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The circulation and consumption of Red Lustrous Wheelmade ware: petrographic, chemical and residue analysis

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Abstract

Red Lustrous Wheelmade ware is one of the most recognisable classes of pottery from the Late Bronze Age of the east Mediterranean. Yet both its production source and the nature of its contents and use remain a source of some debate. These questions are tackled here through an intensive programme of scientific analysis involving 95 samples of Red Lustrous Wheelmade ware and related wares from seven sites in Turkey, Cyprus and Egypt. Petrography and instrumental neutron activation analysis are combined in the study of the ceramic fabrics, with a view to specifying the source of this ware; while gas chromatography and gas chromatography-mass spectrometry are used to analyse absorbed and visible residues in and on the sherd samples, in the hope of shedding light on vessel contents and possible use. The results of the fabric analysis show the ware to be extremely homogeneous, indicative of a single source: northern Cyprus is at present the most likely candidate, although further analysis, particularly of clay samples from the region in question, would certainly be desirable. The residue analysis suggests that Red Lustrous Wheelmade ware might have been used to carry some kind of plant oils, possibly perfumed, and that in some instances the vessel interior was coated with beeswax as a sealant.

Özet

Çarkta yapılmış Kırmızı Parlak Keramik mal grubu (Red Lustrous) Doğu Akdeniz'de Geç Tunç Çağı'na ait en çok tanınan keramik sınıflarından birini oluşturmaktadır. Yine de üretim kaynağı, kapsamının özelliği ve kullanımı tartışma konusu olarak devamlılığını korumuştur. Bu sorular burada yoğun bir bilimsel analiz programı çerçevesinde ele alınmış, 95 adet çarkta yapılmış Kırmızı Parlak Keramik mal grubu (Red Lustrous) ve bu mal grubuyla bağlantılı keramiklerin ele geçtiği Kıbrıs, Mısır ve Türkiye'den 7 yerleşim alanı bu çalışmaya dahil edilmiştir. Bu mal grubunun hangi kaynağa ait olduğunu belirlemek amacı ile petrografi (kayaları sınıflandırma) ve enstrümantal nötron etkinleştirme analizleri keramik dokusu çalışmasında birleştirilmiştir. Ayrıca kapların ne maksatla kullanılmış olabileceğini ve içlerinde neleri bulundurduklarına da açıklık getirmek amacı ile örnek keramik parçalarının yüzeyinde ve içinde emilmiş ya da görünür durumda olan artıkların analizi için gaz kromatografisi ve gaz kromatografisi-kitle spektrometrisi kullanılmıştır. Doku analizinin sonuçları keramik mal grubunun son derece homojen olduğunu göstermekte ve tek bir kaynağa işaret etmektedir: Kuzey Kıbrıs bugün için en olası aday olmakla beraber özellikle konu ile ilgili bölgeye ait kil örneklerinin analizi kesinlikle gereklilik göstermektedir. Ele geçen artıkların analizi, çarkta yapılmış Kırmızı Parlak mal grubunun (Red Lustrous) muhtemelen kokulu olan bazı bitkisel yağların taşınmasında kullanıldığını ve bazı durumlarda kapların içinin tecrit macunu vazifesi gören balmumu ile sıvandığını işaret etmektedir.

During the Late Bronze Age, and in particular the period ca. 1500–1200 BC, a remarkable florescence of 'international' trade is seen across the east Mediterranean and surrounding areas. Archaeological evidence shows the movement of raw materials and artefacts taken to a whole new level, in terms of the distances travelled, the quantities transported and the diversity of products involved. The dynamics of this trade are surely diverse, spanning gift exchange, commodity trade conducted by independent producers and merchants, and the controlled distribution networks of centralised palatial economies. While the relative significance of these different mechanisms has been much debated (Knapp 1991; 1998; Sherratt, Sherratt 1991; 1998; Sherratt 2001), the nature of the evidence in some instances does not allow the debate to progress. For example, one cannot identify with certainty the provenance of some traded materials, such as the tin ingots on the Ulu Burun shipwreck

(Hauptmann et al. 2002). In other cases, ceramic vessels are said to have contained particular precious commodities — perfumed oils in Mycenaean stirrup jars, or opiates in base ring jugs (Merrillees 1962; Bisset et al. 1994; 1996; Koschel 1996) — although the analytical techniques for identifying the residues in such containers cannot always give clear answers. Moreover, attempts have been made to identify the provenance of the ceramic vessels themselves, with varying degrees of success. Sometimes only stylistic assessments are made, often on dubious grounds; neither does the use of ceramic petrography and/or chemical techniques guarantee satisfactory answers.

Red Lustrous Wheelmade (RLWm) ware is one of the many artefact categories that play a part in this story of east Mediterranean international trade. It is a highly distinctive class of Late Bronze Age pottery, which seems to emerge some time during the 16th century BC, and continues in production through until the early 12th century BC. The ware is found most abundantly on Cyprus, but also in significant quantities in Anatolia, Syria, Lebanon, Palestine, Israel and Egypt (Eriksson 1991: 85, fig. 10.2; see fig. 1; see also Eriksson 1993). The wide extent of its distribution, however impressive, is not entirely unique; Mycenaean wares are also very widely distributed (albeit, admittedly, not far into the Anatolian interior; Todd 2001; Kozal 2003), as are Canaanite amphorae (Bourriau et al. 2001). What does seem to be peculiar to Red Lustrous Wheelmade ware, however, is its remarkable homogeneity wherever it is found, indicating, in all likelihood, that it derives from a single source area. Although the circulation of some open shapes, such as bowls, indicates that RLWm ware must have been valued in and of itself to some extent, the predominance of closed shapes also suggests that RLWm vessels were in large part traded for their contents. These contents were presumably liquid and, given the highly constricted nature of the openings of most RLWm vessels, could not have been too viscous. The implication is, therefore, that one valuable liquid commodity — a perfumed oil perhaps — may also have had a very particular provenance within the region, and was widely sought after. The contents of Red Lustrous Wheelmade ware are also investigated in this paper, using gas chromatography-mass spectrometry (see below).

Yet the source of Red Lustrous Wheelmade ware remains something of a mystery, and has been much debated for decades (Eriksson 1993). Whereas White Slip ware, for example, is clearly a Cypriot product, and has even had one of its kiln sites excavated (Todd, Pilides 2001), and Base Ring ware has also been strongly connected to Cyprus (Vaughan 1987; 1991), no production locales for RLWm ware have been found, on Cyprus or elsewhere, and nowhere is it very obviously a local product. Initial investigations favoured north Syria (Gjerstad 1926; Sjöqvist 1940; Merrillees 1963), and although Cyprus had on occasion been put forward as a possibility (Åström 1969), Syria remained the main candidate into the 1970s. However, the challenge to this entrenched position was to grow. Åström followed up his 1969 work with a more substantial analysis (1972) indicating a Cypriot source for RLWm ware. Yet other options were offered, such as Anatolia (Courtois, Courtois 1978), in particular upper Cilicia (Courtois 1979), and in his work on RLWm ware from Boğazköy, Müller-Karpe (1988) suggested a source in either Cilicia or north Syria.

Current opinion favours Cyprus for four principal reasons: the greatest quantities are found on the island; its finds display the fullest range of shapes; the broadest temporal distribution is also encountered in the Cypriot finds (i.e. 16th to 12th century BC); and the pot-marks sometimes incised on certain shapes appear to show affinities with signs in the Cypro-Minoan script (Eriksson 1991; 1993: 145–47). While each of these points in turn is inconclusive, when put together they do create a more convincing story. Nevertheless, Eriksson's reasons for favouring a Cypriot source have not been met with total agreement, and there is indeed some room for argument. Given that the connection between the pot-marks and the Cypro-Minoan script is far from conclusive, the other three reasons are all indirect, and might to some extent be explained by the considerable amount of material recovered from the island in comparison to neighbouring areas such as coastal Anatolia and Syria. More direct forms of evidence are called for, such as the use of physico-chemical characterisation techniques to help establish provenance. Some chemical analysis (using neutron activation analysis [NAA] at the Lucas Heights reactor in Sydney) was initiated by Eriksson in conjunction with Michal Artzy, but the results were never published for want of a fuller database for comparison (Eriksson 1993: 19, n. 3).

The present study

Thus very little is actually known of the physico-chemical characteristics of RLWm ware. The present study seeks to address this gap in our knowledge, through a programme of scientific analysis that combines visual examination, ceramic petrography and instrumental neutron activation analysis (INAA) (detailed methodologies are described below). These methods are employed in an attempt to identify a source area and to shed some light on aspects of its production technology.

Fig. 1. Map of east Mediterranean, showing sites included in this study

Another major gap in present knowledge concerns the possible uses of RLWm ware. Given the shapes of the most common RLWm vessels (fig. 2), with their very narrow necks, it seems highly likely that they were used to transport, store and/or dispense valuable liquids of some kind. However, very little analytical work has been performed with a view to exploring further these apparent functions. Analysis of the residues found inside these distinctive vessels can provide information on vessel contents, although it may not always be possible to say whether contents were actually transported in the vessel or only added at the point of use. While some analysis was carried out on visible residues during the 1960s and 1970s using wet chemistry, the results were far from conclusive, identifying contents as diverse as honey, oil, bitumen, resin and a 'clayey substance' (Åström 1969). The current project uses the more advanced techniques of gas chromatography (GC) and gas chromatography-mass spectrometry (GC-MS). Fifty six absorbed residues and one visible residue have been analysed so far, with some very interesting results.

Thus, by combining data from petrography, INAA, GC and GC-MS, it is possible to put together a picture of an 'international' trade in a luxury commodity across a remarkably wide region (fig. 1), with numerous implications for our understanding of Late Bronze Age political economy and long-distance regional interactions (Knapp 1991; 1998; Knapp, Cherry 1994; Sherratt 1999; 2001; Sherratt, Sherratt 1991).

The ware

As the name suggests, the exterior surface of this ware, especially on closed vessels, is red and highly lustrous. This effect is created by careful burnishing (often in long vertical strokes) and subsequent firing in an oxidising atmosphere of pots whose fabric is red, often with a salmon-pink tinge. The paste is extremely fine and compact, with few if any inclusions or voids. The fact that it is also wheelmade is significant in that many Cypriot wares of this period are handmade, notably Base Ring ware and White Slip ware.

The typical shapes of RLWm ware are the spindle bottle, the lentoid or 'pilgrim' flask and the arm-shaped vessel or 'libation arm' (fig. 2). The most common form is the spindle bottle, for which Eriksson (1993: 23–25) defines five types which vary a little in their proportions of height to maximum diameter, and in their foot

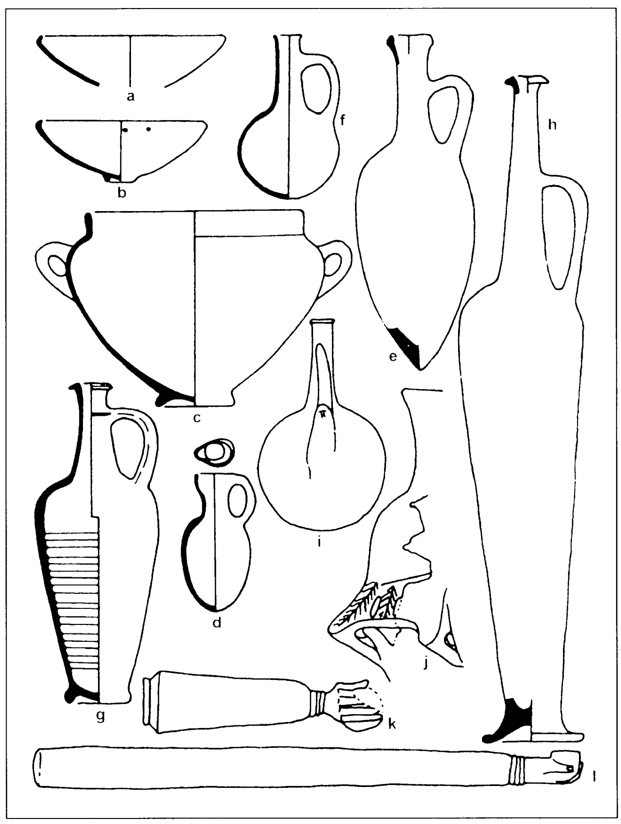

Fig. 2. Main shapes of Red Lustrous Wheelmade ware (after Eriksson 1991: fig. 10.3)

morphology, some having a flaring ring base. Whereas the origin of the spindle bottle as a shape is unclear, the lentoid flask seems to derive from Anatolian prototypes. It mainly varies in its handles, sometimes having two small handles on the body near the neck in addition to the canonical single handle from neck to body. A sub-type also exists with a fenestrated stand; Eriksson (1993: 27) documents only eight examples, but many more have since been found at Kilise Tepe, not all of them in RLWm ware (Hansen, Postgate 1999: figs 2–4; Symington 2001: 170). The arm-shaped vessels consist of a long straight tube that is closed at one end but opens out to a cupped hand at the other, with carefully modelled thumb and fingers. Catalogued examples vary in length, according to Eriksson (1993: 27), from 28.6cm to 84.5cm. They were probably used as containers for some kind of liquid. These three main types — spindle bottle, lentoid flask and arm-shaped vessel — vary somewhat in their temporal and spatial distributions; more details can be found in Eriksson (1993: 139–48).

Methodology

The methodology in this paper seeks to wed new 'scientific' data on fabric composition and residues with the existing typological information, collated in large part through the extensive and thorough research of Eriksson (1991; 1993). An integrated approach, combining typological, technological and compositional data, works best when pursued from the bottom-up, that is to say through investigations at the local level, site by site. This is indeed how the research included in this paper was initiated, through the study of local wares and fabrics at the site of Kilise Tepe in Turkey (Knappett in press; Postgate, Thomas in press). Through such an analysis of the Bronze and Iron Age sequence at the site, using careful visual examination, ceramic petrography and INAA, it emerged that the Late Bronze Age assemblage contained a ware — Red Lustrous Wheelmade ware — that was clearly not local to the site, but of uncertain origin. This led to a wider study that soon took on proportions that made a bottom-up, local approach increasingly difficult. To tackle a provenance question on this scale, a global approach is also needed in conjunction with the local, in order to survey a range of sites from separate regions. Inevitably, this leads to a 'global' single-ware study rather than a 'local' multi-ware study; this can prove problematic in that the single ware can all too easily be taken out of its local context. Ideally a combination of the local and the global is required, and this study has sought to achieve this by ensuring the careful selection of samples in collaboration with site excavators. Wherever possible the samples have been selected personally by the principal investigator (Knappett). Inevitably the process cannot be as carefully controlled as an embedded approach in which the sampling of RLWm ware is just part of a wider multi-ware study (as at Kilise Tepe), but precautions have been taken to mitigate any deleterious effects.

The samples come from seven sites: Kilise Tepe (16 samples), Boğazköy (42), Kalavasos (10), Hala Sultan Tekke (six), Kouklia (six), Kazaphani (ten) and Memphis-Saqqara (five). The quantity of RLWm ware found at each site varies considerably, with very few examples known from Kouklia and Memphis-Saqqara, for example, while a considerable amount has been recovered from Boğazköy, Kazaphani and Hala Sultan Tekke (with moderate amounts from Kalavasos and Kilise Tepe). It is, moreover, difficult comparing numbers because of the different contexts in which the ware is found: at Boğazköy and Kilise Tepe, for example, we are dealing largely with sherds, as the ware has been recovered from fills associated with temples and settlement contexts respectively. At the other sites the ware is from tomb contexts, and so is more frequently preserved as whole or nearly whole vessels. As far as the dates of the samples are concerned, the information available is not very specific. With long-lived tombs it can be difficult specifying the date of individual objects within them. Thus most of those from Cypriot sites date to LC II, roughly 1400–1200 BC. With Kilise Tepe the lack of comparanda in the surrounding area makes close dating difficult, but the LBA there falls into a similar date range. Only for Boğazköy is there more accurate information, with a date of ca. 1400 BC recently put forward for the south pond deposits (Mielke in press).

The samples from all seven sites have been subjected to the same procedures in terms of ceramic petrography and INAA; for the latter, the standard procedure described in detail by Hein et al. (2002) was followed. A portion of each specimen was cleaned with a tungsten carbide drill-bit, then sub-sampled, powdered and kept in glass vials. For the analysis, the powder was left overnight to dry at 120°C and approximately 150mg from each individual was weighed and heat sealed in polyethylene vials. The same procedure was followed for the reference material used, which was an International Atomic Energy Agency SOIL-7. Individuals and standards were irradiated for 30 minutes in batches of ten (eight individuals and two standards) at the swimming pool reactor of NCSR 'Demokritos', at a thermal neutron flux of $3x10^{13}$ $n.cm^{-2}.s^{-1}$. Seven days after irradiation, the individuals and standards were measured for Sm, Lu, U, Yb, As, Sb, Ca, Na, K and La, and 20 days after irradiation for Ce, Th, Cr, Hf, Cs, Tb, Sc, Rb, Fe, Ta, Co and Eu.

Fifty six of the 95 samples subjected to petrographic analysis and INAA have also been analysed for organic residues. The analysis of organic residues in pottery is now a well established procedure (Evershed et al. 1991; 1999; 2001). The majority of the residues that survive within the pores of ancient pottery are the remains of foods, medicines, cosmetics and other materials stored, traded or processed in pottery vessels. Some of these organic materials survive for only a short time after use, such as carbohydrates and proteins, while fats and oils, waxes and resins, collectively known as lipids, can survive for thousands of years (Evershed et al. 2001). For this project the aim was to identify any lipid residues remaining within the pottery. To carry out lipid analysis, separate samples were removed from the interior and exterior surfaces of each sherd using an electric drill with an abrasive tungsten bit. Sampling both surfaces allows the contents of the vessel to be distinguished from contamination due to the burial environment (Stern et al. 2000). Solvent extraction and GC and GC-MS analysis were carried out using the methods described by Stern et al. (2000). All samples were derivatised with BSTFA with 1% TMCS, and C_{34} *n*-alkane was added as an internal standard to allow quantification of the results. Standard procedures were used to minimise and identify any contamination introduced in the laboratory (see Stern et al. 2000).

The residue analysis allows us to make direct comparisons between samples in terms of both their composition and their residues. While the work on the physico-chemical composition of the fabrics has now come to an end, the residue analysis continues apace.

Following the point made above concerning the shift from the local scale to the global in terms of methodology, it makes sense to begin with the analyses from Kilise Tepe, as these are the most fully integrated in their local context (Knappett in press).

Kilise Tepe

The multi-period site of Kilise Tepe was excavated as a rescue project between 1994 and 1998; the major phases of occupation date to the Byzantine, Early and Middle Iron Age, and Early, Middle and Late Bronze Age (Postgate 1998; Postgate, Thomas in press; fig. 3). Finds of RLWm ware, as well as appearing on the surface of the site (Baker et al. 1995), were concentrated in the level III strata of the LBA. The contexts are generally fills, rather than primary deposits, in association with architecture, yet it is apparent that we are dealing with settlement occupation. This is significant in that RLWm ware is overwhelmingly discovered in tombs or ritual settings rather than settlement contexts. A good quantity of RLWm ware, perhaps 100 or so sherds, has been found

Fig. 3. The site of Kilise Tepe (photo: Bronwen Douglas)

at Kilise Tepe. This is consistent with the relatively large quantities of RLWm ware found in the Göksu valley as against its relative paucity in Cilicia Pedias proper (for example, Tarsus).

At Kilise Tepe much of the finer pottery from this period tends to be made of calcareous buff fabrics. On the basis of local clay samples, and petrographic and chemical analysis, these fabrics are very probably local (see fig. 4 for geology of the region around the site). They are visually distinct from the fine pink-red fabric of RLWm ware, which thus stands out at the site. The three most characteristic shapes in RLWm ware — spindle bottles, lentoid flasks and arm-shaped vessels — are all represented in the Kilise Tepe assemblage (Symington 2001: 169, fig. 6). In addition, a form of shallow bowl with in-turned rim, more or less identical in shape to those that are locally produced in semi-fine calcareous buff fabrics, is also present in RLWm ware (Symington 2001: 169). This shape also occurs in a fabric that is the same colour and hardness but contains small white inclusions. Another very similar but coarser fabric is used for storage jars (of which we only have fragments, and no whole profiles). Macroscopic observation suggests that these fabrics could be seen as fine, semi-fine and coarse variants of a single fabric group, even though the coarse wares lack the lustrous surface treatment of the finer specimens (see fig. 5 for sampled sherds). One crucial clue to confirm this suspected continuity comes in the form of a finely-made lentoid flask (Baker et al. 1995: fig. 11.1), the neck and handle of which are in the very fine pink-red fabric, whilst the main body of the vessel is in the coarser red fabric.

Petrography

The fabric in its finest form (samples S79–S84) is a very fine, vivid pink-red with practically no inclusions of any size that can be identified petrographically (fig. 6). In the 16 thin section samples from Kilise Tepe there is, however, a continuity from fine through semi-fine to coarse (Knappett 2000).

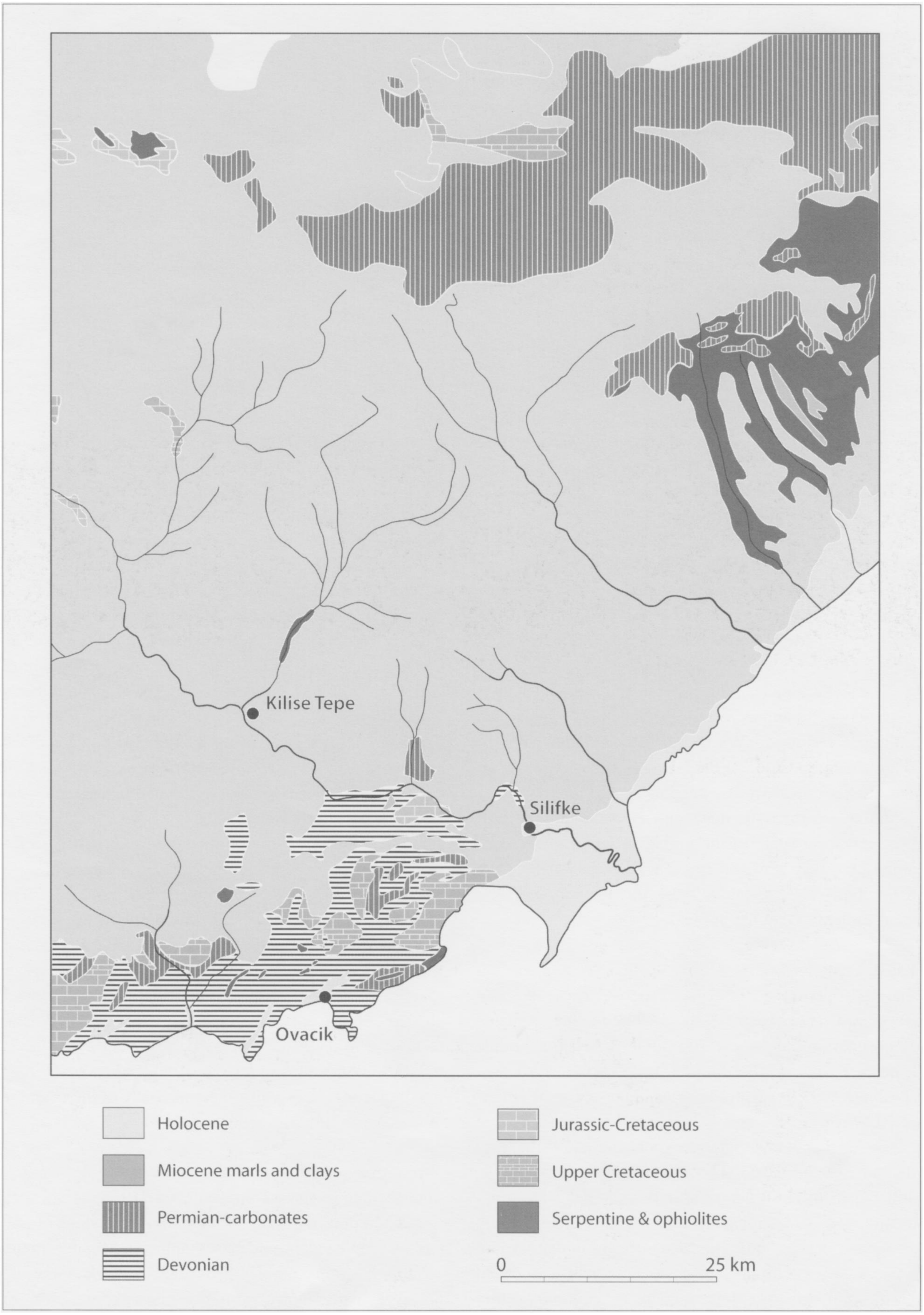

Fig. 4. Geology of the Kilise Tepe area

Fig. 5. RLWm sherd samples from Kilise Tepe

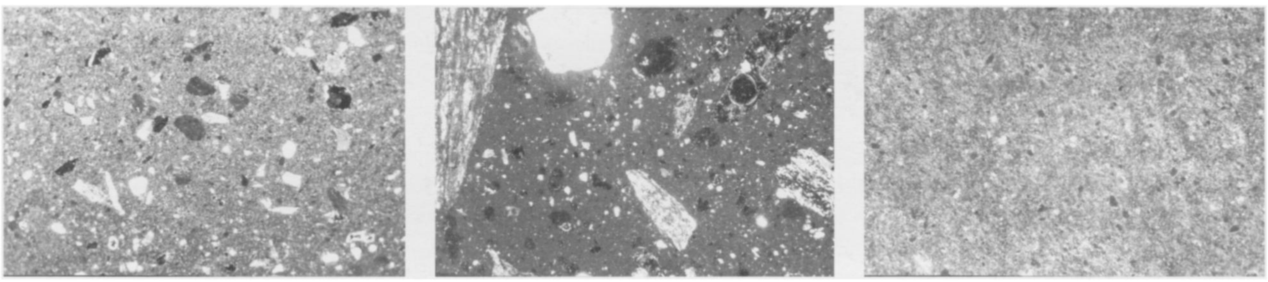

Fig. 6. Thin section photomicrographs of Kilise Tepe samples

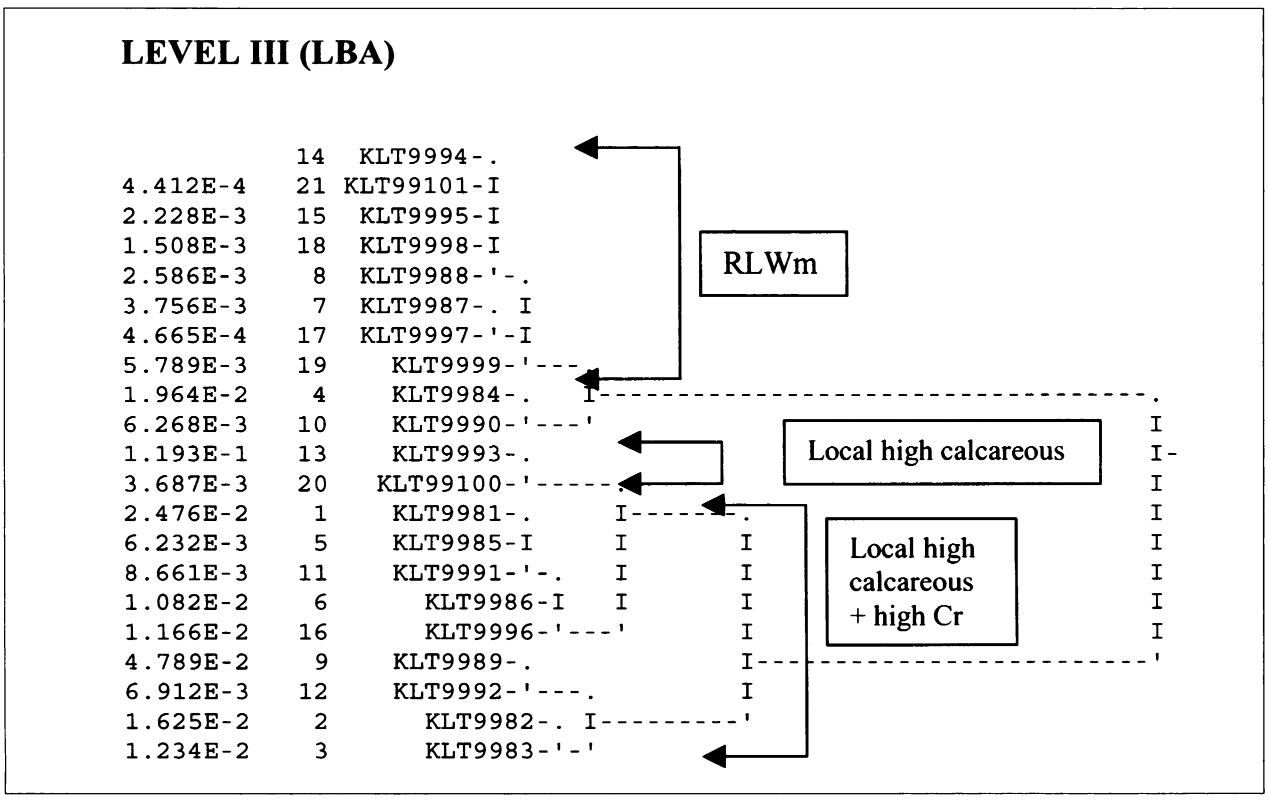

Fig. 7. Dendrogram of Kilise Tepe NAA results

As stated above, this fine red fabric is almost certainly imported. It is calcareous, but far less so than most local fabrics, and the coarser examples contain numerous metamorphic rock fragments (fig. 6). There appears to be a continuum of variation from fine through to coarse (six fine samples, three semi-fine, seven semi-coarse to coarse). The very fine examples are red and micaceous (to varying degrees). Red textural concentration features (tcfs) are common in the fine fraction, along with some quartz and micrite (some of which is possibly shell).

Next come the semi-fine fabrics (samples S86, S87, S89), which are very much like the above in terms of groundmass and fine fraction, but there occurs more quartz, tcfs and micritic limestone (of which some is linear and angular, probably shell) in the coarse fraction. There are very rarely any metamorphic rock fragments.

Samples in the semi-coarse to coarse range (S85, S88, S90–S94) are very much like the above fine and semi-fine examples, except for containing more in the coarse fraction, including metamorphic rock fragments, i.e. various forms of schist and phyllite (see fig. 6). They are commonly 1mm in length, but can be up to 4mm. It should be noted that sample S94 has a thick dark grey core, and so looks quite different macroscopically to the other samples (whilst being the same petrographically).

Detailed petrographic descriptions of the Kilise Tepe RLWm ware samples can be found in the full publication of the Kilise Tepe material (Knappett in press).

INAA

The RLWm ware samples form a very tight group, as can be seen on the dendrogram of the Kilise Tepe level III samples — they comprise the first group located at the top of the dendrogram (fig. 7). Also significant is that fine and coarse samples of this fabric cluster together, thereby confirming the impression from petrography of a continuum in this fabric group from fine through to coarse. Although the number of RLWm samples analysed from Kilise Tepe is small, the spread of the average compositional values is low, indicating a very compact group.

This reflects the common clay source for all eight samples and the strictly similar technology applied for their production. Chemically this group shares strong similarities with the RLWm ware samples from all other sites documented here (table 1). On the other hand, although calcareous, ranging from 4–10% Ca content, members of the RLWm group are far less so than most of the local fabrics, as the chemical profiles indicate.

Residue analysis

Eleven sherds were analysed from Kilise Tepe: S79, S82, S84, S85–90, S92 and S93. Of these, only three (S82, S89 and S90) contained significant amounts of residue (total lipid content of 42µg/g, 29µg/g and 69µg/g respectively) on the interior surfaces indicative of the contents of the vessel. Three more (S84, S86 and S92) revealed traces of fatty acids, again predominantly on the interior surfaces. A typical chromatogram is shown in figure 8. The chromatogram shows a range of saturated fatty acids ($C_{16:0}$, $C_{17:0}$ and $C_{18:0}$) and unsaturated fatty acids ($C_{16:1}$ and $C_{18:1}$). One peak was tentatively identified as a plant sterol, and phthalates, squalene and cholesterol were all present.

The presence of fatty acids is typical of a fat or oil. GC-MS cannot distinguish between degraded plant oils and animal fats, so it is impossible to determine the exact nature of this residue. The presence, however, of a high proportion of unsaturated $C_{18:1}$ fatty acid may indicate that the material was of vegetal origin, as vegetable oils are rich in unsaturated fatty acids. The possible presence of a plant sterol would support this theory.

Phthalates are modern contaminants resulting from the storage of sherds in plastic bags. Squalene is a component of the residues left by handling sherds, and, as it decays over a relatively short time, is indicative of modern 'fingerprints'. Cholesterol is a component of all animal fats, and could indicate that the fatty residue is of animal origin. However, it is also present in human fats and can be deposited on the sherds by handling. In this case, given the presence of squalene and the presence of cholesterol on both surfaces of the sherd, it is most likely to be the result of post-excavation handling.

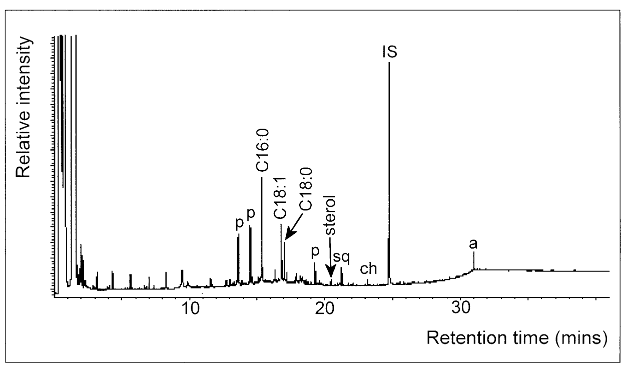

Fig. 8. Chromatogram of the residue from the interior of sherd S89 from Kilise Tepe. IS: internal standard; a: artefact of the GC; p: phthalate plasticizer; sq: squalene; ch: cholesterol; fatty acids are labelled with the number of carbon atoms in the acid molecule, saturated acids: x:0, monounsaturated acids: x:1

Discussion

Analysis of fabric composition, using both petrography and INAA, indicates that the RLWm found at Kilise Tepe is almost certainly imported. The fabric is far less calcareous than most local groups at Kilise Tepe. The presence of metamorphic rock fragments is also suggestive, although not conclusively, of a non-local source. The NAA results clearly show a tightly clustered group that is very distinct from any local groups (fig. 9).

Residue analysis reveals that the contents of the RLWm ware vessels from Kilise Tepe do not relate to the fabric groups as defined by petrographic analysis. The three sherds that contain fatty acid residues represent the very fine (S82), semi-fine (S89) and semi-coarse to coarse (S90) groups. The sherds with only traces of fatty acids and those which contain no residues also represent all three fabric groups. This would indicate, firstly, that the coarseness of the fabric does not affect the survival of organic residues at this site. Further, it appears that the contents of the vessels did not relate to the coarseness of the fabric. The situation represented by these results could be complex, involving storage of an oil/fat product in coarse jars and its use in finer wares, although there is no way to determine this from the evidence available. Future compound specific stable isotope analysis will determine whether the fatty residue present is of plant or animal origin.

Boğazköy

Boğazköy is the site of ancient Hattusha, the capital of the Hittites. Although occupied since the Chalcolithic period, it became the Hittite capital in the latter part of the 17th century BC, and remained as such until around 1190 BC when the empire collapsed (Seeher 1999). The site is substantial, some 180 hectares at its greatest extent, surrounded by imposing fortification walls (fig. 10). With both a lower and an upper city, not to mention the citadel Büyükkale and the vast temple 1 complex, the site's internal organisation is complex. RLWm ware has been found in both upper and lower cities and on the citadel, in 14th and 13th century BC contexts (Eriksson 1993: 129–31). Since Eriksson's survey, however, significantly more material has been unearthed, notably from the so-called south ponds or 'Südteiche' in the upper city (Seeher 2001; 2002). These five ponds were artificial reservoirs for supplying the needs of the city (fig. 11). Interestingly, they appear to have silted up at some stage, and a decision was taken to fill them in fully. Much of this fill was ceramic and composed of thousands of sherds of RLWm ware, presumably disposed of having been used in the nearby central temple district in the upper city (for RLWm ware from these temples, including arm-shaped vessels, see Parzinger, Sanz 1992).

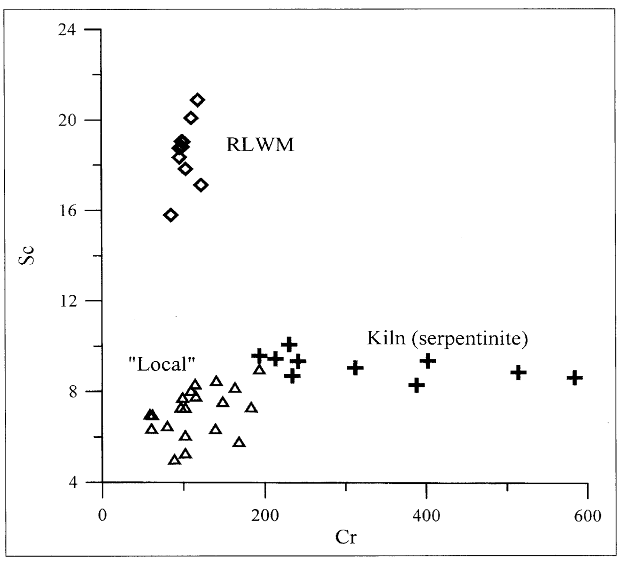

Fig. 9. Scatterplot of Kilise Tepe NAA results

Forty two samples were selected from the material in the south ponds. Samples 1–30 were selected as examples of canonical RLWm ware, as far as could be identified visually (fig. 12). Ten samples (31–40) were chosen as representative of local fabrics, all from large closed shapes, and plain or with a cream slip (fig. 12). Two further samples (41–42) come from very large spindle bottles in a slightly siltier fabric, with some doubt visually whether they might be true RLWm or local versions.

Petrography: imported fabrics

In particular, samples 1–4, 6–7, 9–23 and 30 are absolutely canonical RLWm fabrics, indistinguishable from the finest examples taken from all the other sites (fig. 13, top row, left and middle). Sample 8 looks different macroscopically in being very grey, but in thin section one can see that it is a canonical RLWm fabric that has been heavily overfired (note too its unexpected position chemically in the dendrogram of fig. 15). Samples 5 and 27 are very similar to the canonical fabric but just a little coarser. Samples 24–26 and 28–29 differ in being siltier with less optical activity (e.g. top row, right); the inclusions are mostly quartz, dark textural concentration features and occasional mica in the fine fraction, while in the sparse coarse fraction one also finds textural concentration features and quartz, with metamorphic rock fragments such as elongate phyllites, few carbonates and quartz sandstone, and very rarely plagioclase feldspar; they fall mostly within the 0.1–0.5mm size range. They are comparable to some of the coarser variants of RLWm fabric already sampled from other sites. In addition, samples 41–42, from two very large spindle bottles, are in a similar silty RLWm fabric (e.g. second row, middle). Thus one can identify a silty sub-group within the RLWm ware samples from the site consisting of samples 5, 24–29, 41 and 42.

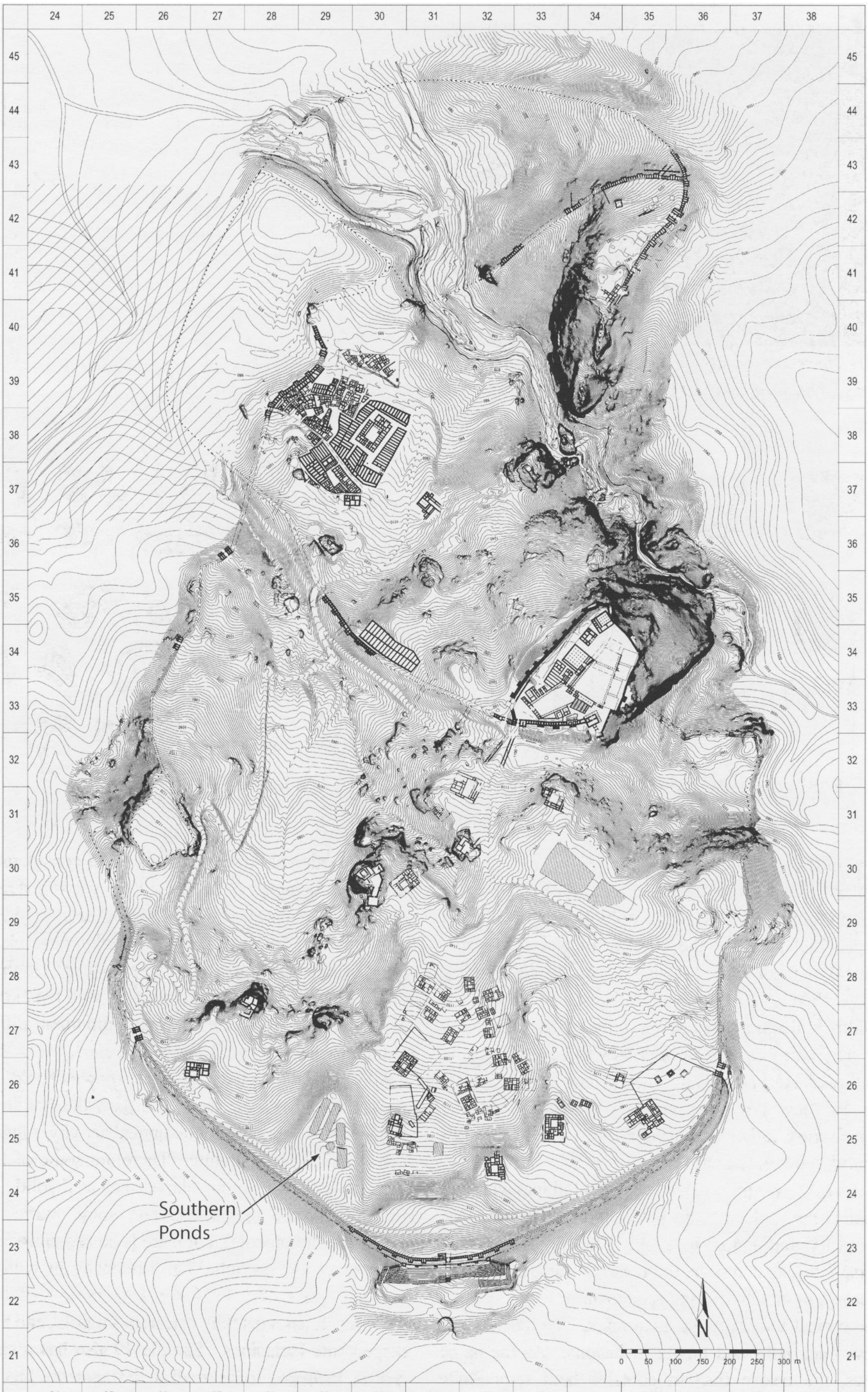

Fig. 10. The site of Boğazköy (courtesy of Jürgen Seeher, Deutsche Archäologische Institut)

Fig. 11. The south ponds in the upper city (courtesy of Jürgen Seeher, Deutsche Archäologische Institut)

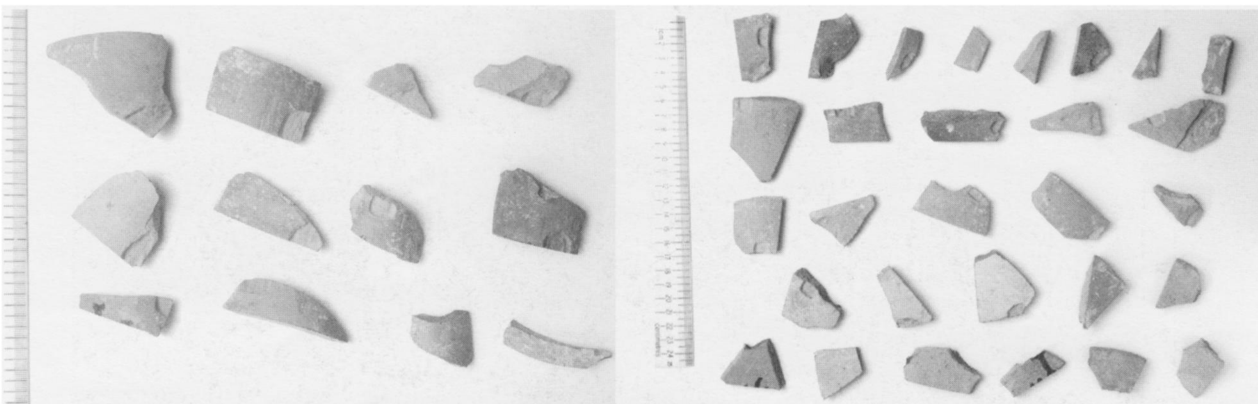

Fig. 12. RLWm and local sherd samples from Boğazköy (samples 1–12 on left; 13–42 on right)

Petrography: local fabrics

The aplastics in the few local fabrics sampled appear to be broadly compatible with the ophiolitic and volcanic outcrops which surround the site (fig. 14, after 1:500,000 geological maps of 1961; see also Ertem, Demirci 1999). However, there is a high degree of heterogeneity in the local fabrics, despite the fact that only ten samples were taken. Here only brief descriptions will be given of the general characteristics of these fabrics, as the aim is merely to show how they contrast markedly with the RLWm fabrics, rather than to characterise the nature of local production at the site.

Seven of the samples (31–35, 38–39) fall into what can be labelled the 'volcanic and serpentinite' group (fig. 13, third row, left and bottom row, left). This is a semi-coarse to coarse fabric that appears to be non-calcareous, varying from brown to orange in hand specimen. It is highly fired with no optical activity in the micromass. The fine fraction has few mica laths and quartz inclusions. As the name suggests, the coarse fraction contains both serpentinite inclusions and volcanic rock fragments, the latter tending to be rhyolitic in character, and quite weathered. The size and proportion of these inclusions varies considerably from sample to sample. Also present to varying degrees are micritic carbonates, monocrystalline and polycrystalline quartz, chert, some of which is radiolarian, plagioclase feldspar, epidote, amphibole and pyroxene. On the whole, however, mafic minerals are not very well represented.

Other samples exhibit some important differences, although there is no reason to believe that these are anything other than local fabrics. Sample 36 (fig. 13, third row, middle) has a calcareous matrix with some small shell fragments visible, and a little optical activity, suggestive of a lower firing temperature. There are some of the same inclusions as in the group above, such as rhyolitic volcanic rock fragments, plagioclase and some mafic minerals (pyroxene, amphibole), but there is no serpentinite at all in the thin section. Sample 37 is different again, with frequent volcanic glass of a kind not seen in any of the other samples. It has a patchily calcareous matrix, and also lacks serpentinite inclusions. Sample 40 also has a calcareous matrix, including some small shell fragments, and is distinguished in the coarse fraction by its high proportion of serpentinite inclusions (fig. 13, bottom row, middle).

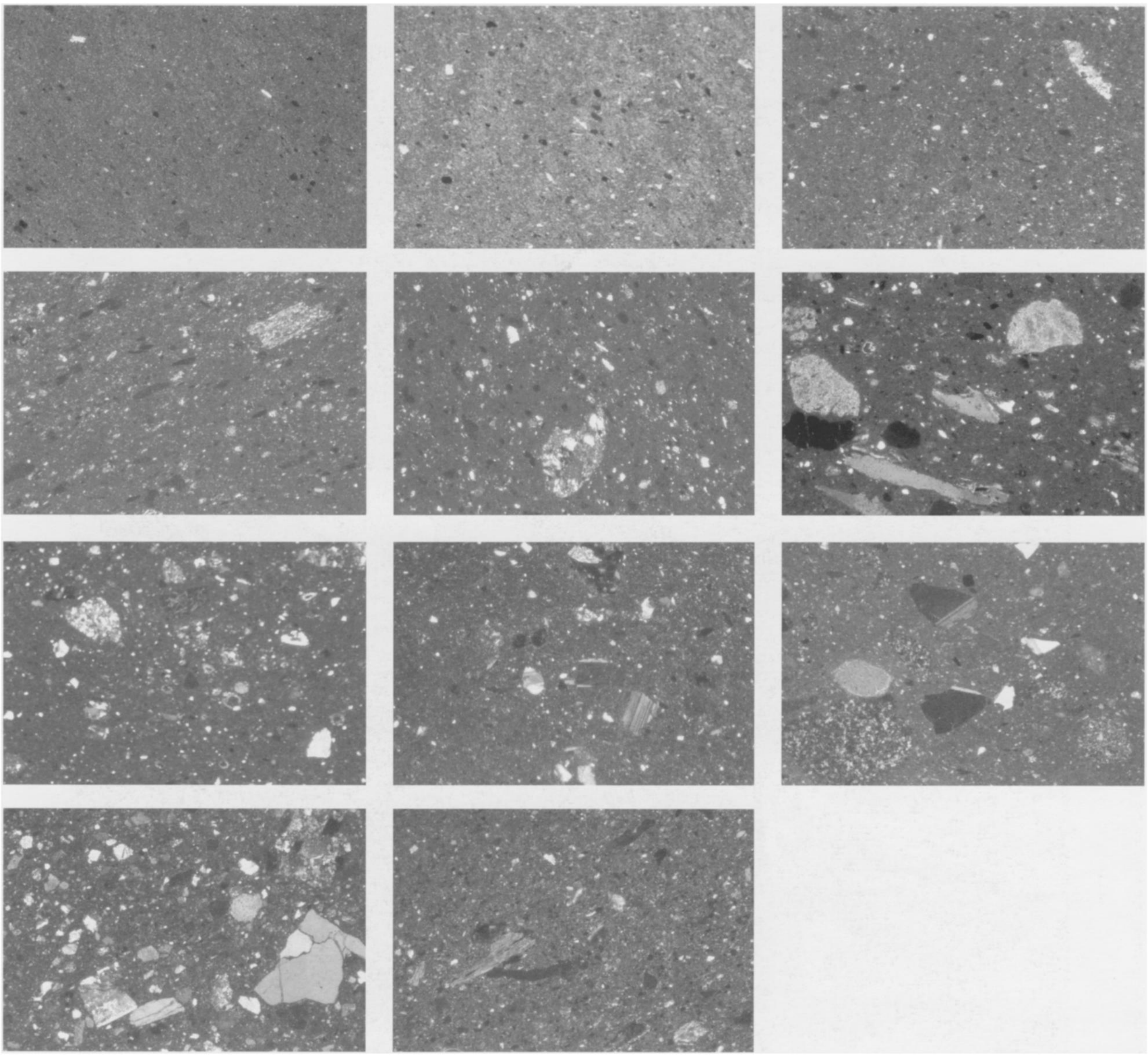

Fig. 13. Thin section photomicrographs of Boğazköy samples

INAA

The results from NAA clearly show the differentiation between the canonical RLWm, the siltier version and the various local Boğazköy fabrics (figs 15, 16). The dendrogram of figure 15 displays the main canonical group occupying the centre, with the siltier version (samples 5, 24, 41, 42, etc) occupying the lower part. At the top of the dendrogram, clearly very different from the two groups described, one sees the various local samples, exhibiting considerable internal variation. Samples 31, 32 and 35 group together, as they do petrographically, but sample 36 sits very much apart. The difference between the closely clustered RLWm groups and the disparate local samples can also be discerned clearly in the scatterplot of figure 16.

In terms of the actual elemental variation between the samples, the silty RLWm group appears to be differentiated from the canonical group chiefly with regard to its elevated chromium, in the 170–180ppm (parts per million) range, rather than the canonical average around 100ppm (table 2). Calcium, however, is far lower in the silty group, varying between 1–2%, rather than approximately 5–10% in the canonical group. As for the local samples, these show huge variations in chromium, from around 100ppm up to 726ppm in sample 32. Other elements such as rubidium and cerium also display considerable variation, adding to the impression that the local samples selected derive from a highly variable background geology (fig. 14).

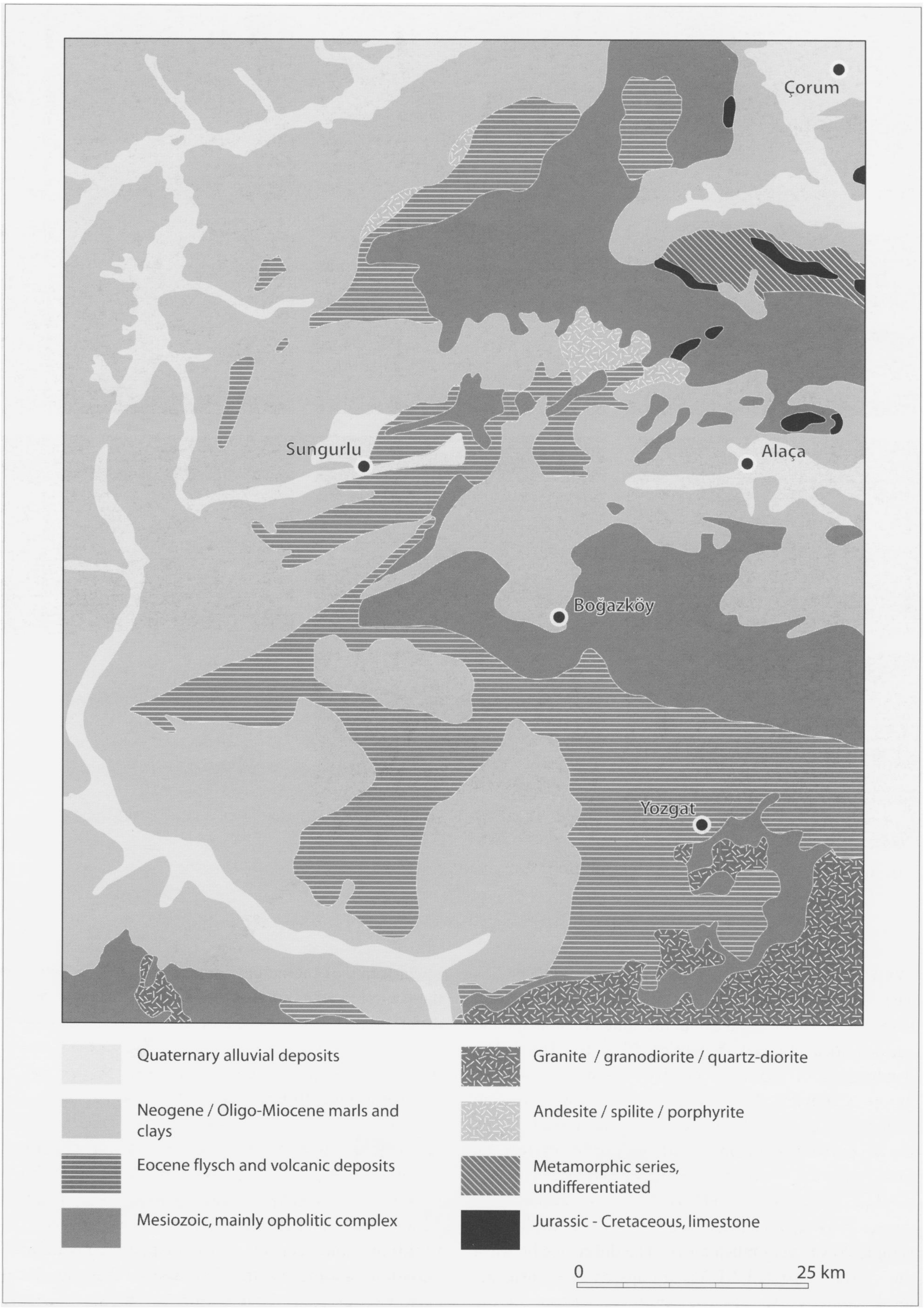

Fig. 14. Geology of Boğazköy area (after 1:500,000 geological map, 1961)

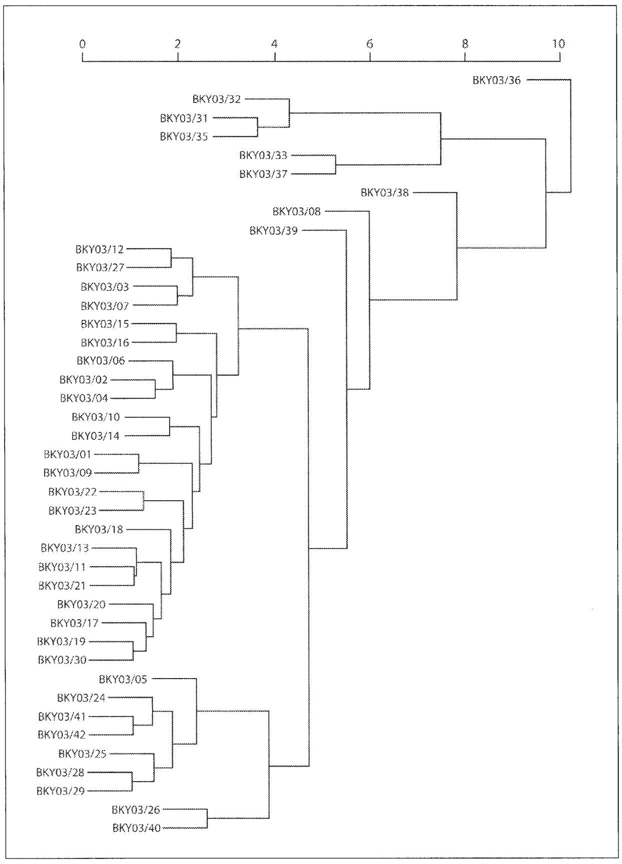

Fig. 15. Dendrogram of Boğazköy NAA results

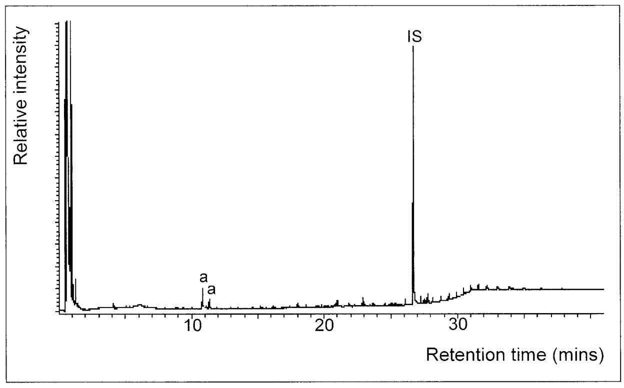

Fig. 17. Chromatogram of the residue from the interior surface of sherd 27 from Boğazköy. IS: internal standard; a: artefact of the GC

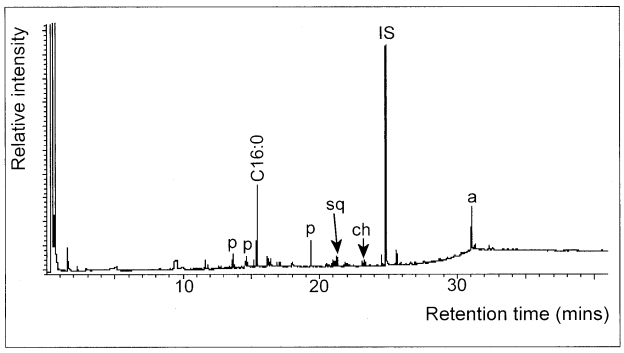

Fig. 18. Chromatogram of the residue from the interior surface of sherd 3 from Boğazköy. IS: internal standard; a: artefact of the GC; p: phthalate plasticizer; sq: squalene; ch: cholesterol; C16:0: saturated fatty acid with 16 carbon atoms

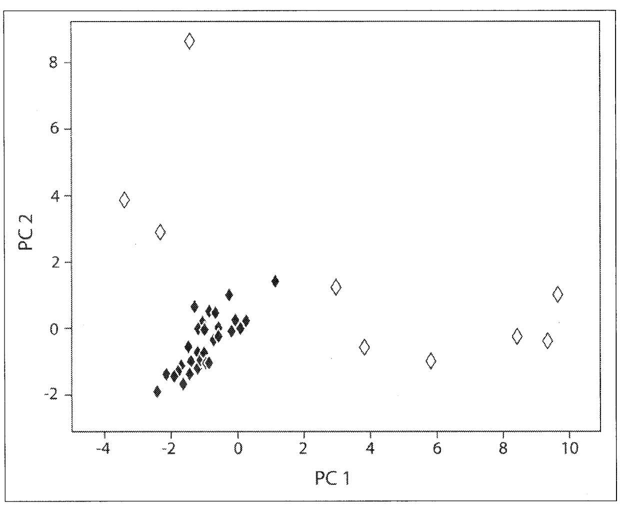

Fig. 16. Scatterplot of Boğazköy NAA results

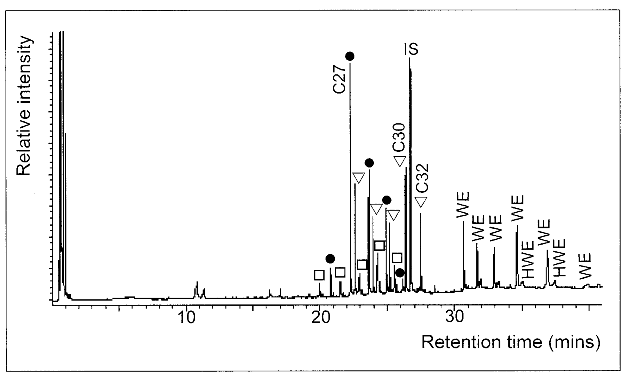

Fig. 19. Chromatogram of the residue from the interior surface of sherd 17 from Boğazköy. IS: internal standard; □ n-alkane; ▽ long chain alcohol; ● n-alkene; WE: wax ester; HWE: hydroxy fatty acid wax ester

Residue analysis

Thirty samples were analysed, 27 RLWm (1–10, 13–15 and 17–31) and three local fabrics (31, 31 and 34). The results divide into four main groups. Group 1 contained no significant residues of any kind and included sherds 9, 14, 15, 18, 20, 22 and 27 (for a typical chromatogram see fig. 17).

Group 2 showed residues of fatty acids, predominantly $C_{16:0}$, and included 1, 3, 8, 10 and 24 (for a typical chromatogram see fig. 18). In all these examples the fatty acids are present at moderate levels (approximately 30µg/g) and most contain phthalates, squalene and cholesterol (see above). Sherds 1, 8 and 24 yielded more residue from the exterior surfaces of the sherds than the interior. This, together with the squalene and cholesterol, probably indicate contamination rather than contents. Sherds 3 and 10 yielded more fatty acid from their interior surfaces and this may represent the remains of the contents of the vessel, a fat or oil.

Group 3 residues showed a mixture of long chain alcohols, *n*-alkanes, *n*-alkenes, wax esters and hydroxy fatty acid wax esters, characteristic of ancient beeswax (Heron et al. 1994; Regert et al. 2001). A typical chromatogram is shown in figure 19. This group includes 17, 19, 30 and 31, and residues are present at between 180µg/g and 670µg/g. Beeswax was used in antiquity for waterproofing, in medicines and cosmetics, as an illuminant, an adhesive and in mummification, and as a decorative finish. In this situation the most likely uses are as a waterproofing agent, as part of a medicine or cosmetic, or as decoration. In all but one case (19) the residues are present in much larger concentrations on the interior surfaces of the sherds. This generally rules out a decorative use. In addition, the shape of most RLWm ware vessels, which have extremely narrow openings, would make it impractical to store pure beeswax in them. This does not eliminate the possibility that the beeswax was part of a mixture, but these sherds show no evidence to support this. The most likely explanation of the presence of beeswax in these vessels is that it was used as a waterproofing finish, as some potters still use it today (Rice 1987: 163; Charters et al. 1995; Bourriau et al. 2000).

Group 4 sherds produce a mixture of beeswax and fatty acids, again predominantly $C_{16:0}$, and include 2, 4–6, 13, 21, 23, 25, 26, 28, 29, 32 and 34. In some of these samples (2, 6, 13, 26 and 32) the levels of fatty acids are low (<10µg/g) and they may represent a degradation product of the beeswax (for an example see fig. 20). In the remaining sherds the amount of fatty acid is larger (20–35µg/g) (fig. 21), and could be the remains of a mixture containing beeswax and an oil or fat, or a sealant (beeswax) and contents (fat/oil), or the result of re-use. Stable isotope analysis may reveal whether the fatty acids derive from the degradation of beeswax.

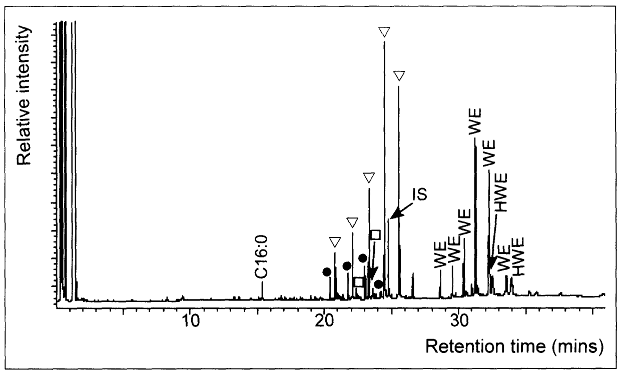

Fig. 20. Chromatogram of the residue from the interior surface of sherd 6 from Boğazköy. Peak identities as in figures 18 and 19

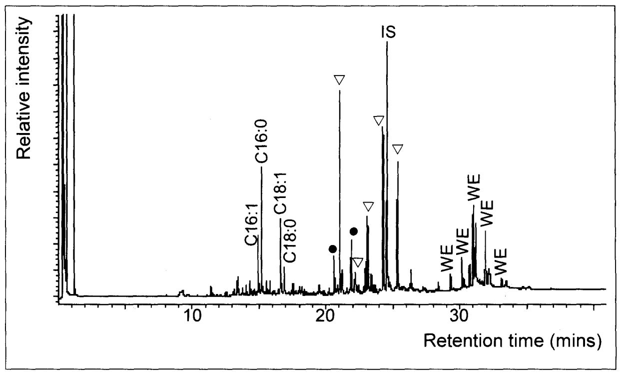

Fig. 21. Chromatogram of the residue from the interior surface of sherd 29 from Boğazköy. IS: internal standard; ● n-alkane; ▽ long chain alcohol; WE: wax ester; fatty acids are labelled with the number of carbon atoms in the acid molecule, saturated acids: x:0, monounsaturated acids: x:1

Discussion

The majority of the RLWm samples taken from the site (samples 1–30, 41–42) are in all likelihood non-local. There are three reasons for coming to this conclusion. First, they are extremely similar in thin section to other samples of RLWm ware analysed from the six other sites included in this study. As the fabric appears to be the same wherever the ware is found, one has to say that the fabric is extremely homogeneous, and is suggestive of a single source area. Secondly, the petrography of these samples is very different to that of the local wares also sampled (for example, plain and cream-slipped wares). These samples tend to contain a range of volcanic inclusions that are never present in RLWm fabrics. Thirdly, the geology of the Boğazköy area (fig. 14) is dominated by ophiolites and other volcanic formations, incompatible with the characteristic limestone/low-grade metamorphism signature of most RLWm samples.

However, these RLWm imports do not all occur in a single fabric group, but rather two groups — one fine and one silty. The fine group is absolutely canonical and looks just like RLWm ware at all other sites. The silty group is not so commonly encountered, and there are perhaps grounds for wondering whether this might perhaps be a local variant of true RLWm ware. Yet there are enough petrographic and chemical similarities between the silty group and the fine group to argue with a reasonable level of confidence that the silty group is indeed itself an import too, closely related to the fine RLWm group.

The various coarse ware samples (31–40), containing serpentinite and/or volcanic rock fragments, are very probably local products. They seem quite consistent with the local geology (based only on 1:500,000 geological maps, not a detailed programme of clay sampling). One might also point out that these fabrics are rather varied — sample 40, for example, stands out in containing a lot of serpentinite. All these local products are quite different in their petrography to both the fine and the silty groups of RLWm ware.

The residue analysis reveals that the contents do not co-vary with either the fabric or the form of the RLWm ware vessels. The three sherds of local ware examined also contained the beeswax or beeswax with fat/oil typical of the RLWm ware sherds. This raises the interesting question of where the beeswax was added to the pottery. Ethnographic studies show that waterproofing treatments such as beeswax are usually applied while the vessels are still warm after firing (Rice 1987: 163). With local pottery this was obviously carried out during manufacture, but did the non-local RLWm ware arrive specially pre-treated or was the beeswax added after it arrived in Boğazköy? At present it is not possible to answer this type of question.

Cyprus: Kalavasos

A total of 579 RLWm ware sherds have been recovered from the site of Kalavasos (Ayios Dhimitrios). Shapes represented are spindle bottles, lentoid flasks and arm-shaped vessels. In the ten samples selected for analysis there are five spindle bottles, four lentoid flasks and one local imitation. These come from a range of contexts (fig. 22), all related directly or indirectly to funerary deposition.

1. The northeast area. M50B, 20.2/24.2 is a deposit which almost certainly represents LBA tomb looting. More than 150 sherds of RLWm come from this area.

2. Tomb 11 seems to have contained a minimum of 17–18 spindle bottles and five lentoid flasks. Note also seven Mycenaean vessels, four White Slip and seven Base Ring. There is also much gold, silver, ivory, glass, etc. Sealed and unlooted, it contained three young women, three infants and a child and dates to LC IIA:2. There is a strikingly high amount of RLWm, associated with young women (see South 1997: 161).

3. Tomb 13 contained six lentoid flasks and one spindle bottle. Many Mycenaean vessels (40 pots, out of a total of 90, including kraters), also gold, ivory, faience, etc, were found. The tomb was partly looted in the LBA. There were about a dozen individuals, of various ages, one middle-aged individual, probably female, on a bench. Mainly dated to LC IIB (South 1997: 163–65).

4. Tomb 14 contained four spindle bottles, two lentoid flasks and three arms. Some Mycenaean material, ivory and gold was also found. The tomb was partly looted/cleared in LBA (South 1997: 165–67, including fig. 8, RLWm arm).

5. Tomb 16 contained a few sherds (seven from the dromos, four from the tomb), but was heavily looted.

Petrography

The nine RLWm sherds (samples 1–8, 10; fig. 23) were all very fine in hand specimens, and indeed this was borne out in the petrographic examination. They contain very small inclusions of quartz, calcite and red-brown tcfs, with little if anything above 0.1mm (fig. 24). There is some variation in optical activity, with, for example, sample 7 exhibiting high optical activity, while sample 4 is optically inactive. The one sherd (sample 9) described as a local Red Lustrous imitation, a gritty brown fabric, does indeed stand out as different petrographically too (fig. 24). Most notably it contains large inclusions of serpentinite, not at all present in canonical RLWm ware.

INAA

In terms of the results from INAA, we see very much the same picture. Samples 1–8 and 10 fall absolutely within the standard range for RLWm ware as seen across the samples from all sites included here (table 1). Here the samples of Kalavasos form a firm chemical group, with low spreads of the mean compositional values. Sample 9, however, identified as local imitation of RLWm ware, shows considerable differences (table 3). For example, chromium in RLWm ware is very often close to 100ppm, with only a 6% standard deviation across all samples. The chromium value for sample 9, however, is significantly higher, 164ppm. Another element, rubidium, averages 142ppm, with a standard deviation close to 10% across all samples; the value for sample 9 though is 36.8ppm. Other elements showing significant differences include cerium, caesium, hafnium and cobalt.

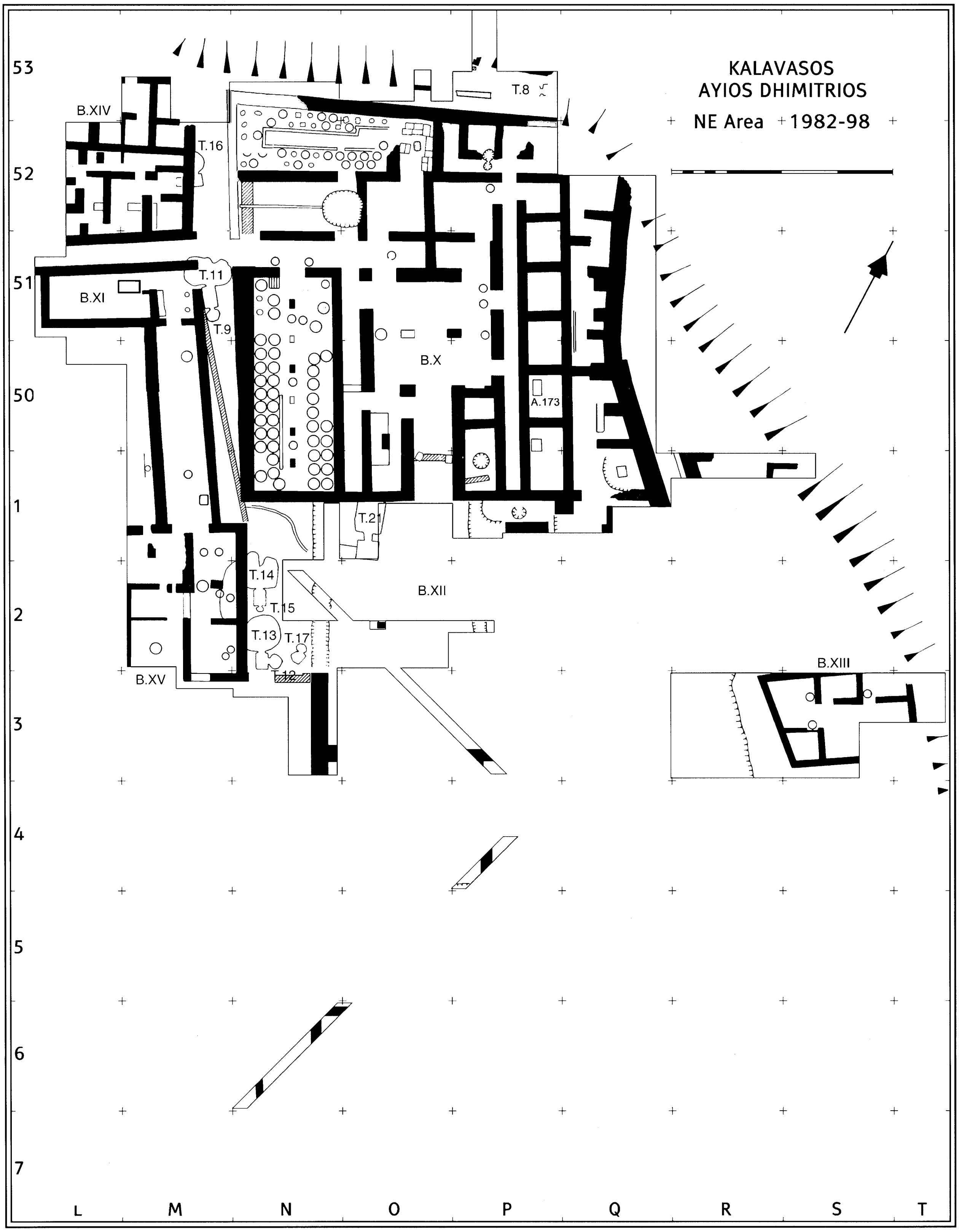

Fig. 22. The site of Kalavasos (Ayios Dhimitrios) (courtesy of Alison South)

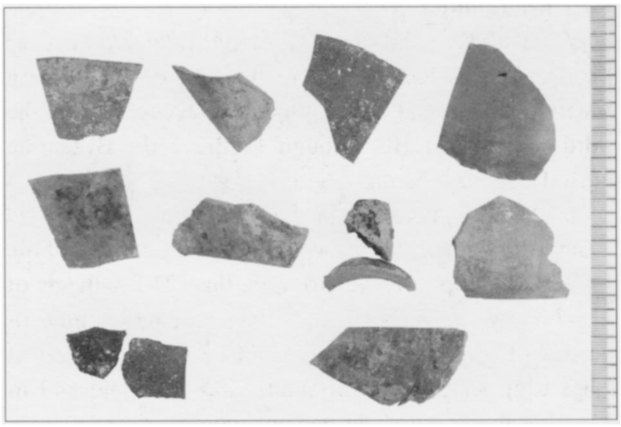

Fig. 23. RLWm sherd samples from Kalavasos

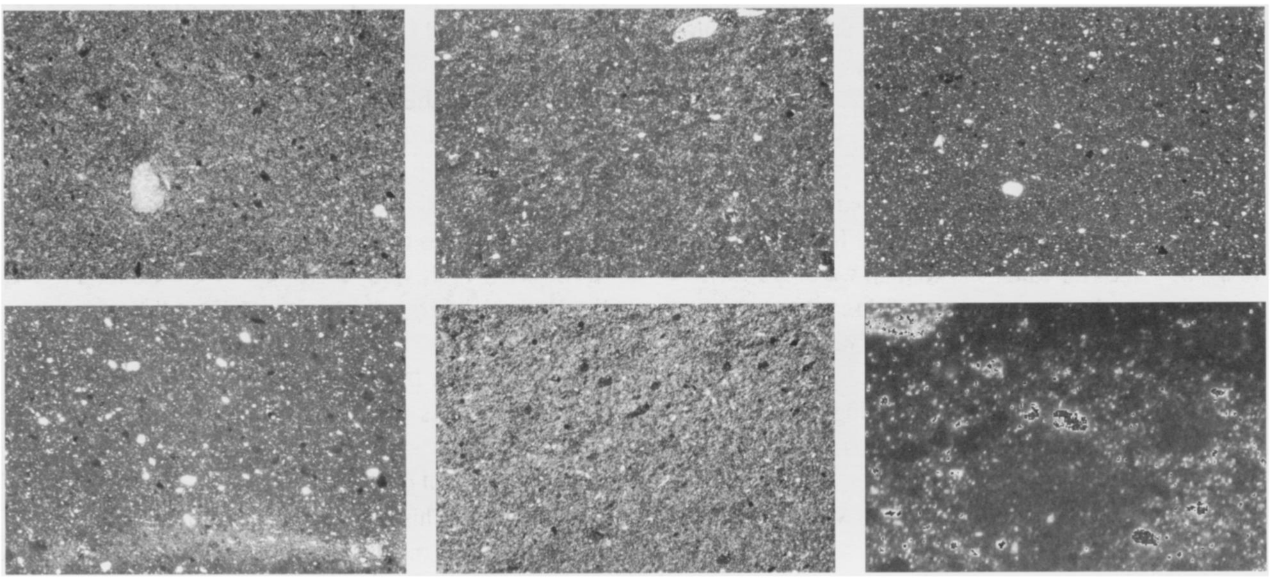

Fig. 24. Thin section photomicrographs of Kalavasos samples

Residue analysis
No samples were analysed from Kalavasos.

Discussion
Although ideally one would want more than one local sample, the indications from petrography and chemistry are that RLWm is unlikely to be local to Kalavasos. This is further supported by the geology of the Kalavasos region, which is heavily dominated by the basic and ultrabasic rocks of the Troodos — with minerals and rock fragments (such as serpentinite) that are not present in the samples of canonical RLWm ware studied here. The Vasilikos river, before flowing past the site of Kalavasos (Ayios Dhimitrios), passes through a large area of 'shattered serpentinite', as well as areas of basaltic pillow lavas, and olivine gabbro (Pantazis 1967).

Cyprus: Hala Sultan Tekke
Like Kalavasos, Hala Sultan Tekke was a major late Cypriot settlement. It is located on the south coast of Cyprus just to the west of Larnaca (fig. 1). Consistent with its probable role as a trading port, a considerable amount of RLWm ware has been found at this site; Eriksson documents over 1,000 sherds (Eriksson 1993). Six samples of canonical RLWm ware were kindly supplied for this study by Paul Åström. They were found in wells F1 and F2 (Åström et al. 1983).

Petrography
In hand specimen all six samples are in the very fine pink-red fabric that is so characteristic (fig. 25). The fineness of the fabric is seen also in thin section, with all samples containing only very small inclusions of

Fig. 25. RLWm sherd samples from Hala Sultan Tekke

quartz, calcite and red-brown textural concentration features (fig. 26). Only sample 6 shows pronounced optical activity. No local samples were taken for comparison.

INAA

The chemistry repeats the familiar pattern, with all six samples falling very much within the highly predictable range of values for canonical RLWm ware (table 1). For example, scandium ranges from 17.9 to 20.1ppm, cesium from 79.5 to 85.7ppm and chromium from 101 to 112ppm, indicating once more a production using a certain type of clay and strict technology.

Residue analysis

No samples were analysed from Hala Sultan Tekke.

Discusssion

Although we have no local wares for comparison in this study, from the published geological information alone we can surmise that RLWm ware is unlikely to be a product local to the area of Hala Sultan Tekke. Its proximity to the Troodos massif suggests that local clays are likely to contain detrital igneous inclusions (Pantazis 1979; see also Vaughan 1991: 358). RLWm ware samples show no signs of such inclusions. The situation is broadly comparable to that at Kalavasos.

Cyprus: Kouklia

The site of Kouklia (fig. 1), sometimes referred to as Palaipaphos, is located just to the east of the modern town of Paphos, and was continuously occupied from the third millennium BC through to the early Byzantine period (Maier, Karageorghis 1984). The site was probably a major centre in the LBA, and has revealed tombs containing Mycenaean pottery, but with little RLWm ware up to now. No more than 22 fragments of RLWm ware have been identified, amongst a total of 10,619 LC sherds, compared against 3,728 fragments of Base Ring ware, 2,631 of White Slip ware and 647 of Mycenaean wares (Maier personal communication).

Sample 1, a fragment of a libation arm, comes from a rescue excavation conducted in the Mantissa locality in 1954 by Colonel Last, who described pit 5 as a well-shaft containing LC, Archaic and late Classical sherds. Samples 2, 3 and 6 derive from the area of the northeast gate of the city; although the area saw LC II/III occupation, the sherds actually come from three different mixed contexts with material ranging from LC to Roman. Sample 4 is from unstratified material from Mitford's excavations in the Asproyi locality (adjacent to Evreti) in 1953. Sample 5 is the only one from a closed context, the fill of a LC II/III well, excavated in the Kouklia-Evreti locality which formed part of the LC settlement area.

Petrography and INAA

The six samples analysed here, kindly provided by Maier, are all very fine, pink-red and seemingly absolutely typical of RLWm ware (fig. 27 shows three of the samples). This impression is supported in both the petrography and the chemistry (table 1). No local wares were selected for analysis but, given the local geology, it seems unlikely that RLWm ware is a local product. Kouklia falls within the area of the Mamonia complex, composed not only of sedimentary rocks such as radio-larian cherts, mudstones, siltstones, quartzitic sandstones, reef limestones and limestone breccias, but also igneous rocks such as basalts, trachytes and pillow lavas (Pantazis 1979). One might well expect local clays to contain detrital igneous minerals due to the proximity to the Troodos massif (Vaughan 1991: 358).

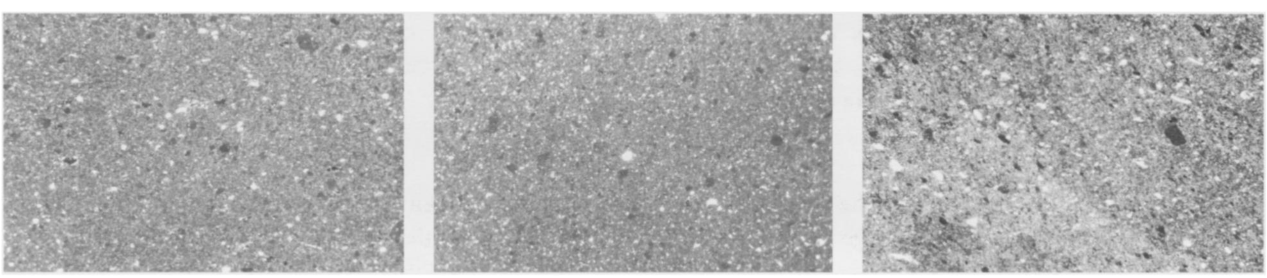

Fig. 26. Thin section photomicrographs of Hala Sultan Tekke samples

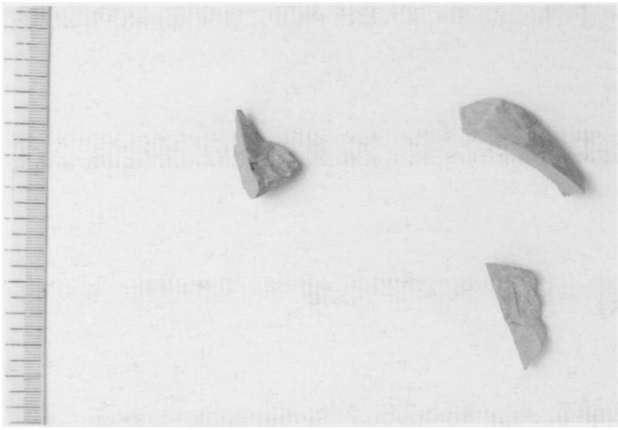

Fig. 27. RLWm sherd samples from Kouklia

Residue analysis

Of the six sherds from Kouklia three (M.PIT 5.1, KD 53.69 and KA 637.4) contained residues. M.PIT 5.1 contained only small quantities of lipids (6µg/g), the main peaks being due to phthalates (see above). KD 53.69 and KA 637.4 showed a series of fatty acids on their interior surfaces (total 60µg/g and 82µg/g respectively), including some unsaturated fatty acids ($C_{16:1}$ and $C_{18:1}$). Shorter chain fatty acids from $C_{9:0}$ to $C_{14:0}$ were present in both sherds. Triacylglycerols were identified in KA637.4 (fig. 28).

The presence of fatty acids on the interior surfaces of these sherds shows the contents of the vessels to have been a fat or oil. Unsaturated fatty acids may indicate a vegetable oil rather than an animal fat. Triacylglycerols are indicative that the residue is well preserved as acylglycerols are lost from degraded fats by hydrolysis (Dudd et al. 1998). Short chain fatty acids are released in this process and their identification may show this

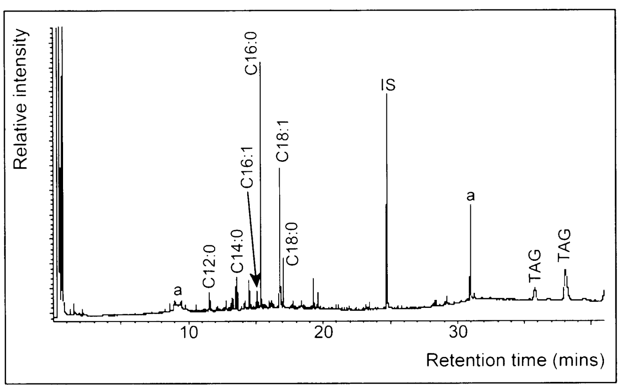

Fig. 28. Chromatogram of the residue from the interior surface of sherd KA637.4 from Kouklia. IS: internal standard; a: artefact of the GC; p: phthalate plasticizer; TAG: triacylglycerols; fatty acids are labelled with the number of carbon atoms in the acid molecule, saturated acids: x:0, monounsaturated acids: x:1

process is incomplete. It is also possible that triacylglycerols and short chain fatty acids are derived from milk, which is used by modern potters as a sealant in unglazed pottery (Rice 1987: 163). Further analysis is needed to determine the exact nature of this residue.

Cyprus: Kazaphani (Ayios Andronikos)

The site of Kazaphani is located in the north of Cyprus (fig. 1), approximately 5km inland from the coastal town of Kyrenia. It has produced some of the highest concentrations of RLWm ware known on Cyprus, principally from tombs 2A–B (Nicolaou, Nicolaou 1989; Eriksson 1993: 54–56). In chamber B alone, at least 54 vessels were found (Eriksson 1993: 55), leading Eriksson to wonder whether this area of northern Cyprus may actually be the source area for the ware (Eriksson 1991: 94).

The ten sherds studied are all fragments of lentoid flasks found in tomb 2, chamber B. Samples 1–9 are canonical RLWm ware (fig. 29), with sample 8 being from a flask with relatively thick walls and in a semi-fine fabric with white grits. Sample 10 stands out as a local imitation, distinguished in being handmade, with a pushed-through handle, and in a gritty pink-grey fabric (fig. 29).

Fig. 29. RLWm sherd samples from Kazaphani

Petrography

In thin section, samples 1–7 and 9 conform to the normal picture for RLWm ware, in being extremely fine and with very few inclusions. Sample 8, identified as being coarser in hand specimen, contains quartz, red-brown textural concentration features and calcite/micrite inclusions, some of which are linear and could be shell fragments (fig. 30, left). This tallies very well in its characteristics with some of the semi-fine examples of

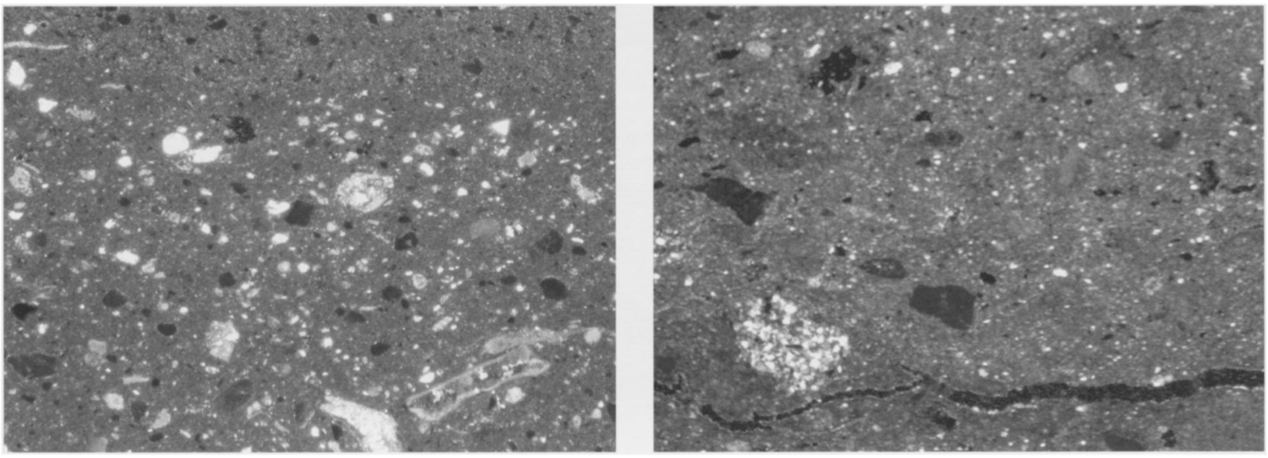

Fig. 30. Thin section photomicrographs of Kazaphani RLWm samples

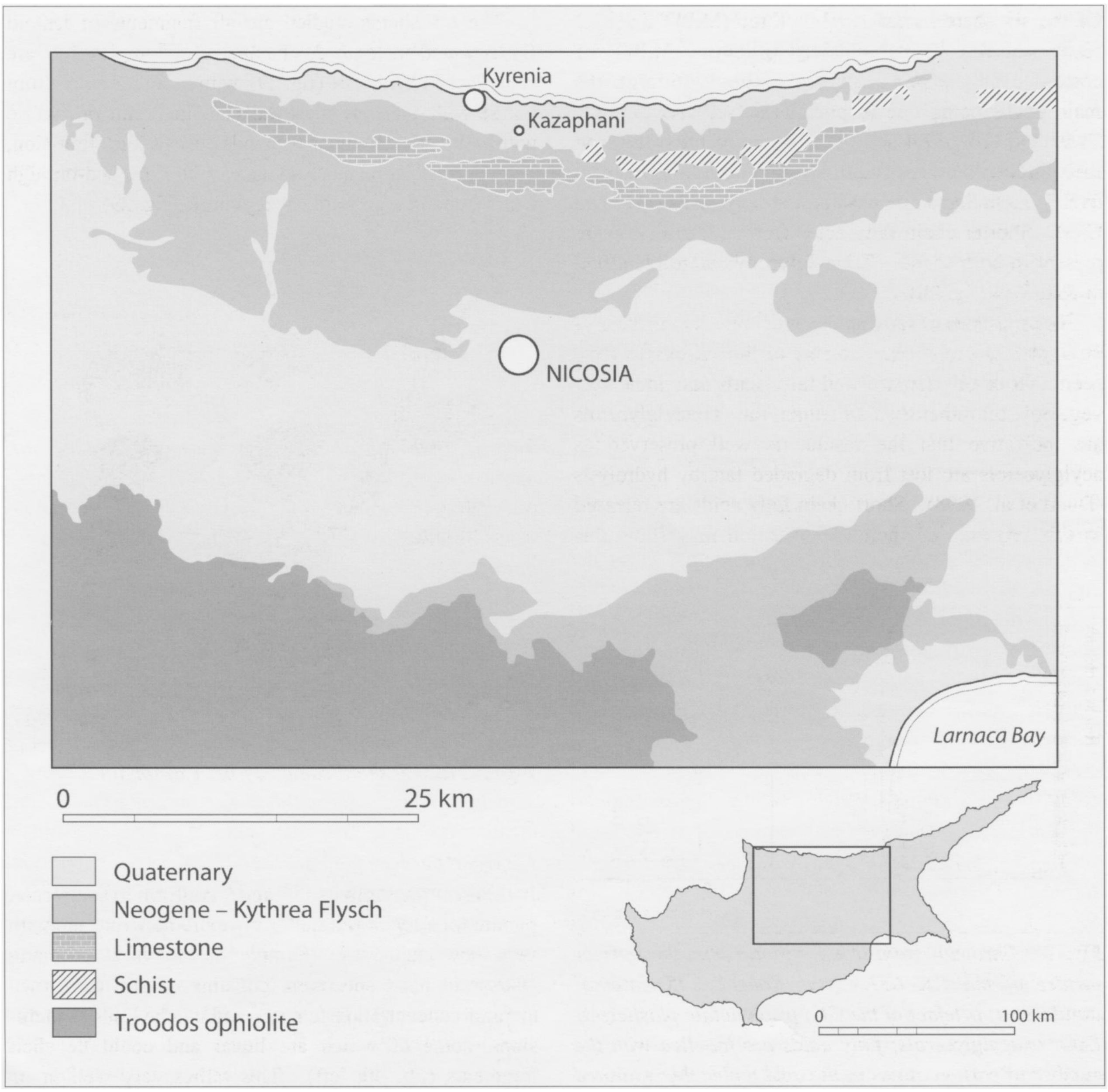

Fig. 31. Geology of Kazaphani area (after Pantazis 1979)

RLWm ware from Kilise Tepe. Sample 10, identified as a local imitation, actually does not stand out as being particularly distinguishable from canonical RLWm ware in its petrography (fig. 30, right). About as coarse as the semi-fine example described above, it too contains textural concentration features, quartz and calcite/micrite inclusions. This presents a very different scenario to that seen with the Kalavasos samples, among which the local imitation stood out petrographically. This Kazaphani sample is the only example thus far encountered in which the local material shows some similarity to the canonical RLWm ware samples.

INAA

What do the INAA results tell us? Once again, the canonical RLWm ware samples form a very tight group (note that the semi-fine sample 8 was not analysed for technical reasons). But, most interestingly, sample 10 — the local imitation — has values that fall largely within the range for canonical RLWm ware (table 4). For example, it contains 15ppm of scandium and 94.7ppm of chromium, both within RLWm ware's narrow ranges for these elements. The match is not perfect, but is much closer than for any other 'local' samples included in this study, and is thus suggestive. While one sample is clearly insufficient to produce clear-cut conclusions, there is at least a preliminary indication here that local products from Kazaphani may not be incompatible compositionally with RLWm ware.

The geology of the area around Kazaphani does appear to be broadly compatible with the petrographic results obtained (fig. 31). As described by Pantazis (1979), the Kyrenia range, consisting of the 'Pentadaktylos Succession', is composed largely of limestones, with marls, chalks, sandstone and conglomerate. From the Jurassic there is recrystallised limestone, and from the Triassic dolomitic limestone. Significantly, there are also pockets of quartz-mica schist (fig. 31), and none of the igneous material predominant in the Troodos massif. Although further study of local wares from Kazaphani, in combination with a programme of clay sampling, is clearly called for, there do seem to be geological and compositional grounds for giving serious consideration to the idea that this area might be the source for RLWm ware.

Residue analysis

Sherds 1, 2, 3, 8 and 9 were analysed for residues. Sherds 1, 2 and 9 contained only phthalates (see above). Analysis of sherds 2 and 3 yielded an unresolved, complex mixture of compounds not separated by chromatography (fig. 32a) with individual peaks visible superimposed over this broad feature. GC-MS revealed a series of *n*-alkanes in the partial chromatogram for *m*/*z* 71 (fig. 32b). The partial chromatogram for *m*/*z* 191 shows a series of hopanes in sherd 3 (fig. 32c) although these could not be identified in sherd 2. The presence of hopanes and *n*-alkanes identify the residue from sherd 3 as degraded bitumen and this is also the suggested identification for the residue from sherd 2.

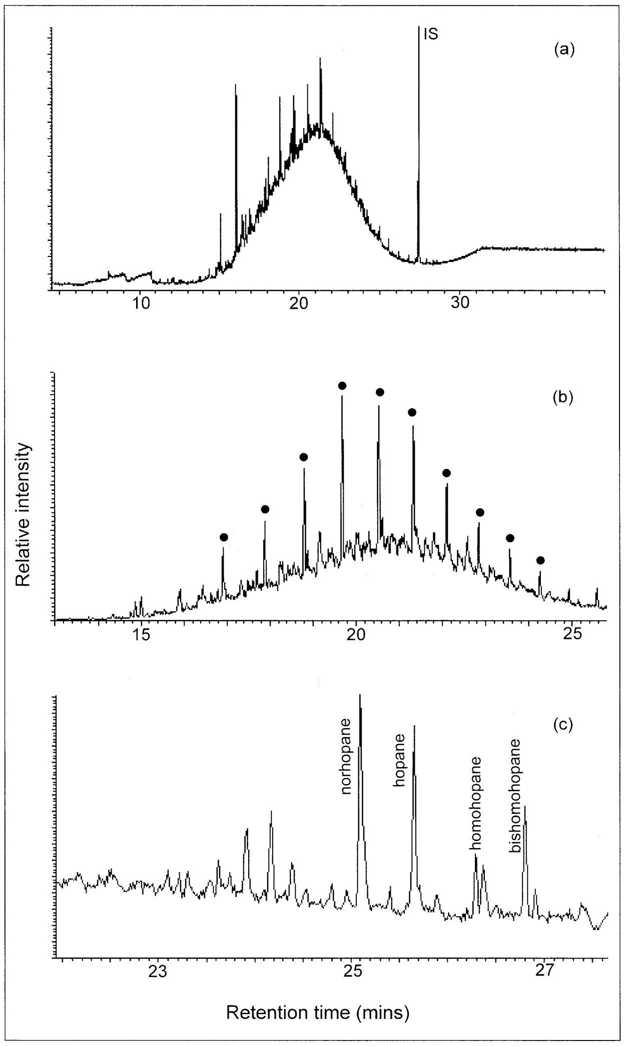

Fig. 32. (a) Total ion chromatogram of the residue from the exterior of sherd 3 from Kazaphani. IS: internal standard. (b) Partial ion chromatogram for m/z 71 showing n-alkane series. (c) Partial ion chromatogram for m/z 191 showing hopanes

Bitumen was used in antiquity for coating statues, making ornaments, as mortar and an adhesive, in medicine, agriculture, mummification, boat building and as a sealant for waterproofing. It would be unlikely that bitumen would be stored in pilgrim flasks as their narrow necks would make this impractical. The most probable uses in this case would be as a waterproofing sealant or for decoration. The higher level of residue on the interior of sherd 2 implies a sealant although sherd 3 yields more residue from the exterior surface which could indicate a decorative use. Waterproofing could be applied to either surface of a vessel. In addition a mixture containing bitumen cannot be excluded on the available evidence.

The discovery of bitumen raises the question of where it originated, as Cyprus has no indigenous sources. Most sources of bitumen have a distinctive signature of stable isotopes and the ratio of carbon isotopes ($\delta^{13}C$) is particularly characteristic (Connan, Deschesne 1996: 115). A comparison of the carbon and hydrogen (δD) stable isotope ratios of ancient and modern bitumen samples from different locations allows the source of a sample to be identified (Connan et al. 1992; Connan, Deschesne 1996). Bulk stable isotope analysis of $\delta^{13}C$ and δD was carried out on a sample of the residue from sherd 3. The results were then compared with those of Connan and Deschesne (fig. 33). This tentatively identifies the source of the bitumen from sherd 3 as the area around Ras Shamra in Syria. Syria would be a reasonable source for bitumen found in Cyprus as trade links between Cyprus and Syria-Palestine, and the ancient city of Ugarit in particular, were well established by the Late Bronze Age (Knapp 1991). Whether the bitumen was imported in other vessels and then used for sealing the RLWm or whether it arrived on Cyprus already in RLWm ware is not possible to determine.

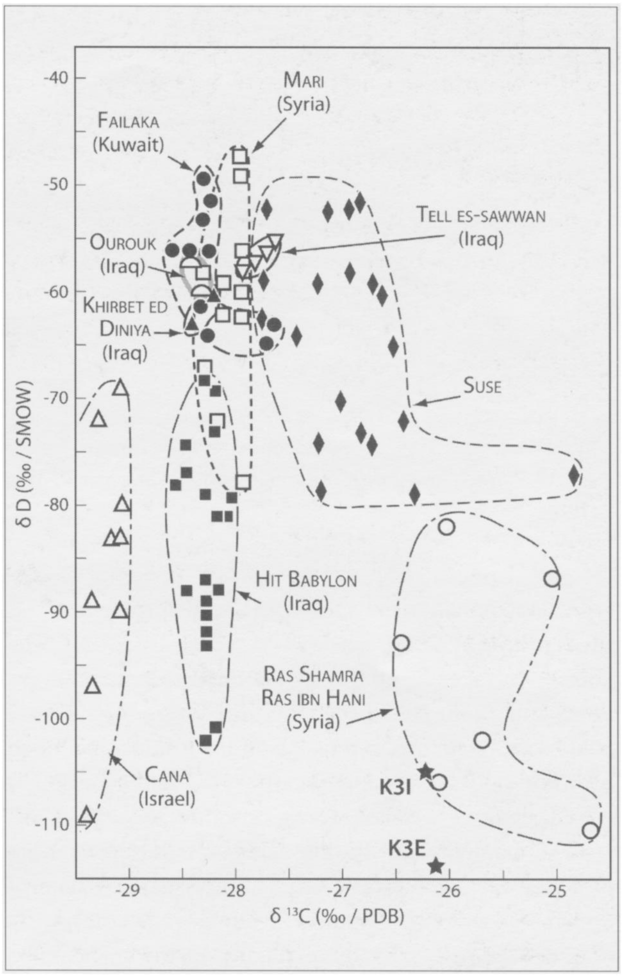

Fig. 33. Isotopic compositions of bitumen from different areas of the Middle East (after Connan, Deschene 1996: fig. 13). K3E and K3I indicate the positions of the samples from the exterior and interior surfaces of sherd 3 from Kazaphani. Errors in K3E and K3I are ± 1.8% in δD and ± 1.0% in $\delta^{13}C$

Egypt: Memphis-Saqqara

The city of Memphis, 30km south of Cairo (fig. 1), was the administrative capital for upper Egypt during the New Kingdom. Saqqara was its main necropolis. The burials from which the RLWm ware samples derive were lying on the surface close to the later Sacred Animal Necropolis. They were not associated with any other specific objects, but were found in an area dotted with many 18th Dynasty burials. The RLWm ware samples can thus be associated with the early 18th Dynasty, and hence date to the beginning of the New Kingdom, in the mid-16th century BC. These samples thus relate to the earlier phases in the production of RLWm ware, and are some three centuries earlier than the samples studied from Boğazköy (see above).

Petrography and INAA

Four samples of RLWm ware were kindly provided for thin section and chemical analysis by Janine Bourriau. In hand specimen they were all very fine, pink-red and, although worn, evidently canonical RLWm ware, in all probability spindle bottles. In thin section all four samples, although very fine, could be grouped closely with the numerous other samples described above (fig. 34). Further support for this assessment was provided by the chemical data, which showed once again the by now predictable pattern for RLWm ware composition. The Memphis-Saqqara samples fit extremely well into the main RLWm group (table 1). Although no detailed geological information for the site is immediately available, three petrological and chemical studies of the local wares have been carried out and there is no suggestion from these that this ware could be local to the area (Bourriau, Nicholson 1992; Bourriauet al. 2000; Bourriau et al. in press).

Residue analysis

The four samples above (2–5) and the visible residue from a fifth sherd (1) were analysed. The visible residue produced the chromatogram shown in figure 35. The chromatogram shows peaks for C_{16} and C_{18} fatty acids, azaleic acid (a dicarboxylic fatty acid) and two peaks which were identified as hydroxy fatty acids. These are

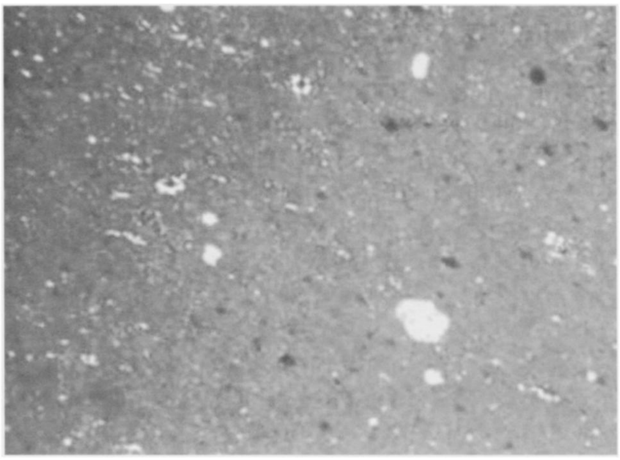

Fig. 34. Thin section photomicrograph of Saqqara RLWm samples

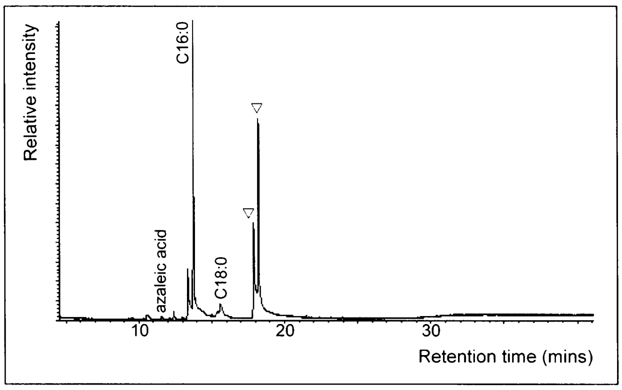

Fig. 35. Chromatogram of the visible residue on sherd 1 from Saqqara. Fatty acids are labelled with the number of carbon atoms in the acid molecule, saturated acids: x:0, monounsaturated acids: x:1; dicarboxylic acids are identified by name; ▽hydroxy fatty acids

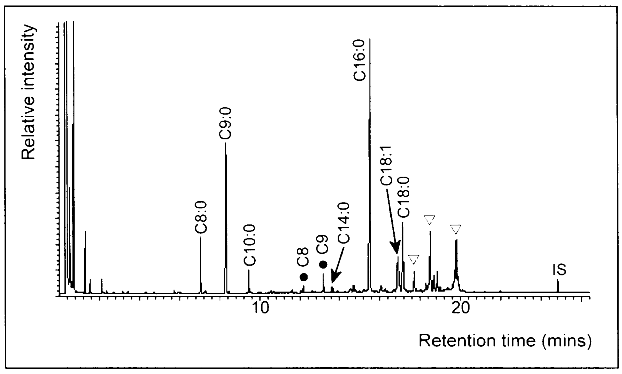

Fig. 36. Chromatogram of the residue from the interior surface of sherd 2 from Saqqara. IS: internal standard; ● dicarboxylic fatty acids with number of carbons as indicated; other peak identities as in fig. 35

typical of polymerised fats or oils and form when oils 'dry' to a semi-solid state (Evershed et al. 2002). The interior surfaces of all the sherds yielded large amounts of residue, with sherd 2 giving 1700µg/g. Again fatty acids were the main components of the residue, including hydroxy fatty acids and dicarboxylic fatty acids. A typical chromatogram is shown in figure 36.

The contents of all the vessels represented were probably the same fat or oil. The polymerised state of this fat or oil may slightly favour a vegetable oil as polymerisation occurs more readily in the unsaturated fatty acids typical of vegetable oils. Bulk stable isotope analysis gave results typical of C_3 plants, which include most common food species except millet (Sherriff et al. 1995). However, this is also within the range of values for ruminant animal fats and hydroxy fatty acids also from within degraded animal fats (Evershed 1990; Evershed et al. 2002). Further analysis is needed to determine the source of this fat or oil.

Overall discussion: provenance and contents

To summarise, samples of RLWm ware from all seven sites show very strong similarities in their fabric composition, as analysed through petrography and INAA. It is therefore highly probable that the ware derives from a single source somewhere in the east Mediterranean, and northern Cyprus is currently the most likely locale. But when it comes to the contents of RLWm ware, we do not see such standardisation; indeed, a rather varied picture has emerged from site to site, with beeswax represented in samples from Boğazköy alone, and bitumen in samples from Kazaphani. These patterns demand further explanation.

In terms of the source of RLWm ware, the argument for northern Cyprus stems in large part from the petrology of the coarser Red Lustrous Wheelmade ware samples from Kilise Tepe and Boğazköy, which point to a geological background of limestone and low-grade metamorphism. Although this is inconsistent with the Troodos range on Cyprus, it does seem to fit reasonably well with another area of the island, namely the northern Kyrenia range (Pantazis 1979). Indeed it is here that the site of Kazaphani is located, where especially significant quantities of the ware have been found in tombs (Nicolaou, Nicolaou 1989). Eriksson herself notes, with an appropriate degree of caution, the possibility that the source of Red Lustrous Wheelmade ware may be in the north of the island (Eriksson 1991: 94). It should be noted though that we cannot as yet entirely rule out other source areas, such as Anatolia; indeed one of the authors (Knappett) has noted that the southern Anatolian coast in the area of Anamur and Ovacik is at least broadly compatible geologically (Knappett 2000; see also Symington 2001: 170). Furthermore, the site of Kilise Tepe, where some very rare coarse ware variants of RLWm ware have been found, is relatively close to this area. Further analysis is required before we can state with greater certainty that northern Cyprus really is the source, ideally through the prospection and analysis of clay samples from the Kyrenia region. Clearly a more extensive analytical programme for RLWm ware from all over the eastern Mediterranean and Anatolia is also called for; the current study is a first step in this direction.

For the Hittite site of Boğazköy, the conclusion that RLWm ware is not made locally, but quite possibly in northern Cyprus, has significant ramifications, given the very substantial quantities of it at the site. It suggests a large-scale and long-distance importation of spindle bottles and libation arms at a time when there are indications that the Hittite empire may have held some sway over the island. Further to this is the relatively high frequency of RLWm ware finds along the Göksu valley, the most likely trade route between Cyprus and Hattusa through the Taurus mountain range.

In terms of the contents of RLWm ware, the variation from site to site is quite striking (and unexpected). Of particular interest is the preponderance of beeswax residues in samples from Boğazköy, and their absence elsewhere (Knapp 1991; Haldane 1993). Does this suggest that vessels destined to travel very long distances, from the north coast of Cyprus to the Hittite heartland for example, were given extra protection for their contents in the form of a beeswax sealant? Or does it mean that the imported vessels at Boğazköy were only treated upon arrival at the site, the use of beeswax being a Hittite practice in this context? Either way, there are some clues that the beeswax may have been used to seal in some kind of oil, although further research (which is indeed ongoing) would be required to specify the type of oil. As for the residues from other sites, the Kazaphani evidence is also intriguing; was bitumen imported from Syria to be used as a sealant to protect the contents of the RLWm lentoid flasks found in the tombs at this site? Samples from Kilise Tepe, Kouklia and Memphis-Saqqara did not present any evidence for sealants, but did show the presence of oils, the type of which is at present unclear, albeit with some evidence to favour plant oil. Overall, therefore, it would appear that RLWm vessels may have been used to transport, store and/or pour oils, possibly of a plant variety, and that these oils may in some cases have been protected in their containers through the use of beeswax or bitumen as sealants.

As for our understanding of international trade in the Late Bronze Age east Mediterranean, the evidence from petrography, NAA and residue analysis presented here demonstrates a degree of specialisation that has rarely been recognised previously. The specialisation is threefold, in terms of the region, with RLWm ware apparently coming from one restricted area, quite possibly northern Cyprus; in terms of the ceramic container, with very standardised forms and fabrics making the ware highly recognisable across large areas; and in terms of the contents, which may have been consistently some kind of plant oil, although this follows only very provisionally and speculatively from the evidence we have collated so far. We cannot even say whether the oils were plant oils for sure, or whether they were always the same kinds of plant oils. They may, for that matter, have been perfumed oils, through comparison with what is known of Mycenaean practices as documented in Linear B and evidenced through stirrup jars. This would make some sense given the frequency with which RLWm vessels are found in tomb contexts, and often alongside Mycenaean stirrup jars (Steel 1998); perhaps perfumed oils played a role in the treatment of the body in funerary ritual. Whether this was the case or not, RLWm ware and its contents are clearly the subject of a very specific kind of demand over large areas of the east Mediterranean, the particular areas in question changing over time, but broadly speaking, from south to north, from Egypt to Anatolia (Eriksson 1993). There is no need to imagine an identical use of the ware's contents over such wide areas and spanning three centuries, as there must surely have been divergent practices, as indeed indicated by the beeswax and bitumen evidence noted above. However, the persistence of this very particular tradition of manufacture in a restricted area, yet one which came to be known across much of the east Mediterranean, tells us a great deal about the range of interaction networks that developed during the Late Bronze Age, incorporating both the local trade in commodities of independent merchants and the 'global' distribution networks of centralised economies.

Acknowledgements

This study would not have been possible without the generous assistance of the numerous site excavators who provided samples: Nicholas Postgate for Kilise Tepe, Jürgen Seeher for Boğazköy, Janine Bourriau for Memphis-Saqqara, Alison South for Kalavasos, Franz Georg Maier for Kouklia, Paul Åström for Hala Sultan Tekke and I. Nikolaou for Kazaphani. Many of the above also kindly gave of their time to provide comments on an earlier draft of this paper. Nicoletta Momigliano provided extremely detailed and invaluable comments in reviewing this paper, for which we are most grateful. Thanks also go to the relevant authorities in Turkey, Cyprus and Egypt for permission to sample this material. Knappett would like in particular to thank Alison South for all her considerable help with the Cypriot material. Seán Goddard assisted expertly with the figures. Financial support has been provided by the British Academy, the British Institute at Ankara and Christ's College, Cambridge; ongoing residue analysis is supported by the AHRC.

Sample	Sm	Lu	U	Yb	As	Sb	Ca(%)	Na (%)	K(%)	La	Ce	Th	Cr	Hf	Cs	Tb	Sc	Rb	Fe(%)	Ta	Co	Eu
CYP00/01	6.56	0.44	5.5	3.07	7.1	1.1	6.09	0.273		36.8	84.1	14.7	107	4.84	9.08	0.8	18.8	147	5.52	1.5	22.5	1.31
CYP00/02	6.47	0.46	5.3	3.09	7.8	1.3	5.56	0.269		38.0	85.6	15.5	115	5.02	10.60	0.7	20.1	153	5.81	1.5	23.5	1.30
CYP00/03	7.20	0.48	5.7	3.32	9.3	1.2	6.56	0.312		41.0	88.9	15.5	109	5.23	10.30	0.9	20.1	149	5.90	1.6	23.2	1.43
CYP00/04	6.47	0.46	4.6	3.37	7.0	1.2	3.99	0.391		39.5	89.8	16.2	119	5.45	10.40	0.9	21.0	155	6.01	1.6	23.0	1.30
CYP00/06	6.34	0.43	4.1	3.10	11.2	1.1	5.31	0.468		36.4	79.1	14.6	107	5.28	8.43	0.7	18.0	135	5.66	1.5	21.6	1.26
CYP00/07	5.64	0.45	4.2	3.26	9.0	1.1	1.48	0.425		28.1	75.8	14.9	102	5.54	7.06	0.7	18.5	126	5.66	1.6	65.5	1.09
CYP00/08	7.33	0.48	5.9	3.63	5.7	1.2	6.82	0.322		40.3	88.9	15.6	108	5.44	9.80	0.9	19.9	156	5.84	1.5	23.5	1.48
CYP00/09	6.66	0.41	3.2	3.40	9.2	2.0	4.77	0.292		41.1	112.0	12.4	164	7.56	3.93	0.9	16.5	37	5.29	1.9	13.2	1.30
CYP00/10	5.88	0.38	3.6	2.77	7.1	1.1	4.29	0.320		30.7	69.8	13.6	97.6	4.10	7.53	0.7	17.9	120	4.92	1.3	20.9	1.10
HST03/01	6.24	0.40	3.8	3.00	6.8	0.9	4.22	0.190	1.93	36.1	81.9	14.5	106	5.09	8.14	0.7	18.5	144	5.74	1.5	22.4	1.24
HST03/02	6.49	0.44	4.3	3.15	7.8	1.2	2.85	0.230	2.62	38.4	85.4	14.9	109	5.19	9.61	0.7	19.8	173	5.88	1.5	22.9	1.33
HST03/03	6.51	0.44	4.6	3.17	nd	1.1	5.10	0.280	2.43	38.3	84.2	14.7	110	4.93	10.00	0.6	19.7	163	5.74	1.6	23.0	1.27
HST03/04	6.69	0.43	3.9	3.11	7.5	1.0	5.07	0.253	2.54	38.4	85.7	14.8	107	5.42	9.44	0.9	19.3	164	5.88	1.5	21.8	1.38
HST03/05	6.51	0.45	4.6	3.25	nd	1.5	3.02	0.224	2.78	38.3	83.7	15.1	112	5.14	10.10	0.7	20.1	180	5.97	1.6	23.6	1.32
HST03/06	6.35	0.42	4.2	3.00	8.4	1.2	4.96	0.209	2.20	35.7	79.5	13.7	101	5.10	8.16	0.7	17.9	153	5.35	1.5	21.2	1.22
KOU03/01	5.59	0.37	3.7	2.93	18	1.0	4.83	0.196	2.05	27.6	76.3	13.2	96.8	4.27	7.99	0.6	17.4	136	5.34	1.4	21.2	1.13
KOU03/03	6.50	0.44	4.5	3.21	nd	1.1	4.20	0.216	2.31	38.3	88.6	15.1	116	4.78	10.80	0.7	20.0	157	5.69	1.5	22.0	1.36
KOU03/04	6.27	0.41	4.1	3.17	11	1.0	7.13	0.241	1.97	36.4	84.4	14.1	102	4.67	8.65	0.7	17.8	132	5.25	1.4	19.7	1.27
KOU03/05	5.98	0.40	4.0	3.24	nd	1.2	5.12	0.252	2.48	34.4	94.4	14.0	97.6	4.94	8.64	0.8	17.9	149	5.38	1.5	20.7	1.18
KOU03/06	6.56	0.40	4.4	3.20	8.8	1.1	8.37	0.255	2.21	37.7	86.7	13.8	103	5.19	8.65	1.0	18.0	134	5.24	1.4	20.8	1.33
KAZ03/02	5.71	0.40	4.5	3.09	11	1.1	2.40	0.288	2.08	34.0	73.7	13.4	100	4.59	7.08	0.7	17.2	129	5.05	1.5	17.3	1.06
KAZ03/03	5.81	0.37	3.7	3.00	8.4	0.9	2.71	0.550	1.70	34.6	74.4	12.4	91.6	4.44	5.51	0.8	15.7	96	4.78	1.4	12.9	1.21
KAZ03/04	5.36	0.35	3.2	2.68	8.1	0.9	2.89	0.368	1.80	31.2	71.8	13.1	98.2	4.18	6.67	0.9	17.3	120	5.06	1.4	14.9	1.13
KAZ03/05	4.27	0.32	3.3	2.57	8.5	0.9	0.99	0.510	1.54	22.7	60.4	nd	97.2	4.72	6.31	0.7	16.4	110	5.10	1.5	17.2	0.95
KAZ03/06	3.79	0.31	3.6	2.34	9.1	0.9	3.38	0.386	1.35	21.4	51.5	11.7	89.4	4.06	5.00	0.6	14.4	92	4.53	1.3	10.2	0.82
KAZ03/07	5.65	0.34	3.7	2.57	7.9	1.0	3.36	0.361	1.33	34.9	73.2	12.4	92.9	3.78	5.48	0.7	16.5	98	4.55	1.3	12.7	1.11
KAZ03/09	5.82	0.36	3.9	2.97	10	0.9	1.88	0.529	1.66	35.6	77.8	13.2	98.7	4.57	6.33	0.7	16.3	104	4.84	1.3	13.7	1.18
KAZ03/10	7.30	0.42	3.4	3.20	13	0.8	1.26	0.781	1.99	43.9	88.1	12.7	94.7	5.01	6.44	0.8	15.0	111	4.53	1.6	10.8	1.35
EGY00/01	6.74	0.43	4.0	3.08	10	1.2	6.83	0.268		38.7	83.2	14.7	108	5.05	9.51	0.9	18.9	152	5.93	1.4	21.4	1.25
EGY00/02	6.68	0.42	3.9	3.13	11	1.2	5.70	0.400		38.7	82.4	14.2	107	4.60	8.95	0.9	18.7	148	5.39	1.4	21.1	1.29
EGY00/03	6.64	0.41	4.2	3.04	9.7	1.2	7.29	0.339		37.9	80.8	14.2	104	4.42	8.87	0.7	18.4	140	5.41	1.4	21.2	1.26
EGY00/04	6.91	0.42	4.0	3.00	11	1.1	5.47	0.337		40.0	85.6	14.6	104	4.73	9.05	0.7	18.8	153	5.47	1.5	21.2	1.36
BKY03/01	7.45	0.47	4.5	3.51	8.6	1.2	5.44	0.199	2.05	42.8	94.5	16.0	nd	5.58	9.75	1.1	20.5	133	5.91	1.6	23.0	1.43
BKY03/02	6.88	0.42	4.3	3.32	8.9	1.2	5.50	0.218	2.24	39.4	87.2	15.1	105	5.31	8.61	0.8	18.5	146	5.40	1.5	21.2	1.34
BKY03/03	7.11	0.43	4.2	3.37	9.6	1.2	5.94	0.208	2.33	40.8	96.5	15.4	114	5.41	9.53	0.8	19.5	154	5.75	1.7	21.5	1.44
BKY03/04	6.93	0.42	4.0	3.24	9.3	1.2	6.32	0.227	2.28	40.7	88.5	15.4	115	5.11	9.76	0.9	19.6	134	5.60	1.6	22.6	1.36
BKY03/05	7.10	0.46	3.1	3.77	9.4	0.8	1.22	0.368	3.19	46.9	104	16.2	173	6.52	10.2	0.9	22.5	154	4.59	1.6	21.7	1.46
BKY03/06	6.57	0.40	3.6	3.24	13	1.2	5.81	0.182	1.74	37.6	84.8	14.6	105	4.78	7.93	0.8	17.9	122	5.55	1.5	20.9	1.25
BKY03/07	6.30	0.39	3.4	3.13	8.8	1.0	5.85	0.171	1.84	35.7	82.2	14.1	103	5.46	8.16	0.6	17.0	130	5.64	1.4	20.1	1.27
BKY03/08	7.28	0.44	4.5	3.41	7.5	1.1	7.25	0.326	2.04	42.2	95.1	15.5	110	nd	9.59	0.6	19.9	138	5.64	1.5	22.5	1.42
BKY03/09	6.60	0.41	3.8	3.05	11	1.2	6.93	0.193	1.78	39.4	87.6	14.9	105	4.69	8.80	1.0	18.6	123	5.42	1.4	21.8	1.29

BKY03/10	7.02	0.43	5.1	3.19	10	1.2	6.73	0.234	2.11	39.9	91.4	15.4	108	4.66	9.50	1.1	19.1	152	5.77	1.6	22.0	1.38
BKY03/11	6.72	0.44	4.1	3.17	9.7	1.1	5.01	0.172	2.18	37.7	86.2	14.9	106	5.06	7.82	0.8	18.1	143	5.42	1.4	21.6	1.30
BKY03/12	6.69	0.39	3.9	3.00	9.6	1.0	7.69	0.226	1.77	37.7	86.3	14.5	99	5.02	8.29	0.7	17.6	144	5.23	1.4	20.0	1.36
BKY03/13	7.13	0.44	3.9	3.41	8.9	1.3	5.48	0.206	2.27	40.4	94.4	15.8	113	5.51	9.59	0.9	19.9	153	5.87	1.5	23.0	1.39
BKY03/14	6.94	0.42	4.1	3.10	13	1.2	7.22	0.210	2.24	40.2	88.4	14.9	105	4.72	8.17	1.0	18.6	142	5.50	1.5	21.6	1.29
BKY03/15	7.00	0.46	4.4	3.36	9.0	1.2	3.89	0.207	2.37	39.9	91.1	16.1	113	5.01	10.2	0.8	20.0	164	5.81	1.6	23.2	1.31
BKY03/16	6.99	0.42	4.4	3.28	9.0	1.2	4.14	0.208	2.48	40.6	89.2	15.3	114	4.93	10.3	0.7	19.5	166	5.66	1.6	22.7	1.31
BKY03/17	6.79	0.40	3.8	3.13	11	1.1	7.98	0.186	2.31	38.3	85.5	14.3	100	4.85	9.02	0.9	18.1	148	5.39	1.4	20.1	1.27
BKY03/18	7.11	0.44	4.6	3.37	10	1.1	5.69	0.218	2.78	40.9	90.7	15.5	110	4.85	10.0	0.8	19.7	166	5.79	1.4	22.2	1.34
BKY03/19	6.45	0.40	3.9	2.96	nd	1.0	5.43	0.193	2.32	36.4	81.6	14.1	96	4.69	7.59	0.9	17.1	133	5.29	1.4	20.2	1.25
BKY03/20	6.99	0.42	4.5	3.12	10	1.1	4.58	0.208	2.20	40.0	88.0	15.1	110	4.95	10.1	0.9	19.6	149	5.64	1.5	22.4	1.30
BKY03/21	7.01	0.44	4.3	3.26	9.6	1.1	4.73	0.202	2.19	41.0	89.4	15.6	111	4.98	9.76	0.8	19.6	146	5.61	1.4	21.9	1.35
BKY03/22	6.80	0.39	3.7	2.98	10	1.0	7.01	0.181	1.94	39.9	88.9	14.8	107	4.62	9.45	0.8	18.8	139	5.49	1.4	21.1	1.34
BKY03/23	7.02	0.41	3.9	3.12	9.3	1.1	7.85	0.167	2.00	41.1	89.4	14.8	107	4.70	9.44	0.8	19.2	134	5.64	1.4	21.5	1.33
BKY03/24	7.38	0.47	3.6	3.54	18	1.0	1.84	0.505	3.16	45.8	102	15.3	182	5.91	10.0	0.8	22.9	153	5.20	1.5	25.3	1.45
BKY03/25	7.26	0.48	3.8	3.52	13	0.9	1.67	0.418	3.57	46.3	102	15.7	173	6.43	10.7	0.9	23.8	161	4.79	1.5	23.5	1.47
BKY03/26	6.33	0.38	3.0	2.86	51	1.2	3.05	0.627	2.83	36.8	81.0	12.6	176	5.60	11.7	0.8	18.4	117	4.61	1.3	24.9	1.34
BKY03/27	6.86	0.41	4.1	2.95	nd	0.9	9.08	0.202	1.81	38.5	82.3	13.1	95	4.88	7.92	0.8	16.9	125	5.04	1.4	18.9	1.32
BKY03/28	7.14	0.46	3.5	3.51	13	1.4	2.01	0.482	3.24	44.1	96.6	14.9	174	6.31	9.42	0.9	22.7	144	5.08	1.5	25.3	1.49
BKY03/29	7.28	0.47	3.7	3.53	0.0	1.1	1.48	0.491	3.34	44.6	98.3	15.3	183	6.58	9.44	0.9	22.8	150	5.21	1.5	26.0	1.48
BKY03/30	6.49	0.40	4.2	2.94	9.9	1.1	4.74	0.174	2.11	36.9	80.9	14.2	97	4.77	8.41	0.8	18.0	140	5.15	1.4	21.4	1.25
BKY03/31	4.69	0.30	2.1	2.35	nd	0.6	6.55	1.930	1.84	25.4	56.6	nd	350	3.94	4.55	0.8	20.8	80	6.00	1.1	37.8	1.34
BKY03/32	4.87	0.31	2.4	2.43	nd	0.7	4.60	1.500	2.06	24.8	51.7	6.3	726	4.00	2.99	0.7	17.3	57	5.29	1.3	39.6	1.21
BKY03/33	3.92	0.25	1.9	2.07	6.9	1.1	5.26	1.380	1.46	23.8	50.7	8.7	660	3.56	3.36	0.7	15.0	65	4.19	0.7	26.6	0.91
BKY03/35	5.26	0.31	1.8	2.63	3.6	0.6	2.70	1.310	1.53	26.0	56.4	6.8	445	4.68	3.97	0.8	22.3	nd	6.38	1.3	38.4	1.32
BKY03/36	9.28	0.41	6.5	2.87	38	2.3	4.89	1.300	2.64	64.2	136	25.2	106	6.58	26.8	1.0	15.8	178	4.49	1.7	19.3	1.91
BKY03/37	3.57	0.27	2.2	2.11	49	4.8	7.95	1.220	1.17	20.6	40.5	8.7	230	3.42	9.78	0.5	14.6	75	3.79	0.7	20.1	0.86
BKY03/38	5.81	0.30	4.3	2.23	16	0.9	9.56	0.959	2.20	41.2	81.1	16.8	93	9.35	10.3	0.7	12.0	125	3.59	1.3	16.3	1.11
BKY03/39	6.11	0.38	4.2	2.70	38	3.2	7.50	1.010	2.03	41.9	83.2	20.8	105	5.10	7.64	0.8	13.4	113	3.43	1.3	14.7	1.21
BKY03/40	5.81	0.34	2.8	2.82	47	1.0	3.49	0.698	2.11	33.3	71.8	10.9	247	5.31	8.18	0.7	17.4	98	4.80	1.2	26.6	1.28
BKY03/41	7.27	0.50	3.6	3.63	nd	0.9	1.71	0.483	2.93	45.6	96.4	15.2	175	6.29	9.96	0.8	23.3	157	5.05	1.5	25.1	1.51
BKY03/42	7.38	0.48	3.3	3.70	nd	0.9	1.77	0.536	3.04	45.7	98.4	15.4	180	6.45	9.34	0.8	23.1	157	5.36	1.6	26.5	1.51
KLT99087	6.75	0.45	4.4	3.27	11	1.3	3.77	0.183		39.2	88.8	15.4	110	4.90	10.10	1.0	20.1	160	5.82	1.6	22.8	1.33
KLT99088	7.29	0.42	3.9	3.25	29	4.7	3.97	0.262		44.5	94.8	15.1	100	5.16	11.40	0.8	19.0	170	5.33	1.4	20.9	1.46
KLT99094	6.82	0.42	4.0	3.13	8.8	1.3	8.63	0.221		38.2	83.0	13.9	103	5.18	8.28	0.9	17.8	140	5.23	1.5	19.8	1.38
KLT99095	7.19	0.40	3.5	3.15	14	2.4	9.48	0.270		41.8	91.2	13.5	96	4.71	7.64	1.3	18.4	150	4.97	1.4	18.5	1.48
KLT99097	7.03	0.46	4.1	3.44	8.2	1.3	4.48	0.191		41.0	93.6	16.2	118	4.95	10.60	1.2	20.9	170	5.98	1.6	23.9	1.42
KLT99098	7.20	0.38	3.6	3.15	25	3.1	7.34	0.313		42.3	91.6	14.6	95	4.34	9.78	1.2	18.8	140	5.29	1.5	21.1	1.38
KLT99099	6.53	0.39	4.2	2.78	11	1.1	10.6	0.214		36.3	78.8	12.9	85	5.18	7.08	0.7	15.8	110	4.61	1.3	19.7	1.28
KLT99101	6.58	0.40	4.0	3.05	11	1.2	10.0	0.210		38.3	82.8	14.1	99	4.61	8.78	1.1	18.8	140	5.38	1.3	20.1	1.26

Table 1. NAA results from all sites

sample	Sm	Lu	U	Yb	As	Sb	Ca (%)	Na (%)	K (%)	La	Ce	Th	Cr	Hf	Cs	Tb	Sc	Rb	Fe (%)	Ta	Co	Eu
BKY03/01	7.45	0.47	4.5	3.51	8.6	1.2	5.44	0.199	2.05	42.8	94.5	16.0	nd	5.58	9.75	1.1	20.5	133	5.91	1.6	23.0	1.43
BKY03/02	6.88	0.42	4.3	3.32	8.9	1.2	5.50	0.218	2.24	39.4	87.2	15.1	105	5.31	8.61	0.8	18.5	146	5.40	1.5	21.2	1.34
BKY03/03	7.11	0.43	4.2	3.37	9.6	1.2	5.94	0.208	2.33	40.8	96.5	15.4	114	5.41	9.53	0.8	19.5	154	5.75	1.7	21.5	1.44
BKY03/04	6.93	0.42	4.0	3.24	9.3	1.2	6.32	0.227	2.28	40.7	88.5	15.4	115	5.11	9.76	0.9	19.6	134	5.60	1.6	22.6	1.36
BKY03/05	7.10	0.46	3.1	3.77	9.4	0.8	1.22	0.368	3.19	46.9	104	16.2	173	6.52	10.2	0.9	22.5	154	4.59	1.6	21.7	1.46
BKY03/06	6.57	0.40	3.6	3.24	13	1.2	5.81	0.182	1.74	37.6	84.8	14.6	105	4.78	7.93	0.8	17.9	122	5.55	1.5	20.9	1.25
BKY03/07	6.30	0.39	3.4	3.13	8.8	1.0	5.85	0.171	1.84	35.7	82.2	14.1	103	5.46	8.16	0.6	17.0	130	5.64	1.4	20.1	1.27
BKY03/08	7.28	0.44	4.5	3.41	7.5	1.1	7.25	0.326	2.04	42.2	95.1	15.5	110	nd	9.59	0.6	19.9	138	5.64	1.5	22.5	1.42
BKY03/09	6.60	0.41	3.8	3.05	11	1.2	6.93	0.193	1.78	39.4	87.6	14.9	105	4.69	8.80	1.0	18.6	123	5.42	1.4	21.8	1.29
BKY03/10	7.02	0.43	5.1	3.19	10	1.2	6.73	0.234	2.11	39.9	91.4	15.4	108	4.66	9.50	1.1	19.1	152	5.77	1.6	22.0	1.38
BKY03/11	6.72	0.44	4.1	3.17	9.7	1.1	5.01	0.172	2.18	37.7	86.2	14.9	106	5.06	7.82	0.8	18.1	143	5.42	1.4	21.6	1.30
BKY03/12	6.69	0.39	3.9	3.00	9.6	1.0	7.69	0.226	1.77	37.7	86.3	14.5	99	5.02	8.29	0.7	17.6	144	5.23	1.4	20.0	1.36
BKY03/13	7.13	0.44	3.9	3.41	8.9	1.3	5.48	0.206	2.27	40.4	94.4	15.8	113	5.51	9.59	0.9	19.9	153	5.87	1.5	23.0	1.39
BKY03/14	6.94	0.42	4.1	3.10	13	1.2	7.22	0.210	2.24	40.2	88.4	14.9	105	4.72	8.17	1.0	18.6	142	5.50	1.5	21.6	1.29
BKY03/15	7.00	0.46	4.4	3.36	9.0	1.2	3.89	0.207	2.37	39.9	91.1	16.1	113	5.01	10.2	0.8	20.0	164	5.81	1.6	23.2	1.31
BKY03/16	6.99	0.42	4.4	3.28	9.0	1.2	4.14	0.208	2.48	40.6	89.2	15.3	114	4.93	10.3	0.7	19.5	166	5.66	1.6	22.7	1.31
BKY03/17	6.79	0.40	3.8	3.13	11	1.1	7.98	0.186	2.31	38.3	85.5	14.3	100	4.85	9.02	0.9	18.1	148	5.39	1.4	20.1	1.27
BKY03/18	7.11	0.44	4.6	3.37	10	1.1	5.69	0.218	2.78	40.9	90.7	15.5	110	4.85	10.0	0.8	19.7	166	5.79	1.4	22.2	1.34
BKY03/19	6.45	0.40	3.9	2.96	nd	1.0	5.43	0.193	2.32	36.4	81.6	14.1	96	4.69	7.59	0.9	17.1	133	5.29	1.4	20.2	1.25
BKY03/20	6.99	0.42	4.5	3.12	10	1.1	4.58	0.208	2.20	40.0	88.0	15.1	110	4.95	10.1	0.9	19.6	149	5.64	1.5	22.4	1.30
BKY03/21	7.01	0.44	4.3	3.26	9.6	1.1	4.73	0.202	2.19	41.0	89.4	15.6	111	4.98	9.76	0.8	19.6	146	5.61	1.4	21.9	1.35
BKY03/22	6.80	0.39	3.7	2.98	10	1.0	7.01	0.181	1.94	39.9	88.9	14.8	107	4.62	9.45	0.8	18.8	139	5.49	1.4	21.1	1.34
BKY03/23	7.02	0.41	3.9	3.12	9.3	1.1	7.85	0.167	2.00	41.1	89.4	14.8	107	4.70	9.44	0.8	19.2	134	5.64	1.4	21.5	1.33
BKY03/24	7.38	0.47	3.6	3.54	18	1.0	1.84	0.505	3.16	45.8	102	15.3	182	5.91	10.0	0.8	22.9	153	5.20	1.5	25.3	1.45
BKY03/25	7.26	0.48	3.8	3.52	13	0.9	1.67	0.418	3.57	46.3	102	15.7	173	6.43	10.7	0.9	23.8	161	4.79	1.5	23.5	1.47
BKY03/26	6.33	0.38	3.0	2.86	51	1.2	3.05	0.627	2.83	36.8	81.0	12.6	176	5.60	11.7	0.8	18.4	117	4.61	1.3	24.9	1.34
BKY03/27	6.86	0.41	4.1	2.95	nd	0.9	9.08	0.202	1.81	38.5	82.3	13.1	95	4.88	7.92	0.8	16.9	125	5.04	1.4	18.9	1.32
BKY03/28	7.14	0.46	3.5	3.51	13	1.4	2.01	0.482	3.24	44.1	96.6	14.9	174	6.31	9.42	0.9	22.7	144	5.08	1.5	25.3	1.49
BKY03/29	7.28	0.47	3.7	3.53	0.0	1.1	1.48	0.491	3.34	44.6	98.3	15.3	183	6.58	9.44	0.9	22.8	150	5.21	1.5	26.0	1.48
BKY03/30	6.49	0.40	4.2	2.94	9.9	1.1	4.74	0.174	2.11	36.9	80.9	14.2	97	4.77	8.41	0.8	18.0	140	5.15	1.4	21.4	1.25
BKY03/31	4.69	0.30	2.1	2.35	nd	0.6	6.55	1.930	1.84	25.4	56.6	0.0	350	3.94	4.55	0.8	20.8	80	6.00	1.1	37.8	1.34
BKY03/32	4.87	0.31	2.4	2.43	nd	0.7	4.60	1.500	2.06	24.8	51.7	6.3	726	4.00	2.99	0.7	17.3	57	5.29	1.3	39.6	1.21
BKY03/33	3.92	0.25	1.9	2.07	6.9	1.1	5.26	1.380	1.46	23.8	50.7	8.7	660	3.56	3.36	0.7	15.0	65	4.19	0.7	26.6	0.91
BKY03/35	5.26	0.31	1.8	2.63	3.6	0.6	2.70	1.310	1.53	26.0	56.4	6.8	445	4.68	3.97	0.8	22.3	nd	6.38	1.3	38.4	1.32
BKY03/36	9.28	0.41	6.5	2.87	38	2.3	4.89	1.300	2.64	64.2	136	25.2	106	6.58	26.8	1.0	15.8	178	4.49	1.7	19.3	1.91
BKY03/37	3.57	0.27	2.2	2.11	49	4.8	7.95	1.220	1.17	20.6	40.5	8.7	230	3.42	9.78	0.5	14.6	75	3.79	0.7	20.1	0.86
BKY03/38	5.81	0.30	4.3	2.23	16	0.9	9.56	0.959	2.20	41.2	81.1	16.8	93	9.35	10.3	0.7	12.0	125	3.59	1.3	16.3	1.11
BKY03/39	6.11	0.38	4.2	2.70	38	3.2	7.50	1.010	2.03	41.9	83.2	20.8	105	5.10	7.64	0.8	13.4	113	3.43	1.3	14.7	1.21
BKY03/40	5.81	0.34	2.8	2.82	47	1.0	3.49	0.698	2.11	33.3	71.8	10.9	247	5.31	8.18	0.7	17.4	98	4.80	1.2	26.6	1.28
BKY03/41	7.27	0.50	3.6	3.63	nd	0.9	1.71	0.483	2.93	45.6	96.4	15.2	175	6.29	9.96	0.8	23.3	157	5.05	1.5	25.1	1.51
BKY03/42	7.38	0.48	3.3	3.70	nd	0.9	1.77	0.536	3.04	45.7	98.4	15.4	180	6.45	9.34	0.8	23.1	157	5.36	1.6	26.5	1.51

Table 2. NAA results from Boğazköy

Sample	Sm	Lu	U	Yb	As	Sb	Ca (%)	Na (%)	La	Ce	Th	Cr	Hf	Cs	Tb	Sc	Rb	Fe (%)	Ta	Co	Eu
CYP00/01	6.56	0.44	5.5	3.07	7.1	1.1	6.09	0.273	36.8	84.1	14.7	107	4.84	9.08	0.8	18.8	147	5.52	1.5	22.5	1.31
CYP00/02	6.47	0.46	5.3	3.09	7.8	1.3	5.56	0.269	38.0	85.6	15.5	115	5.02	10.60	0.7	20.1	153	5.81	1.5	23.5	1.30
CYP00/03	7.20	0.48	5.7	3.32	9.3	1.2	6.56	0.312	41.0	88.9	15.5	109	5.23	10.30	0.9	20.1	149	5.90	1.6	23.2	1.43
CYP00/04	6.47	0.46	4.6	3.37	7.0	1.2	3.99	0.391	39.5	89.8	16.2	119	5.45	10.40	0.9	21.0	155	6.01	1.6	23.0	1.30
CYP00/06	6.34	0.43	4.1	3.10	11.2	1.1	5.31	0.468	36.4	79.1	14.6	107	5.28	8.43	0.7	18.0	135	5.66	1.5	21.6	1.26
CYP00/07	5.64	0.45	4.2	3.26	9.0	1.1	1.48	0.425	28.1	75.8	14.9	102	5.54	7.06	0.7	18.5	126	5.66	1.6	65.5	1.09
CYP00/08	7.33	0.48	5.9	3.63	5.7	1.2	6.82	0.322	40.3	88.9	15.6	108	5.44	9.80	0.9	19.9	156	5.84	1.5	23.5	1.48
CYP00/09	6.66	0.41	3.2	3.40	9.2	2.0	4.77	0.292	41.1	112.0	12.4	164	7.56	3.93	0.9	16.5	37	5.29	1.9	13.2	1.30
CYP00/10	5.88	0.38	3.6	2.77	7.1	1.1	4.29	0.320	30.7	69.8	13.6	97.6	4.10	7.53	0.7	17.9	120	4.92	1.3	20.9	1.10

Table 3. NAA results from Kalavasos

Sample	Sm	Lu	U	Yb	As	Sb	Ca(%)	Na(%)	K	La	Ce	Th	Cr	Hf	Cs	Tb	Sc	Rb	Fe(%)	Ta	Co	Eu
KAZ03/02	5.71	0.40	4.5	3.09	11	1.1	2.40	0.288	2.08	34.0	73.7	13.4	100	4.59	7.08	0.7	17.2	129	5.05	1.5	17.3	1.06
KAZ03/03	5.81	0.37	3.7	3.00	8.4	0.9	2.71	0.550	1.70	34.6	74.4	12.4	92	4.44	5.51	0.8	15.7	96	4.78	1.4	12.9	1.21
KAZ03/04	5.36	0.35	3.2	2.68	8.1	0.9	2.89	0.368	1.80	31.2	71.8	13.1	98	4.18	6.67	0.9	17.3	120	5.06	1.4	14.9	1.13
KAZ03/05	4.27	0.32	3.3	2.57	8.5	0.9	0.99	0.510	1.54	22.7	60.4	nd	97	4.72	6.31	0.7	16.4	110	5.10	1.5	17.2	0.95
KAZ03/06	3.79	0.31	3.6	2.34	9.1	0.9	3.38	0.386	1.35	21.4	51.5	11.7	89	4.06	5.00	0.6	14.4	92	4.53	1.3	10.2	0.82
KAZ03/07	5.65	0.34	3.7	2.57	7.9	1.0	3.36	0.361	1.33	34.9	73.2	12.4	93	3.78	5.48	0.7	16.5	98	4.55	1.3	12.7	1.11
KAZ03/09	5.82	0.36	3.9	2.97	10	0.9	1.88	0.529	1.66	35.6	77.8	13.2	99	4.57	6.33	0.7	16.3	104	4.84	1.3	13.7	1.18
KAZ03/10	7.30	0.42	3.4	3.20	13	0.8	1.26	0.781	1.99	43.9	88.1	12.7	95	5.01	6.44	0.8	15.0	111	4.53	1.6	10.8	1.35

Table 4. NAA results from Kazaphani

Sample list

Kalavasos, Cyprus

Samples selected in Larnaca Museum, 24 February 2000, by Alison South.

1. M50B, 24.2, sherd probably from spindle bottle
2. M50B, 24.2, sherd from lentoid flask
3. M50B, 20.2, sherd from lentoid flask
4. Tomb 13, 5.1, sherd from spindle bottle
5. Tomb 14, 6.3, sherd from lentoid flask
6. Tomb 14, 6.3, sherd from lentoid flask
7. Tomb 14, 5.9, sherd from spindle bottle
8. Tomb 16, 4.1, sherd from spindle bottle
9. Tomb 11, sherds of brown 'Red Lustrous' imitation
10. Tomb 11, sherd of spindle bottle

Hala Sultan Tekke, Cyprus

Samples selected by Paul Åström. All datable to LH IIIA2 (?) (for contexts, see Åström et al. 1983).

1. RLWm sherd from well F1
2. RLWm sherd from well F1
3. RLWm sherd from well F1
4. RLWm sherd from well F1
5. RLWm sherd from well F1
6. RLWm sherd from well F2

Kouklia, Cyprus

Samples selected September 2000 by Carl Knappett, with Maier.

1. M.PIT 5.1, lower body of a large libation arm
2. KA 464.13A, spindle bottle (?)
3. KA 508.12A, spindle bottle (?), greyish core
4. KD 53.69, thick-walled, cylindrical, large libation arm, or spindle bottle
5. TE III 138, thin-walled, cylindrical, spindle bottle (stratified, early 12th century)
6. KA 637.4, thick-walled, cylindrical, spindle bottle (?)

Kazaphani (Ayios Andronikos), Cyprus

Samples selected Cyprus Museum, Nicosia, 26 September 2000 by Carl Knappett; all sherds are of lentoid flasks, from a small white cardboard box (tomb 2b, cat. no. 548).

1. body sherd of lentoid flask, red
2. body sherd of lentoid flask, pink-orange
3. body sherd of lentoid flask, pink-orange
4. body sherd of lentoid flask, red
5. body sherd of lentoid flask, quite orange and worn
6. body sherd of lentoid flask, red
7. body sherd of lentoid flask, red
8. thick-walled flask (?) body sherd, some white grits visible (semi-fine)
9. body sherd of lentoid flask, one-third complete, slightly orange, ripple burnish
10. body sherd of lentoid flask, one-quarter complete, but note it is NOT wheelmade, and is in a gritty pink-grey fabric. Fugitive red burnish. Distinctive ridge at mid body, and pushed-through handle. An imitation, not true RLWm.

Memphis-Saqqara, Egypt

Five samples provided by Janine Bourriau, 1999. Only samples 2–5 examined in thin section and NAA (samples 1–5 subjected to residue analysis).

1. sherd of canonical RLWm ware, fine, with visible residue
2. sherd from spindle bottle, fine RLWm ware, with flaky interior surface
3. sherd from spindle bottle, fine RLWm ware
4. sherd from spindle bottle, fine RLWm ware
5. sherd from spindle bottle, fine RLWm ware

Kilise Tepe, Turkey

Sixteen samples selected at Kilise Tepe 1996–1998 by Carl Knappett, with Nicholas Postgate.

No.	Chem	Unit	CK#	Description
S79	9997	4211	201	fine red, lustrous
S80		4211	4211(2)	very fine red lustrous, libation arm
S81		1428	1428	very fine red lustrous, libation arm?
S82	99101	5501	5501	very fine red lustrous
S83		5502	5502	very fine red lustrous, rim of open rounded bowl
S84	9987	4205	36	very fine red fabric, lustrous
S85	9994	4211	43	semi-fine version of S84, with red burnish to exterior
S86		4211	202	semi-fine red, from inturned rim bowl
S87		4205	203	semi-fine red
S88	9998	4211	204	semi-fine red
S89	9999	4211	205	semi-fine red, from jar with thickened rim
S90		4211	206	semi-coarse to coarse red
S91		4211	207	semi-coarse to coarse red
S92		4211	208	semi-coarse to coarse red, large thickened rim jar
S93	9988	4205	37	very coarse red, thick-walled with white grits (calcite?)
S94	9995	4211	44	very thick-walled semi-coarse red fabric, thick grey core

Boğazköy (Hattuša), Turkey

Forty two samples selected, July 2001 by Carl Knappett, with Jürgen Seeher.

1. quite thick-walled, large spindle bottle. Ripple torsion marks. Classic fine pink-red

2. quite thick-walled, large spindle bottle. No ripple marks, just horizontal rilling. Classic fine pink-red, a little brown
3. medium-walled, probable spindle bottle. Horizontal rilling marks. Classic fine red
4. medium-walled, probable spindle bottle. Some torsion marks. Classic fine red
5. thick-walled, cylindrical, probable spindle bottle. Some torsion marks. Fine lightish-brown, some inclusions
6. medium-walled, cylindrical, probable spindle bottle. Some torsion marks. Classic fine red
7. medium-walled, narrow and cylindrical; libation arm? Classic fine red, burnish a little brown
8. medium-walled, narrow and cylindrical; libation arm? medium-walled, narrow and cylindrical; libation arm? Very heavily overfired; dark grey, some hints of vitrification at interior. Not much burnish remaining
9. medium-walled, spindle bottle. Torsion marks. Classic fine pink-red
10. medium-thick-walled, cylindrical; spindle bottle. Fine orange-brown, not much burnish present
11. thin-medium-walled, cylindrical; small spindle bottle, or libation arm. Fine brown red
12. medium-walled, large vessel (type?). Fine red-brown
13. thick-walled, very large vessel (spindle bottle?). Horizontal rilling. Classic fine pink-red
14. medium-walled, very large vessel, cylindrical, spindle bottle. Torsion marks. Fine, rather brown-red
15. medium-walled, cylindrical, spindle bottle. Horizontal rilling. Fine brownish
16. thin-walled, little curvature (shape?). Horizontal rilling. Classic fine pink-red
17. medium-walled, cylindrical, spindle bottle. Torsion marks. Classic fine pink-red
18. medium-walled, cylindrical, spindle bottle. Horizontal rilling. Classic fine pink-red
19. thin-medium-walled, little curvature (shape?). Horizontal rilling. Fine pink-red, slightly brown
20. medium-walled, cylindrical, spindle bottle. Torsion marks. Fine pink-brown, a little grey
21. medium-thick-walled, large fragment with little curvature, very big spindle bottle. Horizontal rilling. Classic fine pink-red
22. medium-thin-walled, little curvature; spindle bottle? Horizontal rilling. Vertical burnishing. Fine brown-grey
23. medium-walled, little curvature; spindle bottle? Torsion marks. Classic fine pink-red, brownish ext, very good burnish
24. medium-walled, little curvature; spindle bottle? Slightly lighter pink-brown than usual, siltier too
25. thick-walled, very large vessel. Horizontal rilling. Fine pale-brown/pink (some inclusions visible), well burnished
26. medium-walled, cylindrical, spindle bottle. Horizontal rilling. Fine pale-brown/pink, well burnished
27. medium-walled, closed shape. Horizontal rilling. Poor burnish. Semi-fine to semi-coarse pink-brown, with white and brown grits
28. medium-walled, very large closed vessel. Horizontal rilling. Well burnished. Semi-fine pale-brown/pink (same colour as 25–26) with brown silt/sand inclusions
29. medium-walled, quite curved (upper body spindle bottle?). Horizontal rilling. Well burnished. Semi-fine pink (similar to above) with some silty inclusions
30. thin-walled, cylindrical, small spindle bottle. Torsion marks. Classic fine pink-red (softish)
31. medium-walled, large closed shape. Faint rilling marks. Burnished cream slip exterior (not RLWM). Semi-fine to semi-coarse gritty pinkish-red, quite hard-fired
32. medium-thick-walled, large closed shape. Rilling. Cream slip exterior, a little fugitive. Semi-coarse gritty/silty light brown (not RLWM), different to 31
33. medium-thick-walled, large closed shape. Rilling. Cream slip exterior, not burnished. Semi-coarse gritty/silty light-brown/pink (not RLWM), same as 32
34. medium-walled, large closed shape. Rilling. Burnished cream slip ext. Semi-fine to semi-coarse gritty pinkish-red (not RLWM), same as 31
35. thick-walled, large closed shape. Burnished red-brown self-slip. Semi-coarse gritty/silty brown-orange
36. medium-walled, large closed shape. Light brown-orange exterior (once burnished?). Semi-coarse gritty orange-brown, grey at interior core
37. medium-walled, large-closed shape. Pinkish-red burnished ext. Fabric also pinkish-red at exterior, but grey at interior, semi-fine to semi-coarse, small inclusions (silty)
38. medium-walled, large closed shape. Light brown-orange, smoothed or burnished exterior. Semi-coarse gritty brown-orange
39. medium-walled, large closed shape. Orange (pink?), very gritty/silty, rough texture, no surface treatment
40. medium-walled, large closed shape. Orange-pink, slipped (self) and smoothed red exterior (looks no

different to all the other 'local'). Semi-coarse silty/gritty

41. thick-walled, pedestal foot of very large spindle bottle. Semi-fine orange-pink, unlike normal RLWM. Smoothed exterior surfaces
42. very thick-walled, pedestal foot of very large spindle bottle. Semi-fine orange-pink, unlike normal RLWM, actually looks quite silty. Smoothed exterior surfaces.

Bibliography

Aitchinson, J. 1990: 'Relative variation diagrams for describing patterns of compositional variability' *Mathematical Geology* 22: 487–511

Alp, S. 1967: 'Die Libationsgefässe "Schnabelkanne" und "Armförmiges Gerät" und Ihre Hethitischen Bezeichnungen' *Belleten* 31: 531–49

Åström, P. 1969: 'A Red Lustrous Wheel-made spindle bottle and its contents' *Medelhavsmuseet Bulletin* 5: 16–21

— 1972: *The Late Cypriote Bronze Age. Architecture and Pottery.* Lund

Åström, P., et al. 1983: *Hala Sultan Tekke* 8. *Excavations 1971–1979.* Goteborg

Baker, H.D., Collon, D., Hawkins, J.D., Pollard, T., Postgate, J.N., Symington, D., Thomas, D. 1995: 'Kilise Tepe 1994' *Anatolian Studies* 45: 139–91

Bisset, N.G., Bruhn, J.G., Zenk, M.H. 1996: 'The presence of opium in a 3,500 year old Cypriote Base Ring juglet' *Agypten und Levante* 6: 203–04

Bisset, N.G., Bruhn, J.G., Curto, S., Holmstedt, B., Nyman, U., Zenk, M.H. 1994: 'Was opium known in 18th Dynasty ancient Egypt? An examination of materials from the tomb of the chief royal architect Kha' *Journal of Ethnopharmacology* 41: 99–114

Bittel, K. 1957: 'Armförmige Libationsgefässe' in K. Bittel et al., *Boğazköy III, Funde aus den Grabungen 1952–55.* Berlin: 33–42

Bourriau, J.D., Nicholson, P.T. 1992: 'Marl clay pottery fabrics of the New Kingdom' *Journal of Egyptian Archaeology* 78: 29–92

Bourriau, J.D., Smith, L.M.V., Nicholson, P.T. 2000: *New Kingdom Pottery Fabrics: Nile Clay and Mixed Nile/Marl Clay Fabrics from Memphis and Amarna* (Egypt Exploration Society, Occasional Paper 14). London

Bourriau, J.D., Nicholson, P.T., Rose, P.J. 2000: 'Pottery' in P.T. Nicholson, I. Shaw (eds), *Ancient Egyptian Materials and Technology.* Cambridge: 121–47

Bourriau, J.D., Smith, L.M.V., Serpico, M. 2001: 'The provenance of Canaanite amphorae found at Memphis and Amarna in the New Kingdom' in A. Shortland (ed.), *The Social Context of Technological Change: Egypt and the Near East 1650–1150 BC.* Oxford: 113–46

Bourriau, J.D., Bellido, A., Bryan, N., Robinson, V. (in press): 'Egyptian pottery fabrics: a comparison between NAA groupings and the "Vienna System"' in E. Czerny, I. Hein (eds), *Festschrift for Manfred Bietak.* Vienna

Brinkmann, R. 1976: *Geology of Turkey.* Amsterdam

Campbell, A.S. (ed.) 1971: *Geology and History of Turkey.* Tripoli

Charters, S., Evershed, R.P., Blinkhorn, P.W., et al. 1995: 'Evidence for the mixing of fats and waxes in archaeological ceramics' *Archaeometry* 37: 113–27

Connan, J., Deschesne, O. 1996: *La bitume a Suse.* Paris

Connan, J., Nissenbaum, A., Dessort, D. 1992: 'Molecular archaeology: export of Dead Sea asphalt to Canaan and Egypt in the Chalcolithic – Early Bronze Age (4th–3rd millennium BC)' *Geochimica et Cosmochimica Acta* 56: 2743–59

Courtois, J.-C. 1979: 'A propos des tuyaux rituals ou bras de libation en Anatolie et Chypre' in E. Masson (ed.), *Florilegium Anatolicum, Mélanges offerts à Emmanuel Laroche.* Paris: 85–95

Courtois, J.-C., Courtois, L. 1978: 'Corpus céramique de Ras Shamra-Ugarit, niveaux historiques d'Ugarit, Bronze Moyen et Bronze Récent, (deuxième partie)' in C.F.A. Schaeffer (ed.), *Ugaritica VII.* Leiden: 191–370

Courtois, J.-C., Lagarce, J., Lagarce, E. 1986: *Enkomi et le Bronze Récent à Chypre.* Nicosia

Courtois, L. 1971: *Déscription Physico-Chimique de la Céramique Ancienne: La Céramique de Chypre au Bronze Récent.* Unpublished thesis. University of Clermont

Demirtaşlı, E., Turkan, N., Bilgin, A., Selim, M. 1984: 'Geology of the Bolkar Mountains' in O. Tekeli, M.C. Göncüoğlu (eds), *Geology of the Taurus Belt. Proceedings of an International Symposium held in Ankara, Turkey, September 1983.* Ankara: 125–42

Drews, R. 1993. *The End of the Bronze Age. Changes in Warfare and the Catastrophe ca. 1200 B.C.* Princeton

Dudd, S.N., Regert, M., Evershed, R.P. 1998: 'Assessing microbial lipid contributions during laboratory degradations of fats and oils and pure triacylglycerols absorbed in ceramic potsherds' *Organic Geochemistry* 29(5–7): 1345–54

Dupré, S. 1983. *Porsuk I – La Céramique de l'Age du Bronze et de l'Age du Fer* (Editions Recherche sur les Civilisations, Memoire 20). Paris

Eriksson, K.O. 1991: 'Red Lustrous Wheelmade ware: a product of Late Bronze Age Cyprus' in J.A. Barlow, D.L. Bolger, B. Kling (eds), *Cypriot Ceramics: Reading the Prehistoric Record* (Philadelphia University Monograph 74). Philadelphia: 81–96

— 1993. *Red Lustrous Wheelmade Ware* (SIMA 103). Jonsered

Ertem, E., Demirci, Ş. 1999: 'Characteristics of Hittite pottery sherds from sites in the Kızılırmak basin' *Journal of Archaeological Science* 26: 1017–23

Evershed, R.P. 1990: 'Lipids from samples of skin from seven Dutch bog bodies: preliminary report' *Archaeometry* 32(2): 139–53

Evershed, R.P., Dudd, S.N., Charters, S., et al. 1999: 'Lipids as carriers of anthropogenic signals from prehistory' *Philosophical Transcripts of the Royal Society of London*, B, 354: 19–31

Evershed, R.P., Dudd, S.N., Lockheart, M.J., et al. 2001: 'Lipids in archaeology' in D.R. Brothwell, A.M. Pollard (eds), *Handbook of Archaeological Sciences*. Chichester: 331–49

Evershed, R.P., Dudd, S.N., Copley, M.S., et al. 2002: 'Chemistry of archaeological animal fats' *Accounts of Chemical Research* 35(8): 660–68

Evershed, R.P., Heron, C., Charters, S.L.J. 1991: 'The survival of food residues: new methods of analysis, interpretation and application' in A.M. Pollard (ed.), *New Developments in Archaeological Science – a Joint Symposium of the Royal Society and the British Academy*. Oxford: 187–208

Gjerstad, E. 1926: *Studies on Prehistoric Cyprus*. Uppsala

Goldman, H. 1956: *Excavations at Gözlü Kale, Tarsus*, II. Princeton

Haldane, C. 1993: 'Direct evidence for organic cargoes in the Late Bronze Age' *World Archaeology* 24(3): 348–60

Hansen, C.K., Postgate, J.N. 1999: 'The Bronze to Iron Age transition at Kilise Tepe' *Anatolian Studies* 49: 111–21

Hauptmann, R., Maddin, M., Prange, A. 2002: 'On the structure and composition of copper and tin ingots excavated from the shipwreck of Uluburun' *Bulletin of the American Schools of Oriental Research* 328: 1–30

Hein, A., Tsolakidou, A., Iliopoulos, I., Mommsen, H., Montana, G., Buxeda i Garrigós, J., Kilikoglou, V. 2002: 'Standardisation of elemental analytical techniques applied to provenance studies of archaeological ceramics: an inter-laboratory calibration study' *The Analyst* 127: 542–53

Heron, C., Nemcek, N., Bonfield, K.M., et al. 1994: 'The chemistry of Neolithic beeswax' *Naturwissenschaften* 81: 266–69

Jones, R.E. 1986: *Greek and Cypriot Pottery: A Review of Scientific Studies* (Fitch Laboratory Occasional Paper 1). Athens

Knapp, A.B. 1991: 'Spice, drugs, grain and grog: organic goods in Bronze Age east Mediterranean trade' in N.H. Gale (ed.), *Bronze Age Trade in the Mediterranean. Papers Presented at a Conference held at Rewley House, Oxford, December 1989* (SIMA 90). Jonsered: 21–68

— 1998: 'Mediterranean Bronze Age trade: distance, power and place' in E.H. Cline, D. Harris-Cline (eds), *The Aegean and the Orient in the Second Millennium*. Liège 193–207

Knapp, A.B., Cherry, J.F. 1994: *Provenience Studies and Bronze Age Cyprus: Production, Exchange and Politico-Economic Change* (Monographs in World Archaeology 21). Madison, Wisconsin

Knappett, C. 2000: 'The provenance of Red Lustrous Wheelmade ware: Cyprus, Syria, or Anatolia?' *Internet Archaeology* 9: http://intarch.ac.uk/journal/issue9/

— 2002: 'A Near Eastern Bronze Age conundrum: Red Lustrous Wheelmade Ware – made where?' *The Old Potter's Almanack* 10(2): 1–2

— (in press): 'Pottery fabrics and technology' in J.N. Postgate, D. Thomas (eds), *Kilise Tepe: Excavations 1994–98*. Cambridge

Koschel, K. 1996: 'Opium alkaloids in a Cypriot Base Ring I vessel (bilbil) of the Middle Bronze Age from Egypt' *Agypten und Levante* 6: 159–66

Kozal, E. 2003: 'Analysis of the distribution patterns of Red Lustrous Wheel-made ware, Mycenaean and Cypriot pottery in Anatolia in the 15th–13th centuries BC' in B. Fischer, H. Genz, E. Jean, K. Köroğlu (eds), *Identifying Changes: The Transition from Bronze to Iron Ages in Anatolia and its Neighbouring Regions, Proceedings of the International Workshop, Istanbul, November 8–9, 2002*. Istanbul: 65–77

Maier, F.G., Karageorghis, V. 1984: *Paphos. History and Archaeology*. Nicosia

Manning, S.W., Monks, S.J. 1998: 'Late Cypriot tombs at Maroni Tsaroukkas, Cyprus' *Journal of the British School at Athens* 93: 297–351

Mee, C. 1998: 'Anatolia and the Aegean in the Late Bronze Age' in E.H. Cline, D. Harris-Cline (eds), *The Aegean and the Orient in the Second Millennium*. Liège: 137–48

Mellink, M. 1986: 'The Early Bronze Age in west Anatolia: Aegean and Asiatic correlations' in G. Cadogan (ed.), *The End of the Early Bronze Age in the Aegean*. Leiden: 139–52

Merrillees, R.S. 1962: 'Opium trade in the Bronze Age Levant' *Antiquity* 36: 287–92

— 1963: 'Bronze Age spindle bottles from the Levant' *Opuscula Atheniensia* 4: 187–96

Mielke, D.P. (in press): 'Red Lustrous Wheelmade ware from Hittite contexts' in I. Hein, I. Kaplan (eds), *The Lustrous Wares of LB Cyprus and the Eastern Mediterranean. Proceedings of the SCIEM 2000 Conference, Wien, November 2004.* Vienna

Müller-Karpe, A. 1988: *Hethitische Töpferei der Oberstadt von Hattuša: ein Beitrag zur Kenntnis spät-grossreichszeitlicher Keramik und Töpfereibetreibe unter Zugrundelegung der Grabungsergebnisse 1979–82 in Boğazköy.* Marburg

Nicolaou, I., Nicolaou, K. 1989: *Kazaphani. A Middle/Late Cypriot Tomb at Kazaphani-Ayios Andronikos: T.2A, B.* Nicosia

Özgül, N. 1984: 'Stratigraphy and tectonic evolution of the Central Taurides' in O. Tekeli, M.C. Göncüoğlu (eds), *Geology of the Taurus Belt. Proceedings of an International Symposium held in Ankara, Turkey, September 1983.* Ankara: 77–90

Pantazis, T.M. 1967: *The Geology and Mineral Resources of the Pharmakas-Kalavasos Area.* Geological Survey Department, Cyprus, Memoir No. 8

— 1979: *Geological Map of Cyprus, 1:250,000.* Geological Survey Department, Cyprus

Parzinger, H., Sanz, R. 1992: *Die Oberstadt von Hattuša. Hethitische Keramik aus dem zentralen Tempelviertel. Funde aus den Grabungen 1982–1987* (Boğazköy-Hattuša XVI). Berlin

Pinar-Erdem, N., İlhan, E. 1977: 'Outlines of the stratigraphy and tectonics of Turkey, with notes on the geology of Cyprus' in A.E.M. Nairn, W.H. Kanes, F.G. Stehli (eds), *The Ocean Basins and Margins: Volume 4A, The Eastern Mediterranean.* London: 277–318

Postgate, J.N. 1998: 'Between the plateau and the sea: Kilise Tepe 1994–97' in R. Matthews (ed.), *Ancient Anatolia: 50 Years' Work by the British Institute of Archaeology at Ankara.* London: 127–41

Postgate, J.N., Thomas, D. (eds) (in press): *Kilise Tepe: Excavations 1994–98.* Cambridge

Regert, M., Colinart, S., Degrand, L., Decavallas, O. 2001: 'Chemical alteration and use of beeswax through time: accelerated ageing tests and analysis of archaeological samples from various environmental contexts' *Archaeometry* 43(4): 549–69

Rice, P.M. 1987: *Pottery Analysis: A Sourcebook.* Chicago

Schoop, U.-D. 2003: 'Pottery traditions of the later Hittite Empire: problems of definition' in B. Fischer, H. Genz, E. Jean, K. Köroğlu (eds), *Identifying Changes: The Transition from Bronze to Iron Ages in Anatolia and its Neighbouring Regions, Proceedings of the International Workshop, Istanbul, November 8–9, 2002.* Istanbul: 167–78

Seeher, J. 1999: *Hattusha – Guide: A Day in the Hittite Capital.* Istanbul

— 2001: 'Die Ausgrabungen in Boğazköy-Hattuša 2000' *Archäologischer Anzeiger*: 333–62

— 2002: 'Die Ausgrabungen in Boğazköy-Hattuša 2001' *Archäologischer Anzeiger*: 59–78

Sherratt, S. 1999: '*E pur si muove*: pots, markets and values in the second millennium Mediterranean' in J.P. Crielaard, V. Stissi, G.J. van Wijngaarden (eds), *The Complex Past of Pottery: Production, Circulation and Consumption of Mycenaean and Greek Pottery.* Amsterdam: 163–211

— 2001: 'Potemkin palaces and route-based economies' in J. Killen, S. Voutsaki (eds), *Economy and Politics in the Mycenaean Palace States* (Cambridge Philological Society, Supplementary Volume 27). Cambridge: 214–38

Sherratt, A.G., Sherratt, E.S. 1991: 'From luxuries to commodities: the nature of Mediterranean Bronze Age trade' in N.H. Gale (ed.), *Bronze Age Trade in the Mediterranean. Papers Presented at a Conference held at Rewley House, Oxford, December 1989* (SIMA 90). Jonsered: 351–86

— 1998: 'Small worlds: interaction and identity in the ancient Mediterranean' in E.H. Cline, D. Harris-Cline (eds), *The Aegean and the Orient in the Second Millennium. Proceedings of the 50th Anniversary Symposium. Cincinnati, 18–20 April 1997.* Liège: 329–43

Sherriff, B.L., Tisdale, M.A., Sayer, B.G., et al. 1995: 'Nuclear magnetic resonance spectroscopic and isotopic analysis of carbonized residues from sub-Arctic Canadian prehistoric pottery' *Archaeometry* 37(1): 95–111

Sjöqvist, E. 1940: *Problems of the Late Cypriot Bronze Age.* Stockholm

South, A.K. 1997: 'Kalavasos-Ayios Dhimitrios 1992–1996' *Report of the Department of Antiquities, Cyprus*: 151–75

South, A.K., et al. 1989: *Vasilikos Valley Project 3: Kalavasos-Ayios Dhimitrios II* (SIMA 71:3). Goteborg

— (forthcoming): *Kalavasos-Ayios Dhimitrios III. Tombs 9, 11–21*

Steel, L. 1998: 'The social impact of Mycenaean imported pottery in Cyprus' *Journal of the British School at Athens* 93: 285–96

Stern, B., Heron, C., Serpico, M., et al. 2000: 'A comparison of methods for establishing fatty acid concentration gradients across potsherds: a case study using Late Bronze Age Canaanite amphorae' *Archaeometry* 42(2): 399–414

Symington, D. 2001: 'Hittites at Kilise Tepe' in E. Jean, A.M. Dinçol, S. Durugönül (eds), *La Cilicie: Espaces et Pouvoirs Locaux (2e millénaire av. J.-C. – 4e siècle ap. J.-C.), Actes de le Table Ronde Internationale d'Istanbul.* Paris: 167–84

Todd, I.A. 2001: 'Early connections of Cyprus with Anatolia' in V. Karageorghis (ed.), *The White Slip Ware of Late Bronze Age Cyprus.* Vienna: 27–43

Todd, I.A., Pilides, D. 2001: 'The archaeology of White Slip production' in V. Karageorghis (ed.), *The White Slip Ware of Late Bronze Age Cyprus.* Vienna: 203–13

Turkey, Geological Map of, 1950–1965, scale 1:500,000, 18 sheets. Bull. Min. Res. Explor. Inst. Turk. Turkiye Jeolojik Haritasi

Vaughan, S.J. 1987: *A Fabric Analysis of Late Cypriot Base Ring Ware: Studies in Ceramic Technology, Petrology, Geochemistry, and Mineralogy.* Unpublished PhD thesis. University College London

— 1991: 'Late Cypriot Base Ring ware: studies in raw materials and technology' in A. Middleton, I. Freestone (eds), *Recent Developments in Ceramic Petrology* (British Museum Occasional Papers 81). London: 337–68

Whitbread, I.K. 1995: *Greek Transport Amphorae: A Petrological and Archaeological Study* (Fitch Laboratory Occasional Papers 4). Athens

Yalçin, M.N., Görür, N. 1984: 'Sedimentological evolution of the Adana basin' in O. Tekeli, M.C. Göncüoğlu (eds.), *Geology of the Taurus Belt. Proceedings of an International Symposium held in Ankara, Turkey, September 1983.* Ankara: 165–72

Yannai, E., Gorzalczany, A., Peilstöcker, M. 2003: 'A group of vessels from the Syrian coast found in the coastal plain of Israel' *Levant* 35: 101–16