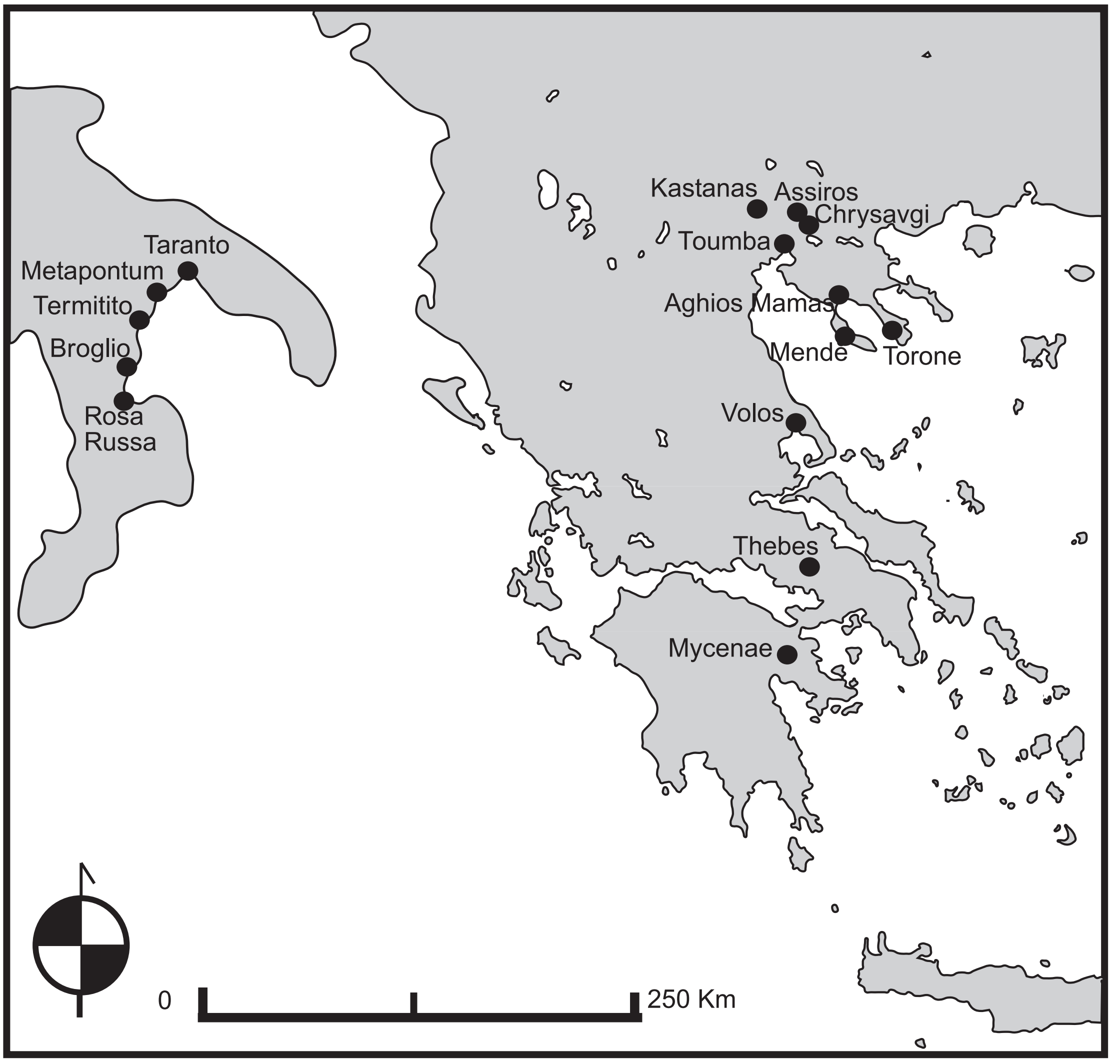

Figure 1. Map of Macedonia and Southern Italy

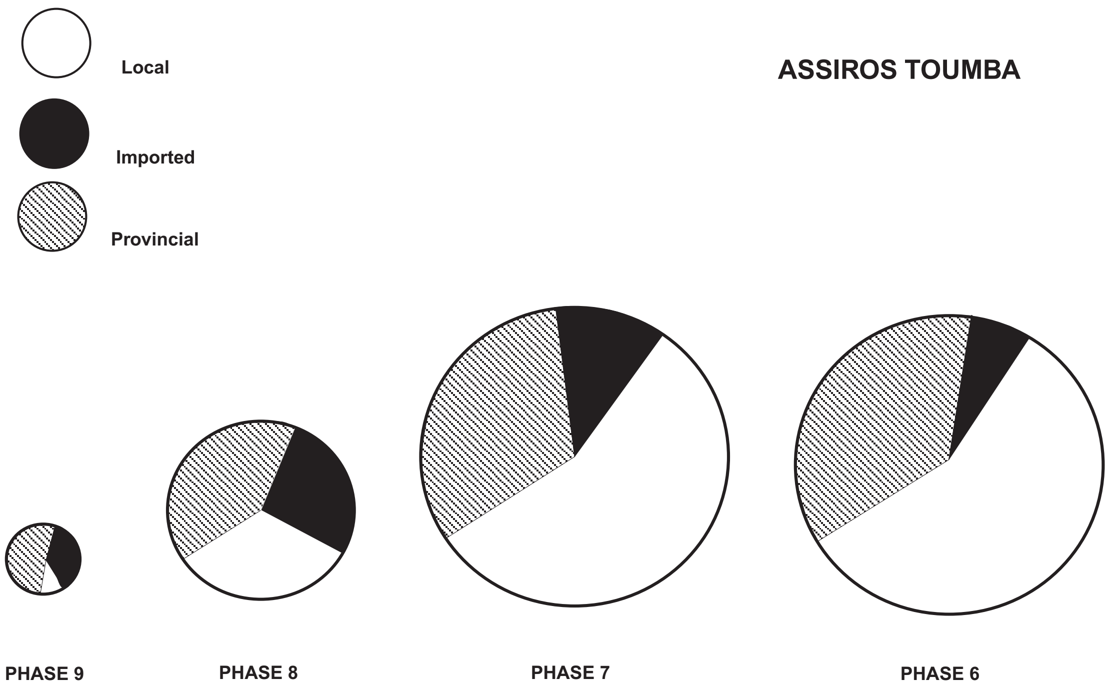

Figure 2. Changes in frequency of the different classes of Mycenaean pottery at Assiros (Local (ALM), Provincial (APM) and Imported (AIM)), based on visual characteristics. Assisors phases 9, 8, 7 and 6 correspond to LH IIIA2, LH IIIB, LH IIIC and LH IIIC respectively. The area of each circle is proportional to the relative frequency of Mycenaean sherds in each phase (sherds per 100 m^3 of deposit). After Wardle 1993, Figure 5

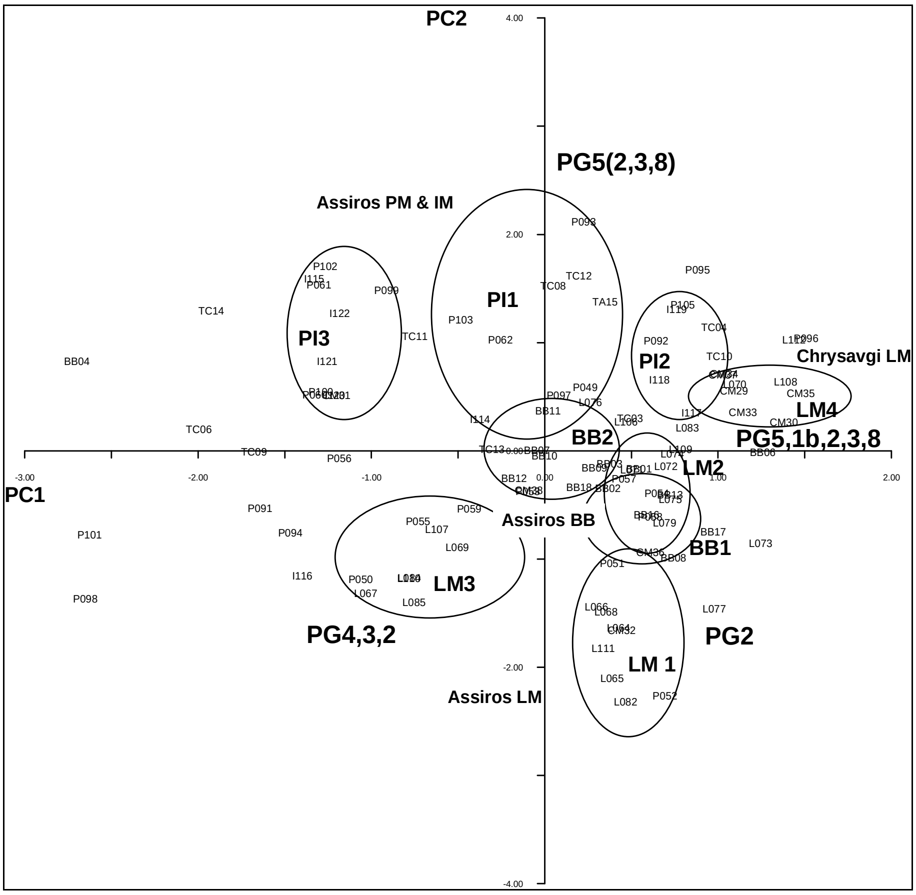

Figure 3. PCA of the Macedonia INAA data. Plot of PC1 vs. PC2, explaining 62% and 11% respectively of the total variance. All chemical groups, except *LM5*, are shown; their limits are not probabilistic ellipsoids. The petrographic groups (PG) are superimposed on the plot. For the purpose of legibility, samples are labelled in abbreviated form: L (for **ALM**), P (for **APM**), I (for **AIM**), BB (for **ABB**), TC (for **TMY**), TA (for **TMA**), and CM (for **CLM**)

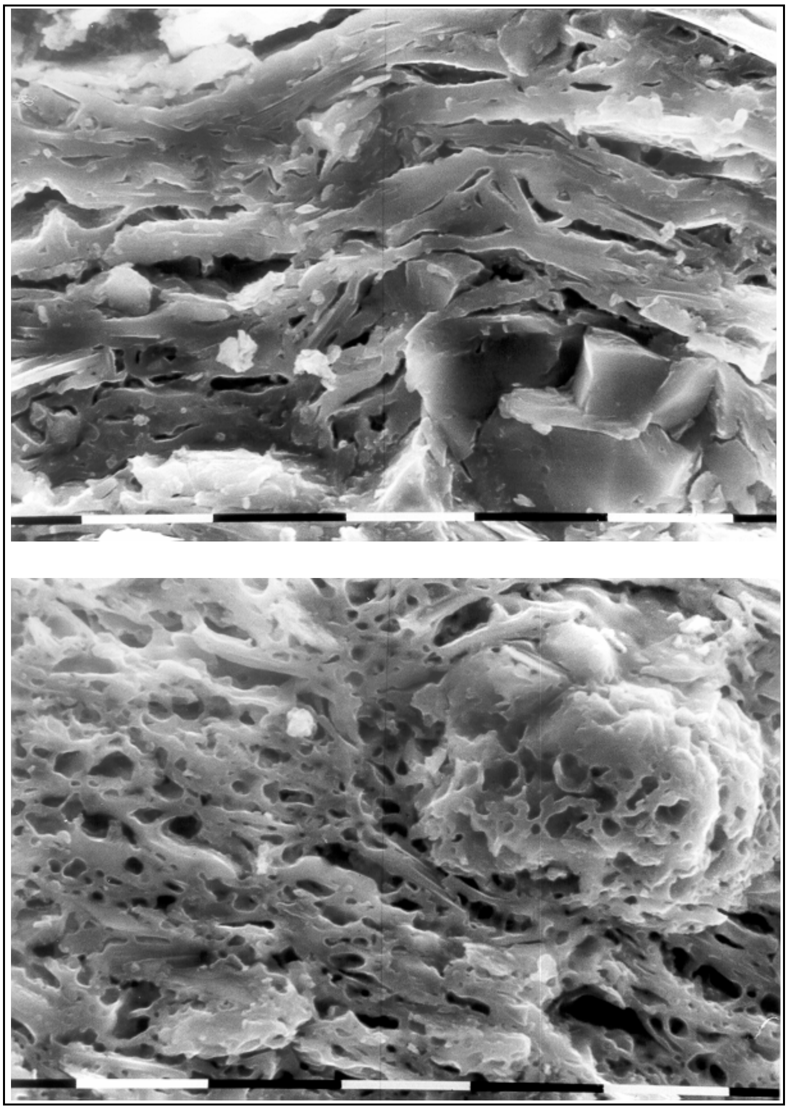

Figure 4. SEM microphotographs of **ALM**111 (in group *LM1*) showing (top) typical Vc (continuous vitrification) microstructure in the areas close to the external and internal surfaces, and (bottom) the microstructure in the grey core with high concentration of fine bloating pores. Magnification 2.02 x 10^3. The bar indicates 10 μm

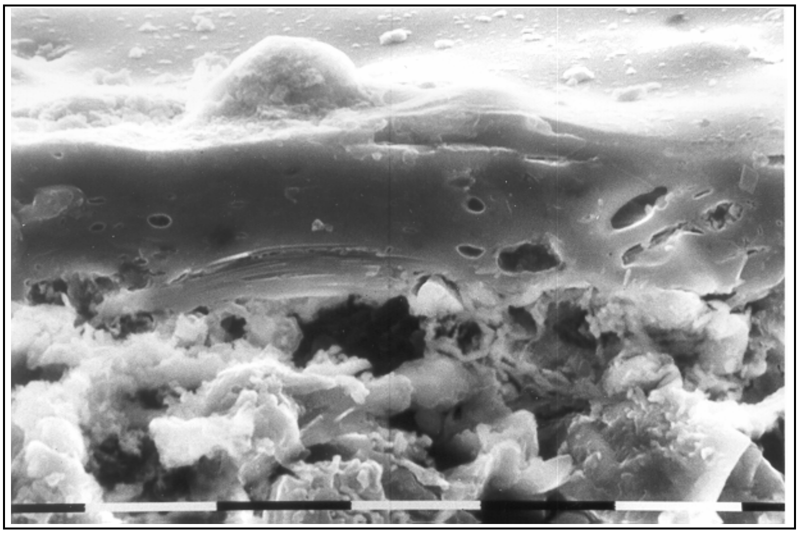

Figure 5. SEM microphotograph of Assiros Provincial Mycenaean sample 99 (group *PI3*) with black decoration of good quality. Magnification 2.02 x 10^3. The bar indicates 10 μm

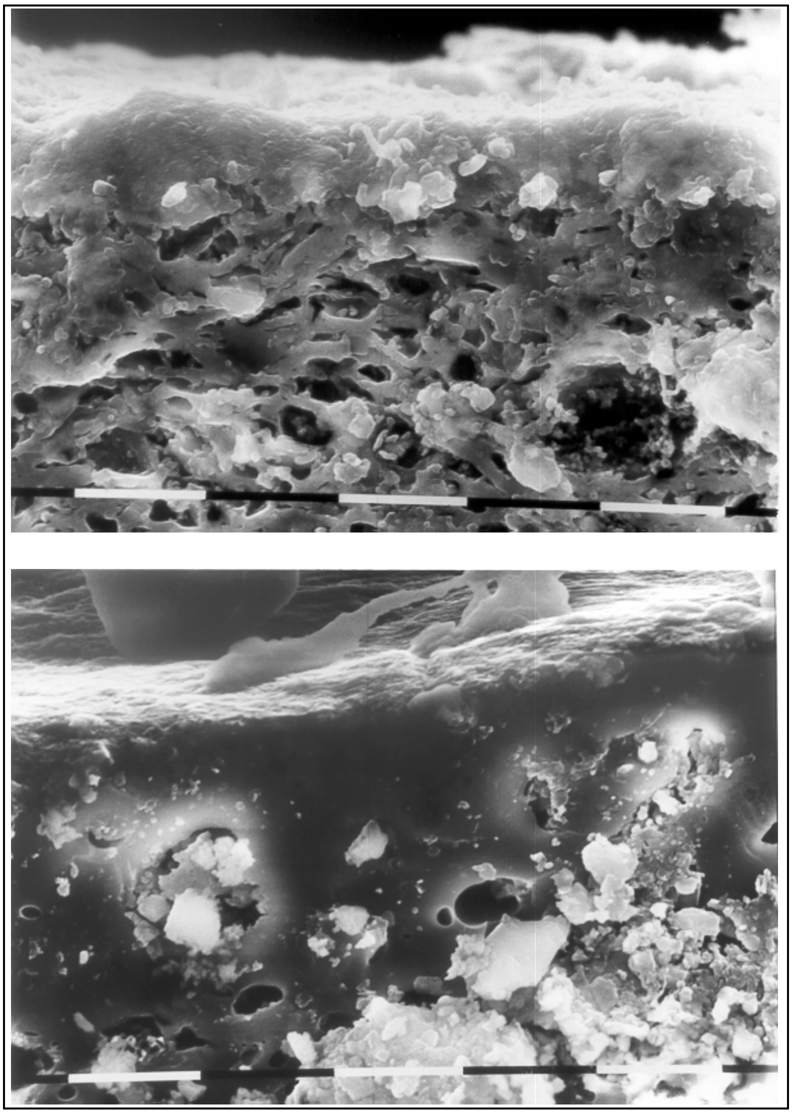

Figure 6. SEM microphotographs of (top) **BTA**68 (Mycenaean decorated) showing the white decoration and matrix of a Vc (continuous vitrification) microstructure, and (bottom) **BTG**28 (Grey ware) showing the black decoration and Vc+/TV (continuous vitrification plus/total vitrification) matrix. Magnification 2.02 x 10^3. The bar indicates 10 μm

Table 1 The material analysed from Macedonia and southern Italy, according to site and technique. In brackets, abbreviations of archaeological categories used in the text

Site and Archaeological Type	***NAA***	***SEM***	***XRD***	***PE***
MACEDONIA				
Assiros				
Brown Burnished (**ABB**)	15		7	28
Local Mycenaean (**ALM**)	27	9	9	22
Provincial Mycenaean (**APM**)	29	17	12	5
Imported Mycenaean (**AIM**)	9	9	3	
Total	*80*	*35*	*31*	*55*
Chrysavgi				
Local Mycenaean (**CLM**)	10		3	10
Aghios Mamas				
Mycenaean type (**AM**)				10
Thessaloniki				
Mycenaean type (**TMY**)	14	7	7	
Matt painted (**TMA**)	2	2		
Total	*16*	*9*	*7*	
ARGOLID				
Mycenae				
Decorated LH IIIA-B		5		
SOUTHERN ITALY				
Broglio di Trebisacce				
Aegean/Mycenaean type (**BTA**)	6	13		
Grey ware (**BTG**)	6	9		
Figulina (**BTF**)	6	9		
Dolia (**BTD**)	6	10		
Impasto (**BTI**)	5	9		
Miscellany (**BT**)		3	3	
Total	29	53	3	
Rosa Russa				
Impasto (**BTI**)	1	4		

Table 2. Macedonia: correspondence between chemical groups along the top row and the archaeologically-derived classes in the left-hand column (see abbreviations in Table 1). Clay type: C, calcareous; LC, low calcareous. FF = fast firing

	LM1	***LM2***	***LM3***	***LM4***	***LM5***	***PI1***	***PI2***	***PI3***	***BB1***	***BB2***	**Unassigned**	**Total**
ALM	6	4	6	2	1						8	**27**
APM	2	3	2			3	3	6			10	**29**
AIM						1	3	4			1	**9**
CLM	1	1		6				1			1	**10**
TMY					4	2	2	2			4	**14**
TMA						1					1	**2**
ABB									4	7	4	**15**
Total	**9**	**8**	**8**	**8**	**5**	**7**	**8**	**13**	**4**	**7**	**29**	**106**
Clay type	LC	LC	LC	LC	C	C	C	C	LC	LC		
Firing temp. °C	800- 900 FF	<800 (FF)	800- 900 FF	<800 (850?)	<800 (850?)	850- 1050	850- 1050	850- 1050	<800	<800		
Mycenae (all C): 900-1050°C (4 samples), 1050-1080°C (1 sample)												

Table 3. Means (m), in ppm (except Ca, Na and Fe in %), and standard deviation in % (%sd) of the chemical composition groups from Assiros, Chrysavgi and Toumba Thessaloniki, and *A1* from Southern Italy

	LM1		***LM2***		***LM3***		***LM4***		***LM5***		***PI1***		***PI2***		***PI3***		***BB1***		***BB2***		***A1***	
	(n=9)		(n=8)		(n=8)		(n=8)		(n=5)		(n=7)		(n=8)		(n=13)		(n=4)		(n=7)		(n=18)	
	m	%sd	m	%sd	m	%sd	m	%sd	m	%sd	m	%sd	m	%sd	m	%sd	m	%sd	m	%sd	m	%sd
Sm	7.81	11.9	7.38	6.6	5.85	6.5	7.56	10.2	4.55	7.5	6.12	13.1	6.66	4.5	5.30	10.2	9.48	6.7	6.83	6.7	6.54	7.9
Lu	0.44	13.6	0.41	9.8	0.37	8.1	0.48	12.5	0.30	6.7	0.39	15.4	0.39	5.1	0.35	8.6	0.52	9.6	0.41	9.8	0.36	11.1
U	5.1	31.4	4.4	22.7	2.2	13.6	3.9	28.2	1.7*	29.4	2.7	18.5	2.7	14.8	2.3	26.1	4.6	26.1	2.9	13.8	2.9	20.7
Yb	3.77	11.14	3. 39	5.3	3.20	6.2	4.03	7.2	2.61	11.5	3.28	9.4	3.29	5.2	3.00	5.7	4.06	7.6	3.56	9.0	2.88	9.4
As	22.5	36.4	13.0	55.4	17.7	37.3	10.7	17.8	13.0	81.5	7.2	45.8	6.9*	82.6	11.0	129.1	8.9	55.1	21.1	92.9	6.1	31.1
Sb	0.7	22.8	0.6	33.3	1.1*	18.2	0.7	14.3	1.2	25.0	0.7	14.3	0.2*	50.0	0.5*	20.0	0.5*	12.0	0.7*	57.1	0.7*	14.3
Ca %	nd*	nd	2.58*	26.0	4.15*	27.2	4.20*	nd	4.31*	15.1	4.11*	18.5	4.57	26.0	6.10*	23.1	nd*	nd	1.85*	21.6	5.37*	24.2
Na %	1.25	14.4	1.50	9.3	1.11	5.4	1.32	22.0	1.79	6.1	1.68	14.9	1.88	10.6	1.13	25.7	1.18	6.8	1.29	10.8	0.82	14.6
La	47.4	6.4	40.2	7.0	31.5	4.8	44.1	11.6	24.1	3.7	33.3	5.4	34.3	4.7	29.1	7.2	53.1	7.2	36.4	7.1	36.9	7.8
Ce	113.5	6.6	93.7	9.1	76.4	5.6	100.4	11.9	60.2	3.0	79.6	6.5	83.6	5.3	73.4	7.9	112.1	11.5	85.3	11.6	82.0	7.2
Th	19.7	7.1	15.6	10.9	10.9	7.3	17.9	17.9	10.0	3.0	13.4	4.5	13.3	4.5	11.9	9.2	19.3	7.2	12.6	7.9	13.8	10.9
Cr	107.4	5.9	104.8	14.2	136.6	4.7	91.1	15.0	284.6	6.6	196.7	13.5	94.4	10.9	416.8	12.8	130.5	4.1	121.8	16.1	85.6	13.4
Hf	2.68	20.5	4.74	12.9	4.72	13.1	7.81	17.1	4.23	12.1	5.53	15.9	5.85	10.1	3.85	9.1	6.29	9.5	6.85	10.1	4.89	10.0
Cs	7.65	6.3	6.46	9.6	5.42	9.8	6.92	9.4	48.66	42.8	6.54	8.9	4.20	17.4	6.04	15.6	8.35	5.4	4.49	12.9	7.47	16.5
Tb	1.0*	20	0.9*	22.2	0.5*	60.0	1.0	20.0	0.5	60.0	0.8	50.0	0.8	25.0	0.6*	33.3	1.0*	30.0	0.8*	62.5	0.7*	42.9
Sc	19.51	3.6	17.34	6.6	19.58	4.4	15.72	9.1	20.47	3.7	16.20	9.6	13.80	6.2	19.01	6.6	20.84	4.7	18.01	6.4	13.79	6.7
Rb	187	9.1	166	12.6	120	17.5	161	7.4	144	36.8	121	17.3	161	11.2	133	21.0	187	13.9	129	24.0	136	16.9
Fe %	5.76	5.0	4.79	9.6	4.99	4.4	4.38	10.5	4.69	7.9	4.21	8.1	4.25	9.2	5.65	6.4	5.48	5.6	4.79	5.4	4.04	7.4
Ta	1.6	18.7	1.6	12.5	1.0	30.0	1.7	11.8	1.0	20.0	1.3	15.4	1.1	18.2	1.2	16.7	1.9	10.5	1.4	21.4	1.3	30.8
Co	23.63	8.42	19.70	17.0	25.64	6.9	17.31	8.3	29.18	13.8	21.88	11.4	17.74	9.0	42.00	10.2	21.94	8.4	21.09	19.1	13.79	10.7
Eu	1.66	15.7	1.60	11.9	1.35	11.1	1.50	7.3	1.02	10.8	1.31	15.3	1.44	15.3	1.21	14.9	1.93	16.6	1.58	15.8	1.23	8.1

* Group *LM1*: Ca, not determined for any individual; Tb, determined only for 8 individuals. Group *LM2*: Ca, determined only for 4 individuals; Tb, determined only for 5 individuals. Group *LM3*: Sb, determined only for 6 individuals; Ca, determined only for 6 individuals; Tb, determined only for 4 individuals. Group *LM4*: Ca, determined only for 1 individual. Group *LM5*: U, determined only for 3 individuals; Ca, determined only for 4 individuals. Group *PI1*: Ca, determined only for 6 individuals. Group *PI2*: As, determined only for 6 individuals; Sb, determined only for 5 individuals. Group *PI3*: Sb, determined only for 9 individuals; Ca, determined only for 11 individuals; Tb, determined only for 11 individuals. Group *BB1*: Sb, determined only for 3 individuals; Ca, not determined for any individuals; Tb, determined only for 3 individuals. Group *BB2*: Sb, determined only for 6 individuals; Ca, determined only for 2 individuals; Tb, determined only for 6 individuals. Group *A1*: Sb, determined only for 17 individuals; Ca, determined only for 17 individuals; Tb, determined only for 17 individuals. (m = mean; %sd = standard deviation in %; nd = non determined)

Table 4. Petrographic classification (see abbreviations in Table 1)

Petrographic Group	Archaeological Class and number of individuals	Characteristics
1a	**ABB -** 19	Variable colour; dark core; micaceous clay with much metamorphic quartz; biotite and muscovite; occasional rounded, weathered quartz-mica schist
1b	**ABB** - 4 **CLM** - 1	Similar to 1a but more schistose. Schist is biotite
1c	**ABB -** 3	Similar to 1a but some coarse, altered calcareous material
2	**CLM** - 3 **ALM** - 8 **APM** - 4	Similar variation in colour and grey core as Group 1. Small-size quartz and mica; occasional altered calcareous material
3	**CLM** - 1 **AM** - 9 **ALM** - 1 **APM** - 4	Similar to Groups 1 and 2, but no common alignment of inclusions and less micaceous material
4	**ALM** - 8 **APM** - 4	Fine grained inclusions of quartz, mica, schist and calcareous material
5	**ALM** - 2 **APM** - 1 **AM** - 1 **CLM** - 3	Inclusions similar to previous groups, but notable presence of polycrystalline quartz with plagioclase (microcline) feldspar
6	**APM** - 6	Rounded, unaligned quartz and mica
7	**ALM** - 3	Fine-grained group
8	**APM** - 2 **CLM** - 1	Fine-grained group dominated by micaceous and mica-schist inclusions
Singletons	**ABB** -1 **CLM** - 1	

Table 5. Southern Italy: correspondence between chemical group, type of pottery and technological parameters. Ca, clay type: C, calcareous; LC, low calcareous. Atmosphere: O, oxidising; R, reducing; RO/O, reducing-oxidising/ oxidising. * presence of a darker core. NV, no vitrification; IV, initial vitrification; Vc, extensive vitrification; TV, total vitrification

Type	*Samples*	*Ca*	*Atmosphere*	*Decoration*	*Firing temperature °C*
Group A1					
Aegean	**BTA**69	C	O		NV <800
	BTA5	C	RO/O	Red	Vc 850-1050
	BTA1	C	RO/O	Red	Vc/Vc+ 850-1080
	BTA4	C	RO/O*	Black	TV >1080
Figulina	**BTF**42	C	O		NV <800
	BTF41	C	RO/O		IV/Vc- 750-850
	BTF21	C	O		Vc/Vc+ 850-1080
Grey Ware	**BTG**22	C	R*		NV <800
	BTG71	C	R		Vc-/Vc 800-1050
	BTG26	C	R*		Vc 850-1050
	BTG24, 67	C	R		Vc/Vc+ 850-1080
	BTG25	C	R		Vc+ 1050-1080
Dolia	**BTD**34, 36	C	R; O		NV/IV <850
	BTD30	C	O		Vc 850-1050
Impasto	**BTI**50, 66	LC	R; RO/O		NV <750
Group A2					
Figulina	**BTF**39	C	O	Red	NV/IV <850
	BTF37	C	R	Black	Vc/Vc+ 850-1080
Dolia	**BTD**63	C	O		Vc-/Vc 800-1050
Group B					
Dolia	**BTD**35	LC	RO/O		V 800-900
	BTD62	C	RO/O		Vc 850-1050
Group C					
Impasto	**BTI**55, 65, 70	LC	RO/O		NV <750
Outliers					
Aegean	**BTA**3, 68	C	R; O	Black	Vc 850-1050
Figulina	**BTF**43	C	O		NV/IV <850
Impasto	**BTI**59	LC	RO/O		NV <750
Not analysed by NAA					
Aegean	**BTA**7, 8, 11	C	RO/O; O	Red	NV <800
	BTA6, 16	C	R; RO/O		Vc 850-1050
	BTA2, 9	C	RO/O	Red; Black	Vc/Vc+ 850-1080
Figulina	**BTF**47	C	RO/O		NV/IV <850
	BTF48	C	O		Vc-/Vc 800-1050
	BTF38	C	RO/O	Black	Vc/Vc+ 850-1080
Grey Ware	**BTG**23	C	R*		NV/IV <850
	BTG27, 28	C	R*; R	Black	Vc+/TV >1050
Dolia	**BTD**29, 31, 32, 33	C	O		Vc 850-1050
Impasto	**BTI**49, 51, 54, 60, 57, 61	LC	RO/O; R		NV <750
	BTI56	C	RO/O		NV<750