hesperia 80 (2011)
Pages 511–558

A World of Goods

Transport Jars and Commodity Exchange at the Late Bronze Age Harbor of Kommos, Crete

ABSTRACT

The harbor site of Kommos, Crete, has yielded rich evidence for long-distance exchange in the form of ceramic transport jars of types used not only for distribution within Crete and the Aegean, but also across the eastern Mediterranean. An integrated petrographic and chemical approach is here employed in order to determine the provenance of short-necked amphoras, transport stirrup jars, Egyptian jars, and Canaanite jars. The results reveal a detailed picture of local jar production within southern Crete, as well as jars that have their origins in the Nile Delta and at several specific locations along the Levantine coast.

TRANSPORT JARS AT KOMMOS

Situated on the coast of the large, fertile plain of the Mesara, the Minoan harbor town of Kommos (Fig. 1) has yielded more evidence for intercultural exchange in the form of imported ceramics than any other Bronze Age site in the Aegean.[1] The unusual range and quantity of foreign pottery recovered at Kommos were initially recognized and documented by Vance Watrous.[2] These studies have been cited repeatedly in subsequent synthetic overviews of Bronze Age trade in the eastern Mediterranean,[3] and have been extended and fine-tuned by Jeremy Rutter in the light of the most recent excavations at the site during the 1990s.[4]

A substantial portion of the ceramic imports in question are containers designed to ship commodities in bulk, often referred to as transport

1. Kommos has been excavated over 15 summers (1976–1985, 1991–1995) by a team directed by J. W. and M. C. Shaw of the University of Toronto, under a permit issued to the American School of Classical Studies at Athens. For permission to sample transport jars from the site, we are grateful to the Directorate of Conservation and the 23rd Ephorate of Classical and Prehistoric Antiquities in Herakleion. Funding for this study was generously provided by the Institute of Aegean Prehistory. The results of the study have been previously presented in two conference papers (Day, Kilikoglou, and Rutter 2004; Day et al. 2006). All dates are b.c.

2. Watrous 1985, 1989; *Kommos* III; Watrous, Day, and Jones 1998.

3. E.g., Knapp and Cherry 1994; Cline 1994.

4. Rutter 1999, 2006b, 2006c.

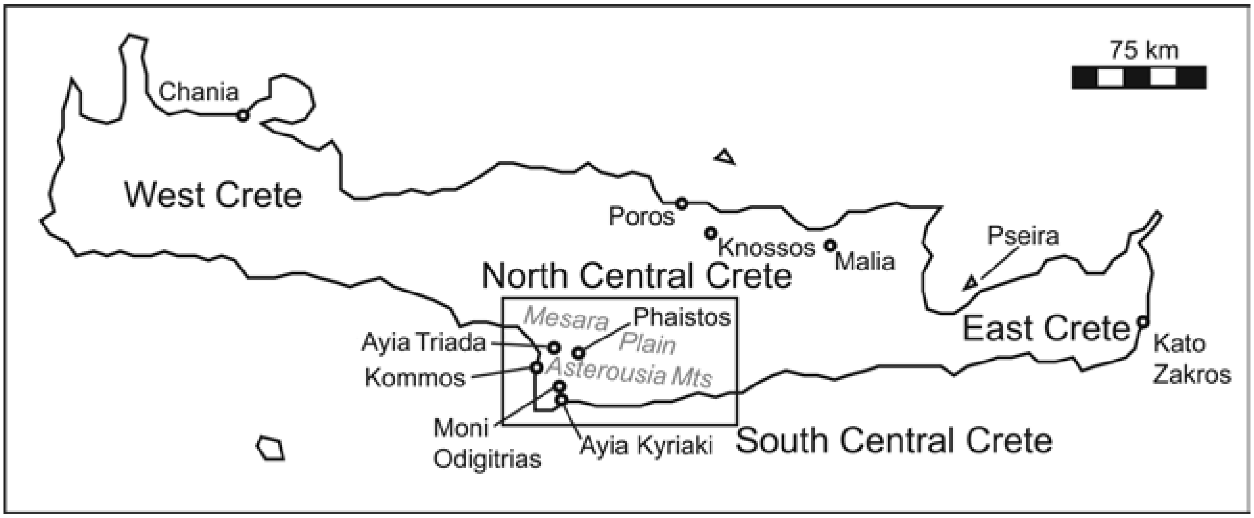


Figure 1. Map of Crete showing the locations of Kommos and other archaeological sites. P. S. Quinn

vessels; there are also analogous Minoan vessels that seem to represent containers for outgoing exchange. When they occur in the archaeological record of the Graeco-Roman era, such transport vessels in the central and eastern Mediterranean are almost invariably described as "amphoras," closed shapes with two vertical handles on the shoulder or linking the shoulder with the neck or rim. In the Middle and Late Bronze Age, however, the forms taken by such transport vessels tend to be characteristic of particular regions within a larger zone that witnessed increasingly intense intercultural exchanges between ca. 1750 and 1200.[5] Within the southern Aegean, the most common form in the Late Bronze Age is a large version of the false-necked amphora or stirrup jar, conventionally termed the transport stirrup jar (Fig. 2).[6] The form preferred along the Syro-Palestinian coast and widely exported to, as well as imitated in, both Cyprus and Lower Egypt is a shoulder-handled vessel often referred to as the Canaanite jar or amphora (Fig. 2).[7] Differences in fabric and surface treatment make possible the recognition of amphoras of several subvarieties produced in Egypt, some closely comparable in shape to the Canaanite jar (Fig. 2).[8] Finally, at Kommos itself, around the end of the first quarter of the 14th century, a distinctive variant of the traditional Minoan oval-mouthed amphora made its appearance, featuring a round mouth, a comparatively low neck, and two almost cylindrical handles attached at the shoulder and rim. Christened the short-necked amphora (Fig. 2),[9] this form was soon being mass-produced, to judge from the thousands of fragments recovered from 14th- and 13th-century contexts at the site.[10]

5. For recent discussions of the absolute chronology of the Aegean Late Bronze Age, see Shelmerdine 2008, pp. 3–7; Manning and Bruce 2009, pp. 275–332 (including contributions by M. H. Wiener, W. L. Friedrich et al., and S. W. Manning et al.); Wild et al. 2010. For recent discussions of later Minoan Palatial and Postpalatial terminology in terms of ceramic chronology, see Hatzaki 2007a, 2007b; Langohr 2009, pp. 11–14, 181–233.

6. For transport stirrup jars, see Haskell et al. 2011; also Haskell 1981a, 1981b, 1984, 2005; Day and Haskell 1995; Day 1999.

7. Smith, Bourriau, and Serpico 2000; Bourriau, Smith, and Serpico 2001; Cohen-Weinberger and Goren 2004.

8. Aston 1998.

9. *Kommos* III, pp. 135, 144.

10. Rutter 2000.

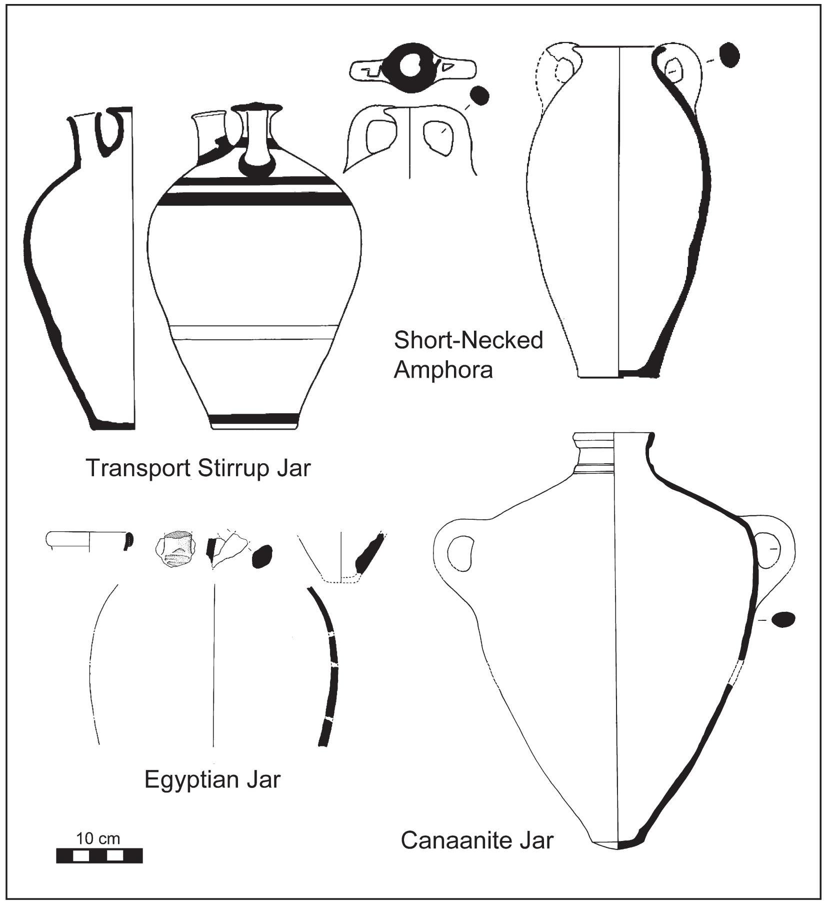


Figure 2. Late Minoan transport jars from Kommos

Clearly, these ceramic vessels have much to tell us about maritime trade and exchange, as well as about the production and distribution of value-added commodities from Crete. Lying as it does in a region of prime agricultural land and at a strategic position for the movement of goods through the Mediterranean, Kommos offers the possibility of investigating the relations between Crete and the wider Bronze Age world in a number of distinct but interrelated ways. It was against this background that the authors of this article undertook a program of thin-section petrography and instrumental neutron activation analysis (INAA) focused on the four groups of transport vessels described above. A total of 88 samples were selected, including 18 transport stirrup jars (TSJs), 13 short-necked amphoras (SNAs), 34 Canaanite jars (CJs), and 19 Egyptian jars (EJs) (Table 1).[11]

11. Rutter had not always correctly identified the sherds and larger vessel fragments selected for sampling in 1998 on the basis of their morphological features and macroscopic examination of their fabrics. Thus three of the supposed SNAs were actually examples of earlier amphora types, in all cases probably locally produced (samples 98/18, 23, and 26 = C7989, C11093, and C11195, respectively). One of the CJs (sample 98/66 = C9100) was identified by visiting authorities on Egyptian ceramics as an Egyptian import. Of four mistakenly identified EJs, three were reclassified as CJs (samples 98/38, 46, and 51 = C10723, C8726, and C7070, respectively) and one as a nonlocal but probably Cretan import (sample 98/53 = C6949). The revised totals are those given in the text. For the identifications Rutter is extremely grateful to D. Aston and B. Bader of the SCIEM Project, Austrian Academy of Sciences; P. Rose of the Tell el-Amarna excavations; and M. Serpico of the Cambridge Amphora Project.

TABLE 1. LATE MINOAN TRANSPORT JAR SAMPLES FROM KOMMOS

Sample No.	*Inv. No.*	*Type*[1]	*Date*
Kommos 98/1	C2849	TSJ	LM IIIB
Kommos 98/2	C2893	TSJ	LM IIIB
Kommos 98/3	C3318	TSJ	LM II
Kommos 98/4	C2470	TSJ	LM IIIB
Kommos 98/5	C6355	TSJ	LM IIIB
Kommos 98/6	C11077	TSJ	LM IA Final
Kommos 98/7	C7874	TSJ	LM IIIB
Kommos 98/8	C4940	TSJ	LM IIIA1
Kommos 98/9	C9273	TSJ	LM IIIB
Kommos 98/10	C11241	TSJ	LM IIIB
Kommos 98/11	C11179	TSJ	LM II
Kommos 98/12	C10976	TSJ	LM IIIA2
Kommos 98/13	C10258	TSJ	LM II
Kommos 98/14	C9063	SNA	LM IIIA2
Kommos 98/15	C285	SNA	LM IIIB
Kommos 98/16	C9276	SNA	LM IIIB
Kommos 98/17	C9386	SNA	LM IIIB
Kommos 98/18	C7989	SNA[2]	LM IIIA2 Early
Kommos 98/19	C9836	SNA	LM IIIB
Kommos 98/20	C9662	SNA	LM IIIB
Kommos 98/21	C10219	SNA	LM IIIB
Kommos 98/22	C10348	SNA	LM IIIB
Kommos 98/23	C11093	SNA[2]	LM IIIA2
Kommos 98/24	C11152	SNA	LM IIIA2
Kommos 98/25	C11194	SNA	LM IIIA2
Kommos 98/26	C11195	SNA[2]	LM IIIA2
Kommos 98/27	C11231	SNA	LM IIIA2
Kommos 98/28	C5582	TSJ	LM II
Kommos 98/29	C7986	TSJ	LM IIIA2 Early
Kommos 98/30	C7819	TSJ	LM IIIB
Kommos 98/31	C7987	TSJ	LM IIIA2 Early
Kommos 98/32	C7981	TSJ	LM IIIA2 Early
Kommos 98/33	C10765	EJ	LM II
Kommos 98/34	C10655	EJ	LM IIIB
Kommos 98/35	C10218	EJ	LM IIIA2
Kommos 98/36	C7476	EJ	LM IIIA2 Early
Kommos 98/37	C9837	EJ	LM IIIA
Kommos 98/38	C10723	EJ[3]	LM II
Kommos 98/39	C9504	EJ	LM IIIA2
Kommos 98/40	C9489	EJ	LM IIIA2
Kommos 98/41	C8837	EJ	LM IB
Kommos 98/42	C8336	EJ	LM IIIB
Kommos 98/43	C9625	EJ	LM IIIA2 Early
Kommos 98/44	C8006	EJ	LM IIIA1
Kommos 98/45	C6392	EJ	LM IIIB
Kommos 98/46	C8726	EJ[3]	LM IIIA2 Early
Kommos 98/47	C7448	EJ	LM IIIA2
Kommos 98/48	C4574	EJ	LM IIIA
Kommos 98/49	C3559	EJ	LM II

TABLE 1—*Continued*

Sample No.	*Inv. No.*	*Type*[1]	*Date*
Kommos 98/50	C7072	EJ	LM IIIA2 Early
Kommos 98/51	C7070	EJ[3]	LM IIIA2 Early
Kommos 98/52	C3350	EJ	LM IIIA2
Kommos 98/53	C6949	EJ[4]	LM IIIB
Kommos 98/54	C2763	EJ	LM IB Early
Kommos 98/55	C8069	CJ	LM IIIA2 Early
Kommos 98/56	C9167	CJ	LM IIIA2
Kommos 98/57	C6840	CJ	historic levels
Kommos 98/58	C11232	CJ	LM IIIA2
Kommos 98/59	C11141	CJ	LM IIIB
Kommos 98/60	C10362	CJ	LM IIIB
Kommos 98/61	C10360	CJ	LM IIIB
Kommos 98/62	C9865	CJ	LM IIIA
Kommos 98/63	C9624	CJ	LM IIIA2 Early
Kommos 98/64	C10656	CJ	LM IIIA2 Early
Kommos 98/65	C9398	CJ	LM IIIB
Kommos 98/66	C9100	CJ[5]	LM IIIA2
Kommos 98/67	C9941	CJ	LM IIIB
Kommos 98/68	C8730	CJ	LM IIIA2
Kommos 98/69	C8058	CJ	LM IIIA2 Early
Kommos 98/70	C8053	CJ	LM IIIA2 Early
Kommos 98/71	C8728	CJ	LM IIIA2
Kommos 98/72	C8244	CJ	LM IIIA2
Kommos 98/73	C5140	CJ	LM IIIB
Kommos 98/74	C6839	CJ	LM IIIB
Kommos 98/75	C3351	CJ	LM IIIA2
Kommos 98/76	C7440	CJ	LM IIIA2 Early
Kommos 98/77	C8729	CJ	LM IIIA2 Early
Kommos 98/78	C8216	CJ	LM IIIA2 Early
Kommos 98/79	C7115	CJ	LM IIIA2 Early
Kommos 98/80	C8144	CJ	LM IIIA2 Early
Kommos 98/81	C6990	CJ	LM IIIA2 Early
Kommos 98/82	C7074	CJ	LM IIIA2 Early
Kommos 98/83	C7638	CJ	LM IIIA2 Early
Kommos 98/84	C7336	CJ	LM IIIA2 Early
Kommos 98/85	C7428	CJ	LM IIIA2 Early
Kommos 98/86	I47*A	CJ	LM IIIA2 Early
Kommos 98/87	C11086	SNA	LM IIIB
Kommos 98/88	C11197	SNA	LM IIIB

[1] CJ = Canaanite jar; EJ = Egyptian jar; TSJ = transport stirrup jar; SNA = short-necked amphora.

[2] Subsequently reclassified as an earlier amphora type (see n. 11, above).

[3] Subsequently reclassified as a CJ (see n. 11, above).

[4] Subsequently reclassified as a probable Cretan import (see n. 11, above).

[5] Subsequently reclassified as an Egyptian import (see n. 11, above).

RESEARCH QUESTIONS AND AIMS

The Kommos Transport Jar Project was focused on a specific functional class, the transport vessel, and included not only specimens strongly suspected of having been locally manufactured (the SNAs and some TSJs), but also those that were related either functionally (CJs and EJs) or formally (some TSJs), but were clearly not local products. The specific questions to which we hoped to find answers varied according to the formal category of the vessels. In characterizing the ceramics by both chemical and petrographic means, we hoped to be able to group the jars compositionally and, where possible, to suggest their provenance. By establishing the origins of the vessels we hoped to identify patterns in the production of the Cretan vessel types and in the movement of ceramic vessels and their contents around the eastern Mediterranean. Since the project as a whole was directly inspired by the discovery at Kommos of SNAs in such great quantities as to suggest that the form played an important role in the local economy, we begin with this class of amphora.

Short-Necked Amphora

The discovery of thousands of fragments of these vessels in the ruins of the monumental Late Minoan (LM) IIIA2–B Building P at Kommos, which was plausibly identified on architectural grounds as a facility for the storage and maintenance of ships during seasons considered unsuitable for sailing,[12] suggested that the structure might also have served as a warehouse in which to stockpile SNAs. The vessels would then have been used as containers to ship one or more local products in bulk to consumers outside of Crete, if not indeed outside of the Aegean. Analysis of the distinctive form and chronology of the SNA had suggested that it should be viewed as a variant of the long-lived oval-mouthed amphora of the Mesara, expressly designed to advertise the newly recovered independence of the region following centuries of Knossian domination.[13] The SNA initially drew some inspiration from its chief competitors for recognition as the optimally designed transport vessel within the eastern Mediterranean: thus the earliest SNAs imitated the angular shoulder of the Syro-Palestinian CJ and the decoration of the body with broad horizontal wavy bands typical of the Central Cretan TSJ.[14] By the 13th century, the SNA had developed into a round-shouldered, plain shape (Fig. 2) produced in enormous quantities within narrowly prescribed limits of size and shape.

This reconstruction of the SNA's history and its potential political and economic significance, however, is based entirely on the evidence from the single site of Kommos. No examples of this shape have been found in contemporary strata at the nearby sites of Ayia Triada and Phaistos, even though Kommos is universally believed to have functioned as the chief harbor for one or the other of these Minoan political centers throughout most of the Middle and Late Bronze Age, rather than as an independent political entity. In fact, aside from a single example published by Evans from Knossos,[15] no example of a SNA has been identified to date at any

12. M. Shaw 1985; J. Shaw 2006a, pp. 70–85; 2006b, pp. 850–853.
13. Rutter 2000.
14. Haskell 2005, pp. 208–209.
15. *PM* II, pp. 627–629, fig. 392:3.

other Minoan site. Moreover, although Kommos may well have shipped hundreds or thousands of SNAs with their contents to one or more sites overseas, the fact remains that, as of 2008, no example of this distinctive ceramic form had yet been published from any Aegean or eastern Mediterranean site known to the authors.

Against this backdrop, there was a good deal to be learned about the SNA from a program of petrographic and neutron activation analyses. In how many distinct fabrics was the form produced? Were all these fabrics "local"—that is, was the vessel manufactured somewhere in the western Mesara in the immediate neighborhood of Kommos itself? Was there any evidence of a shift in the preferred clay recipe for SNAs over time, as there demonstrably was in their decoration and aspects of their shape? Of the 13 SNAs eventually sampled, four date from the LM IIIA2 period and nine probably from LM IIIB (Table 1). The number of samples is not large, in view of the thousands of examples that could have been selected for analysis, but we agreed that such a sample should at least allow several of the most basic questions to be addressed. Moreover, the results of the analyses of these samples should provide some indication of how future programs of analysis involving this particular shape might most usefully be structured.

Transport Stirrup Jar

In contrast to SNAs, TSJs have been recovered in substantial numbers at both coastal and inland sites on the Greek mainland and on Crete, as well as throughout the Aegean islands and along the western Anatolian coast, especially in contexts spanning the 15th to 13th centuries. They constitute an impressive percentage of the transport vessels recovered from three well-known shipwrecks of this period located within the Aegean (Cape Iria) or just outside it along the southern Turkish coast (Cape Gelidonya and Uluburun), and they have also been found in smaller quantities at coastal locales in Cyprus and the Levant, as well as at Tell el-Amarna, a good distance up the Nile in Egypt.[16] Although this shape was clearly manufactured at a number of different sites across the southern Aegean, a majority of the examples that have so far been subjected to petrographic and trace-element analyses have proved to be Cretan products.[17] Previous analyses (discussed below) have distinguished between TSJs made in the neighborhood of Chania in West Crete, those produced in Central Crete, sometimes specifically in the Mesara Plain, and those manufactured at one or more centers in East Crete.

The TSJs chosen for analysis in the present project come from well-dated contexts ranging from Neopalatial times through the Monopalatial era of LM II–IIIA1 to the 13th century (LM IIIB, variously termed Postpalatial, Final Palatial, or developed Third Palace period) (Table 1). The aim was to learn how homogeneous or heterogeneous the sources of the TSJs used at Kommos might have been over time, especially during the period when SNAs appear to have been the preferred local transport vessel (i.e., ca. 1375/1350–1200). The number of samples was modest, but this particular category of transport vessel, as noted above, had already been

16. Iria: Lolos 1999; Uluburun: Rutter 2005. For the Levant and other Mediterranean sites outside the Aegean, see Leonard 1994, pp. 45–47; Ben-Shlomo, Nodarou, and Rutter 2011, pp. 335–337; Haskell et al. 2011, pp. 125–131.

17. Haskell 2005; Haskell et al. 2011.

subjected to a large number of petrographic and chemical analyses, so a far larger comparative database existed for this group than for the SNAs.[18] Equally, it was suspected that, while the SNA was a specifically local, south-central Cretan phenomenon, many of the TSJs would prove to have been manufactured in the northern part of Central Crete.

Canaanite Jar

During the developed Late Bronze Age, the shoulder-handled transport vessels known as CJs were the favored transport vessels throughout the Levant, including Cyprus and the Nile Delta, playing much the same role in the easternmost Mediterranean as that played by the TSJ within the Aegean. Just as the TSJ was produced at a number of centers throughout its zone of principal use, so too was the CJ manufactured throughout the Levant, from the Nile Delta to Cilicia, as well as imitated on Cyprus. Visual inspection of the more than 60 highly fragmentary to fully restorable examples of this form recovered at Kommos revealed a number of distinct fabrics, but how many different centers or regions of production these represented and how they were distributed over the 300 years of their use was unknown.

It is worth noting that CJs also occur at Chania during the LM III period, and are found in earlier contexts at a number of sites, such as Poros-Katsambas, Kato Zakros, and Pseira.[19] Previous studies have examined the production, exchange, and use of the CJ in the Near East and Egypt.[20] Its use as a container for resins and oil seems clear, but some vessels may also have contained wine.[21]

With these issues in mind, 32 CJs from Kommos were sampled for analysis in 1998 (Table 1). Subsequently, in 2002 and 2003, examination of the ceramic imports to Kommos by archaeologists with particular expertise in the study of Egyptian and Syro-Palestinian pottery resulted in a modest expansion of this sample from 32 to 34.[22]

Egyptian Jar

Well over a decade after the initial publication by Watrous of the remarkable range of foreign ceramic imports to Kommos, this south Cretan harbor remains the only site in the Aegean where Late Bronze Age pottery from Egypt has been found. The Egyptian pottery is, almost without exception, undecorated.[23] Aside from two recently recognized sherds of red-slipped carinated bowls produced in Nile silt fabrics, all the fragments belong to closed shapes that appear to have been manufactured from marl clays; most

18. See Day and Jones 1991 (Malia); Day and Haskell 1995 (Thebes); Day 1995a (Mycenae); Day 1999 (Iria); Rutter 2005 (Uluburun); Day and Joyner 2006 (Cannatello, Italy). See also Haskell et al. 2011, which includes petrographic analysis of 195 thin sections of TSJs from a variety of sites in the Aegean and eastern Mediterranean, along with chemical analysis of 350.

19. For Chania, see, e.g., Stampolidis, Karetsou, and Kanta 1998, pp. 57–58, nos. 4, 5. For other references, see Rutter 1999, p. 153, n. 34, and forthcoming.

20. Recent studies include Sugerman 2000; Smith, Bourriau, and Serpico 2000; Bourriau, Smith, and Serpico 2001; Smith et al. 2004; Cohen-Weinberger and Goren 2004.

21. Resins and oils: Serpico 1996, 2000; Bourriau, Smith, and Serpico 2001; Serpico et al. 2003. Wine: Leonard 1996.

22. See n. 11, above; Rutter 2006b, p. 712, nn. 215–216, 218.

23. A single flask fragment (C7550, from House X) is decorated with painted concentric circles.

are amphoras, but there are also several flasks and a pair of necked jars.[24] Bourriau and her coworkers have published typologically similar vessels from Egypt.[25] These jars have been linked primarily with the transportation of wine, mainly on the basis of their hieratic inscriptions.[26] The association of the EJ with the elite-controlled production and exchange of an alcoholic drink makes their appearance on Crete very significant.

Essentially the same questions asked of the CJs were also asked of the Egyptian imports, although the latter exhibited far less variability of fabric at a macroscopic scale. Since the total number of Egyptian imports to Kommos was appreciably smaller, but at the same time represented a broader range of shapes within what appeared to be a single fabric, we decided to include samples from shapes other than amphoras, so that we could determine whether any significant petrographic or chemical differences could be detected among the distinct Egyptian closed shapes represented at the site (Table 1).[27]

Project Aims

Overall, then, the present analysis of transport jars from Kommos was concerned mainly with the determination of ceramic provenance, with the aim of contributing to a better understanding of the nature of contact and trade relations between the Minoan world and other Mediterranean centers in the Late Bronze Age. Specific goals included the separation of imported vessels from those produced on Crete, and the identification of compositional groups of common origin within both the local and imported groups of ceramics. By comparing the Cretan groups with our database of Minoan ceramics and Cretan geology, we hoped to locate their places of manufacture on the island. Where possible, we also identified comparative material for the nonlocal ceramics, drawing on studies conducted elsewhere in the Aegean, the Near East, and Egypt.

With these aims in mind, we decided that a combination of thin-section petrography and INAA was most appropriate for the project. The 88 coarse-ware transport jar samples are well suited to thin-section petrographic analysis, a technique that has proven very successful for the determination of provenance in coarse wares from Crete and the Aegean, as well as elsewhere in the Mediterranean.[28] INAA has also been applied widely in provenance studies in the Aegean, the Near East, and Egypt.[29] As a result, large databases of comparative INAA data exist for these areas, covering a wide range of elements, including many trace elements. Both analytical techniques have been used previously to characterize production of pottery at Kommos during the LM IA period.[30]

24. Flasks C10655 and C8006 were sampled as 98/34 and 98/44. The necked jars C9489 and C6392 (Rutter 2006a, p. 534, no. 57f/2, pl. 3.65, and p. 548, no. 61/7, pl. 3.73) were sampled as 98/40 and 98/45.

25. Bourriau, Smith, and Nicholson 2000; Bourriau 2004.

26. Bourriau 2004, p. 78; McGovern 1997; 2003, pp. 120–134, esp. fig. 6.4.

27. As with the CJs, a number of the 22 sampled Egyptian pieces turned out to have been inaccurately identified, so that the actual number of Egyptian samples was ultimately 19. See n. 11, above.

28. For Crete and the Aegean, see, e.g., Riley 1983; Wilson and Day 1994; Whitelaw et al. 1997; Tomkins, Day, and Kilikoglou 2004.

29. Studies of Aegean material include Jones 1986; Kilikoglou et al. 2007; Mommsen and Sjöberg 2007; Newton et al. 2007.

30. Buxeda i Garrigós, Kilikoglou, and Day 2001; Shaw et al. 2001, pp. 111–133, 139–155.

PREVIOUS ANALYSES AND COMPARATIVE MATERIAL

A number of previous petrographic and chemical analyses are relevant to our study of the Kommos transport jars. The analysis of prehistoric TSJs, especially those inscribed with Linear B, has been central to the field of Aegean ceramic analysis, and indeed has often been considered a test case for the effectiveness of analytical techniques. A series of papers published by the University of Oxford and the Fitch Laboratory of the British School at Athens from the 1960s to the 1980s created much interest and is summarized in an important review by Jones.[31] This chemical work was supplemented by INAA conducted by the Manchester group in the early 1990s.[32] Subsequent analyses, building on Riley's pioneering petrographic study,[33] have added detail to the picture of provenance by examining TSJs found on both Crete and the Greek mainland. A major program of analysis that includes large numbers of inscribed and uninscribed TSJs found over a wide area from Italy to Cyprus confirms that these jars had a number of different sources.[34] Most of the "canonical" coarse-ware stirrup jars have an origin in West, Central, or East Crete. Although much attention had been directed toward north-central Crete and Knossos as a likely source, it appears that at least some of these Central Cretan ceramics were manufactured in the south of the island.

Ceramics from the site of Kommos itself have been relatively well studied in such analyses. Myer and Betancourt characterized the products of the western Mesara at Kommos using thin-section petrography.[35] Imported pottery has also received attention.[36] The discovery of a Neopalatial kiln at Kommos led to a detailed set of analyses that aimed to establish a reference group for the site.[37] INAA has also been conducted on a limited set of ceramics from Kommos by Hancock and Betancourt.[38] The wider area of the Mesara and the foothills of the Asterousia Mountains to the south are also generally well covered by ceramic analyses of Bronze Age material.[39]

There are several petrographic studies of New Kingdom transport jars from Egypt, which are related typologically to the Late Minoan EJ samples found at Kommos.[40] INAA has been the dominant chemical technique applied to Egyptian pottery, and the results have been presented in a number of publications.[41] McGovern has suggested that amphoras belonging to the Marl D group have an origin in the vicinity of Thebes, on the basis of comparisons with both natural clays and a control group of samples of

31. Jones 1986, pp. 477–493.
32. Tomlinson 1995, 1996.
33. Riley 1981.
34. Haskell et al. 2011.
35. Myer and Betancourt 1990.
36. Watrous, Day, and Jones 1998.
37. Shaw et al. 1997, 2001; Buxeda i Garrigós, Kilikoglou, and Day 2001. For the products from another roughly contemporary kiln at a nearby site, see Belfiore et al. 2007.
38. Hancock and Betancourt 1987; Tomlinson, Rutter, and Hoffmann 2010.
39. We have an extensive collection of data for most major Bronze Age sites on the island. In Central and East Crete, coverage is most complete for the Early Bronze Age, but we also have substantial comparative datasets for the Late Bronze Age. Our datasets for the site of Knossos are especially detailed for both periods. In West Crete we have nearly complete coverage for the Early Bronze Age, with some Late Bronze Age material from Chania.
40. Nicholson and Rose 1985; Bourriau and Nicholson 1992; Bourriau, Smith, and Nicholson 2000.
41. For INAA of Egyptian jars, see Allen et al. 1982; Allen and Hamroush 1984; Hancock, Millet, and Mills 1986; Redmount and Morgenstein 1996; McGovern 1997, 2000.

supposed Theban origin.[42] The validity of this group has been challenged, however, as it appears that some samples have been assumed rather than demonstrated to be local Theban products. Bourriau and her colleagues have analyzed samples of the Marl D group by INAA and petrography and suggested that they were made in the Memphis region, close to the Delta and Faiyum vineyards, from Nile clays, or a mix of Nile and marl clays.[43]

Several petrographic studies have addressed the origins of CJs with considerable success. Sugerman has studied the movements of these jars,[44] while Smith's thin-section analyses have established a petrographic typology, not only suggesting source areas for each type, but also correlating individual sources with the transport of specific goods.[45] This work has benefited greatly from the petrographic analyses of Goren and his coworkers, who have carried out extensive work on the ceramics of the Levantine coast, including the characterization of the clays used to produce the Amarna tablets.[46] A more recent study examined the transport jars found at the site of Tell el Dab'a in the Nile Delta.[47]

With the availability of such a range of comparative chemical and geological information, and with the emphasis of the project focused firmly on provenance, an integrated petrographic and chemical approach was chosen in order to better characterize and discriminate groupings. Some of the data from the project has been used to develop and test the first true mixed-mode data procedures.[48]

PETROGRAPHIC ANALYSIS

The 88 transport jar samples from Kommos were prepared as ceramic thin sections and studied with a polarizing microscope. Petrographic fabrics were classed according to a variety of criteria, including the mineralogy and texture of the dominant inclusions and the nature of the clay micromass, and described according to a modified version of the system proposed by Whitbread.[49]

We divided the thin sections into a total of 26 petrographic fabric groups (Table 2). When compared with the typology of the transport jars, these groups fall neatly into fabrics considered Cretan (TSJ and SNA = fabrics A–J) and those considered imports (CJ and EJ = fabrics 1–12). The broad provenances of these groups on petrographic grounds are in close agreement with those based on typology.[50]

Summaries of the main characteristics of each of the 26 petrographic fabric groups are given below and illustrated with thin-section micrographs of a sample of each fabric (Figs. 3–6). These summaries indicate the mineralogical, petrographic, and textural features used to group and separate

42. McGovern 2000.
43. Bourriau, Smith, and Nicholson 2000.
44. Sugerman 2000.
45. Smith, Bourriau, and Serpico 2000; Bourriau, Smith, and Serpico 2001; Smith et al. 2004.
46. Goren et al. 2003; Goren, Finkelstein, and Na'aman 2003.
47. Cohen-Weinberger and Goren 2004.
48. Baxter et al. 2008.
49. Whitbread 1989, 1995.
50. One exception is fabric 9, which consists of a sample originally classified as an EJ (98/53), but which appears to be Cretan on the basis of its petrography (see n. 11, above).

TABLE 2. PETROGRAPHIC FABRIC CLASSIFICATION OF LATE MINOAN TRANSPORT JAR SAMPLES FROM KOMMOS

Fabric[1]	*Description*	*Samples*
A	Main south-central Cretan	Kommos 98/1, 2, 4, 7, 9, 11, 14, 16, 17, 22, 24, 26–30, 32
B	Medium/coarse igneous	Kommos 98/15, 19, 20, 87, 88
C	Serpentine	Kommos 98/21, 25
D	Fine calcareous phyllite	Kommos 98/3, 13
E	Metasedimentary	Kommos 98/18, 23
F	Quartzite, phyllite, and schist	Kommos 98/6, 31
G	Phyllite, siltstone, and chert	Kommos 98/5
H	Phyllite	Kommos 98/8
I	Quartz, polycrystalline quartz, schist, and microfossil	Kommos 98/12
J	Schist	Kommos 98/10
1	Quartz and calcite	Kommos 98/33–37, 39–45, 47–49, 52, 66, 76
1a	Quartz and calcite with chert	Kommos 98/51, 64, 73, 84
2	Macrofossiliferous clay pellet	Kommos 98/56, 59, 68, 71, 72, 74, 75, 78, 80, 81, 86
3	Quartz and clay pellet	Kommos 98/60, 63, 67, 85
3r	Quartz and clay pellet related sample	Kommos 98/82
4	Quartz, chert, and macrofossil	Kommos 98/70, 79, 83
2/4r	Fabrics 2 and 4 related sample	Kommos 98/61
5	Chert	Kommos 98/58, 65
5r	Chert related sample	Kommos 98/62
6	Fusilinid	Kommos 98/50, 54
7	Serpentine and micrite	Kommos 98/55, 69
8	Polycrystalline quartz and calcite	Kommos 98/77
9	Quartz and metamorphic	Kommos 98/53
10	Micaceous quartz and feldspar	Kommos 98/38
11	Quartz and schist	Kommos 98/46
12	Alkali feldspar	Kommos 98/57

[1] A–J = fabrics represented by TSJ and SNA samples (Cretan); 1–12 = fabrics that include CJ or EJ samples (imported).
Abbreviations: a = subfabric; r = related sample.

the thin sections, and give an impression of the range of variation in groups containing many samples. The probable origin of each group is discussed in the light of comparisons with our database of thin sections of Bronze Age ceramics and the previous studies summarized above. We have also commented on a range of technological aspects of the fabrics, where these can be interpreted from detailed analysis of the thin sections. Full descriptions of each petrographic fabric can be found in online Appendix 1.[51]

Cretan Petrographic Fabrics A–J

Fabric A: Main South-Central Cretan

Kommos 98/1, 2, 4, 7, 9, 11, 14, 16, 17, 22, 24, 26–30, 32

This fabric is characterized by the occurrence of a wide range of coarse-grained, rounded, aplastic inclusions, which do not occur within every sample (Fig. 3:a–c). The aplastics include volcanic rock fragments, metamorphic rock fragments, and siltstones. In spite of the differences between individual samples, they form a coherent, if heterogeneous, fabric.

51. See http://dx.doi.org/10.2972/hesperia.80.4.0511.app1.

Comparative material for fabric A comes from a variety of Early Minoan (EM) sites in the Mesara Plain of Crete, from kilns at Kommos and Ayia Triada,[52] and from Neopalatial storage jars found at Kannia, Phaistos, Kommos, and Ayia Triada. Petrographically, it is very similar to the fabric encountered in previous analyses of coarse-ware stirrup jars, including many of those from Kommos.[53] The petrographic variability in the fabrics of the Mesara and the difficulty of discriminating between them has been noted elsewhere.[54] For this reason, it is impossible to determine the precise provenance of fabric A. The presence of fine-grained volcanic rock fragments is well documented in ceramics at Kommos, however, and has been taken to be diagnostic of an origin in the western Mesara.[55] It is notable that fabric A includes both TSJ and SNA samples, some of which are indistinguishable in thin section. This is a clear indication that at least some vessels of these two types were manufactured at the same location in the western Mesara.

Fabric B: Medium/Coarse Igneous

Kommos 98/15, 19, 20, 87, 88

Fabric B is characterized by the occurrence of very coarse to very fine, medium-grained, acid or intermediate igneous rock fragments (cf. granodiorite) and their constituent minerals, set in a clay-rich micromass (Fig. 3:d). Most samples seem to have been moderately well fired in an oxidizing atmosphere, although the low optical activity of sample 98/87 suggests that it was fired at a much higher temperature. Granodiorite inclusions have been found in EM fabrics from Moni Odigitrias and Ayia Kyriaki in southern Crete. Rocks of this composition occur in the foothills of the nearby Asterousia Mountains, which border the southern part of the Mesara Plain.[56] Fabric B differs from the well-documented granodiorite fabric found in the Mirabello Bay area of East Crete.[57]

Fabric C: Serpentine

Kommos 98/21, 25

The two samples in this fabric are characterized by the presence of very coarse to fine inclusions of altered serpentine, igneous rock fragments, siltstone, phyllite, and schists, set in a noncalcareous clay with sparse, very fine quartz and biotite (Fig. 3:e). Fabric C is strongly associated with TSJs, which contain chert and serpentine.[58] It has its origin in the ophiolite

52. Shaw et al. 2001; Belfiore et al. 2007.

53. Day 1995a; Day and Haskell 1995; Haskell et al. 2011, pp. 58–60, fabric 11.

54. Wilson and Day 1994, pp. 57–77; Shaw et al. 2001, pp. 116–119, 141–150.

55. Myer and Betancourt 1990, pp. 9–10, pl. A; Shaw et al. 2001, p. 118.

56. Wilson and Day 1994, pp. 54–57; Bonneau, Jonkers, and Meulenkamp 1984.

57. Betancourt 1984; Day 1995b; Tomkins and Day 2001.

58. For the chert and serpentine fabric, see Day and Haskell 1995 (Thebes); Haskell et al. 2011, pp. 52–54, fabric 8.

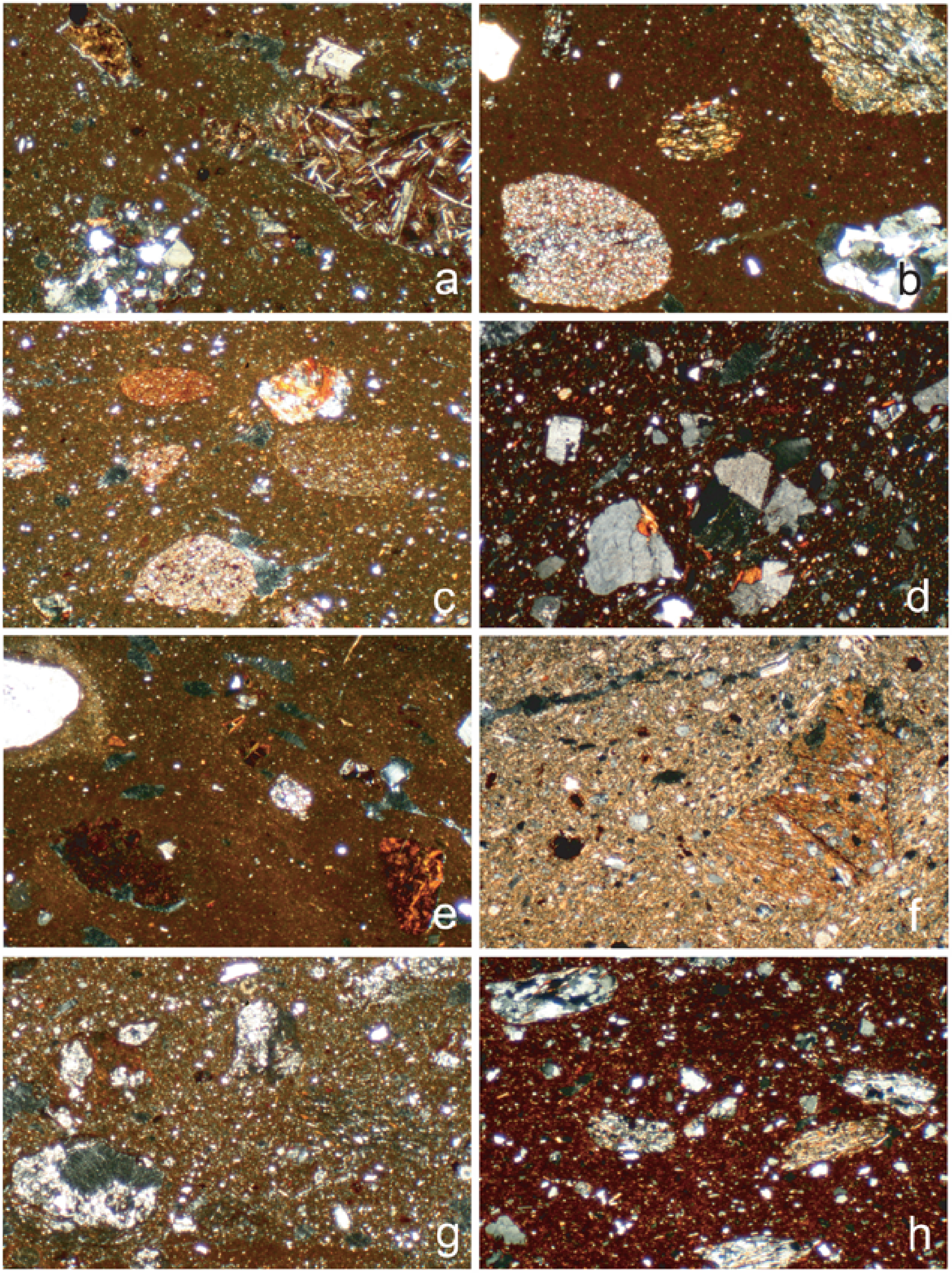


Figure 3. Thin-section micrographs of LM transport jars from Kommos: (a) fabric A (Kommos 98/1); (b) fabric A (Kommos 98/27); (c) fabric A (Kommos 98/9); (d) fabric B (Kommos 98/15); (e) fabric C (Kommos 98/25); (f) fabric D (Kommos 98/3); (g) fabric E (Kommos 98/23); (h) fabric F (Kommos 98/6). Field of view = 2.0 mm.

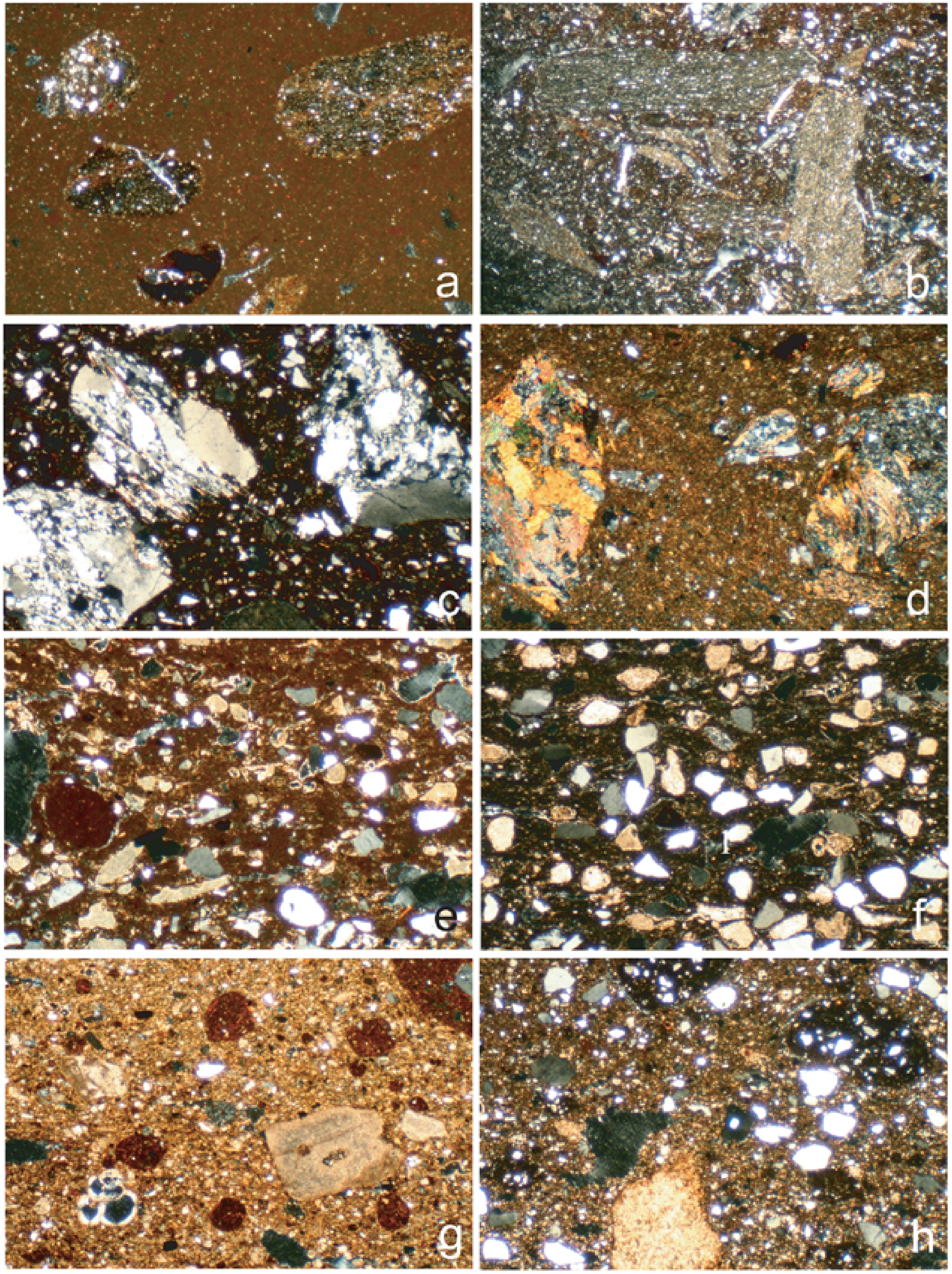
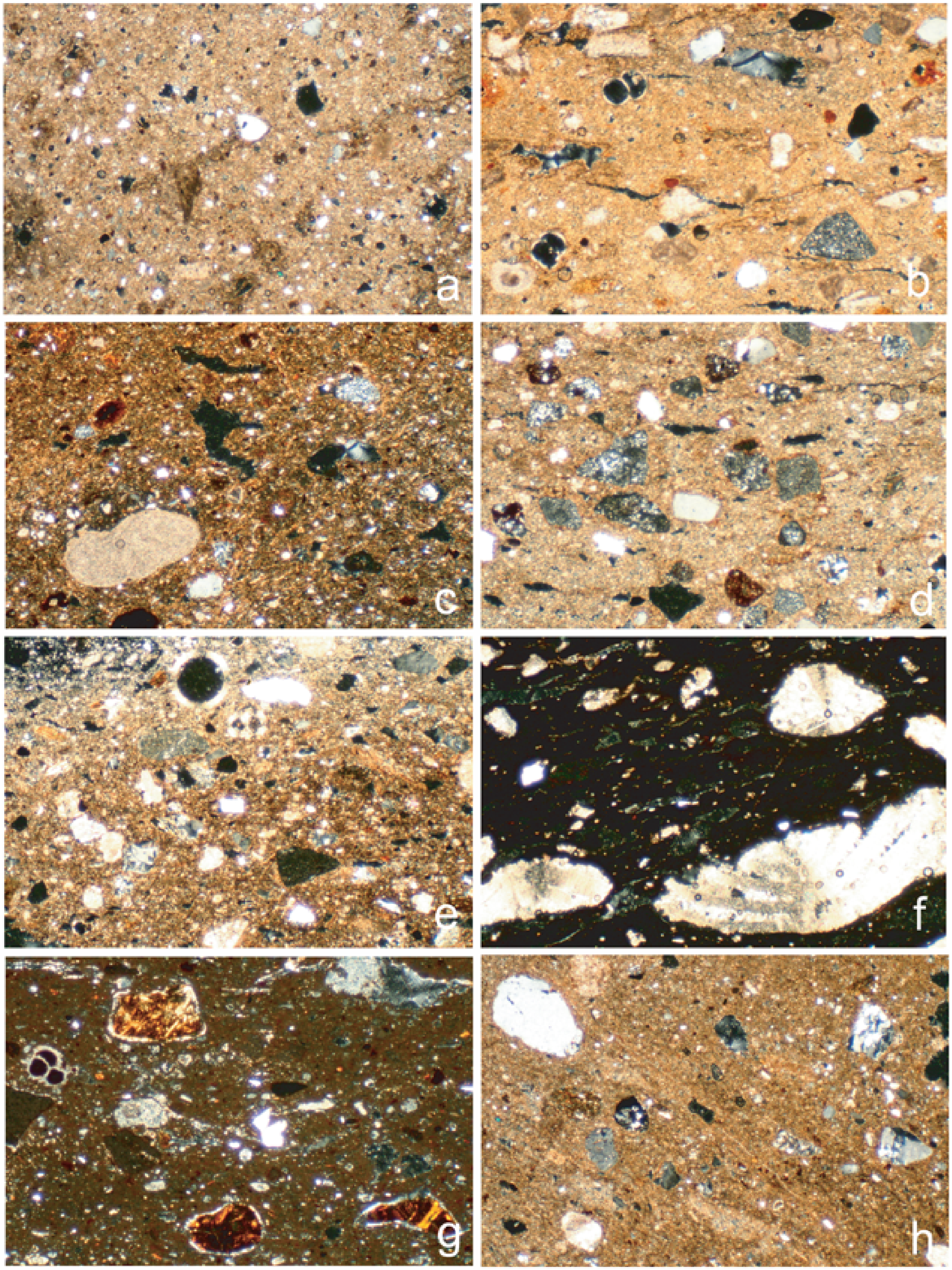


Figure 4. Thin-section micrographs of LM transport jars from Kommos: (a) fabric G (Kommos 98/5); (b) fabric H (Kommos 98/8); (c) fabric I (Kommos 98/12); (d) fabric J (Kommos 98/10); (e) fabric 1 (Kommos 98/43); (f) subfabric 1a (Kommos 98/84); (g) fabric 2 (Kommos 98/56); (h) fabric 3 (Kommos 98/60). Field of view = 2.0 mm.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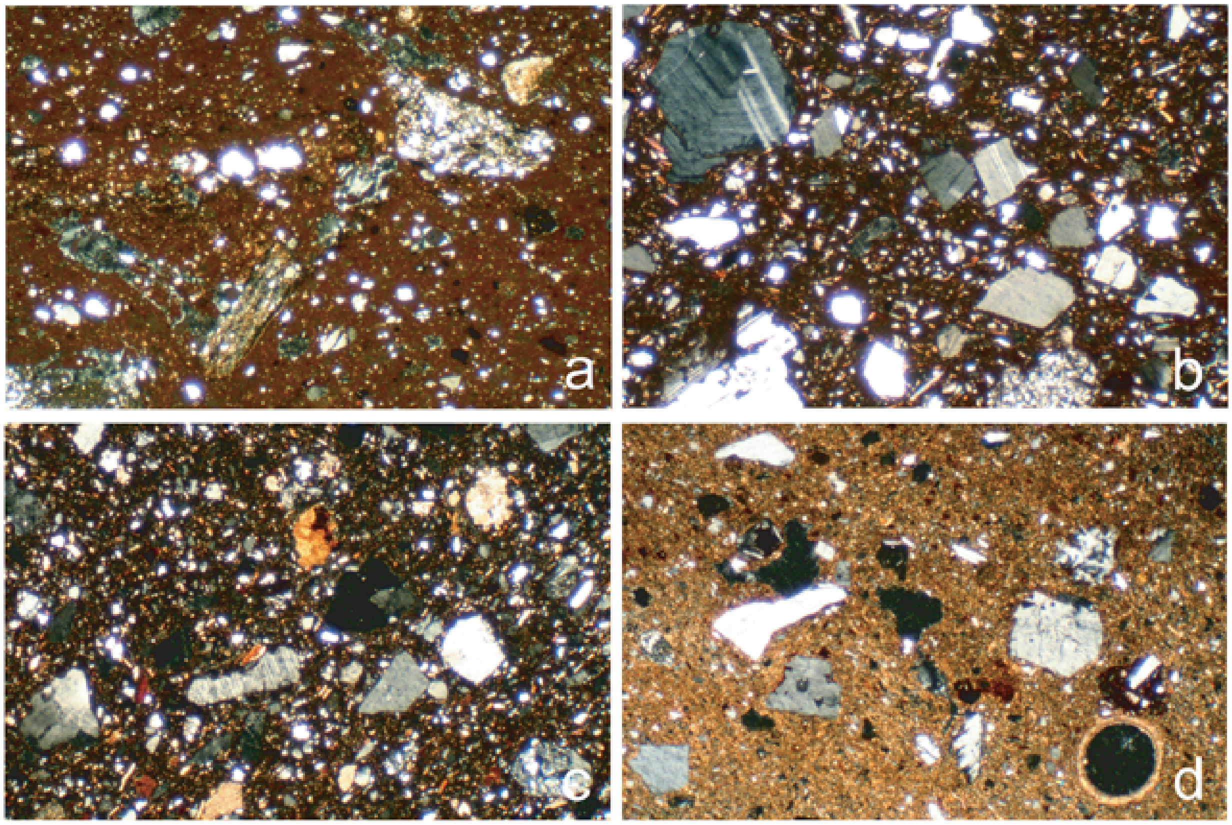

Figure 5 ***(opposite)*****. Thin-section micrographs of LM transport jars from Kommos: (a) fabric 3 related sample (Kommos 98/82); (b) fabric 4 (Kommos 98/70); (c) fabrics 2 and 4 related sample (Kommos 98/61); (d) fabric 5 (Kommos 98/58); (e) fabric 5 related sample (Kommos 98/62); (f) fabric 6 (Kommos 98/54); (g) fabric 7 (Kommos 98/69); (h) fabric 8 (Kommos 98/77). Field of view = 2.0 mm.**

Figure 6 ***(above)*****. Thin-section micrographs of LM transport jars from Kommos: (a) fabric 9 (Kommos 98/53); (b) fabric 10 (Kommos 98/38); (c) fabric 11 (Kommos 98/46); (d) fabric 12 (Kommos 98/57). Field of view = 2.0 mm.**

complex of Crete, which is present in a variety of locations in the central and eastern parts of the island. Comparable samples come from Knossos and a number of other sites, including Thebes, Enkomi, and the Uluburun shipwreck, as well as from Malia,[59] although the geology of the area around this last site does not seem compatible with their petrography.

Fabric D: Fine Calcareous Phyllite

Kommos 98/3, 13

This fabric is characterized by the presence of rare, very coarse phyllite grains set in fine calcareous clay containing monocrystalline quartz, mica, micrite, and microfossils (Fig. 3:f). The two samples are texturally very different, although this can be explained by the wide variation in grain size and relative quartz content of calcareous clays from Crete,[60] and by the deliberate addition of phyllite temper. Both samples show strong optical activity, indicating a relatively low firing temperature. This fabric stands out from that of all other TSJs in the study, a fact that most likely reflects the very early date (LM II) of the vessels, and perhaps their provenance as well.

Fabric E: Metasedimentary

Kommos 98/18, 23

This fabric is characterized by inclusions of micrite and a range of metamorphic, sedimentary, and metasedimentary rock fragments (Fig. 3:g). The paste appears to have been produced by the mixing of a light-colored

59. Day and Jones 1991.
60. Hein et al. 2004.

calcareous clay with a darker, noncalcareous clay. Both samples were fired at relatively high temperatures in an oxidizing atmosphere. Fabric E has no matches in the comparative material that we have examined. In geological terms, however, it is not incompatible with an origin in Central Crete.

Fabric F: Quartzite, Phyllite, and Schist

Kommos 98/6, 31

The two samples in this fabric are characterized by the presence of very coarse to very fine mono- and polycrystalline quartz, schist, and phyllite inclusions, plus textural features (TFs), set in a fine, noncalcareous clay with quartz, micas, and metamorphic rock fragments (Fig. 3:h). The two samples, which are of different dates, contain different proportions of these inclusions. The fabric is related to fabric I (discussed below), but differs in texture. Fabric I also contains micrite and microfossils, which are absent from fabric F. Sample 98/31 is very similar to Day's West Cretan transport jar group 1,[61] as well as Riley's West Cretan group of transport jars from Mycenae.[62] The sample contains frequent quartzite, which is characteristic of fabrics found in West Crete, specifically in EM pottery and modern geological samples from the Chania Plain.[63]

Fabric G: Phyllite, Siltstone, and Chert

Kommos 98/5

Fabric G is represented by one sample containing coarse, usually well-rounded phyllite, chert, and siltstone inclusions in a noncalcareous, micaceous clay (Fig. 4:a). It has been highly fired in an oxidizing atmosphere. The sample is very similar to Day's siltstone/igneous/chert transport jar group 9 and fabric 2B found in the Kommos kiln.[64] It may also be related to our fabric C, which is dominated by serpentine. Fabric G is likely to have an origin in Central Crete.

Fabric H: Phyllite

Kommos 98/8

This sample is characterized by the presence of large phyllite rock fragments and equant quartz inclusions, contained in a fine, noncalcareous clay with quartz, phyllite, and biotite (Fig. 4:b). Phyllite fabrics of this type can be related to the phyllite-quartzite series of rocks that occur in various locations on Crete. The closest comparative archaeological material is from East Crete, although exact parallels are difficult to find.[65] The petrography of the sample does not seem to support a typological link with Kos. While Koan amphoras sometimes have phyllite inclusions, they are usually found in association with volcanic glass, which is not present in this sample.[66]

61. Day 1995a, pp. 311–312; Day and Haskell 1995, pp. 90–91; Haskell et al. 2011, pp. 42–46.
62. Riley 1981.
63. Nodarou 2011, pp. 20–26, 42–46, pls. 14, 15.
64. For group 9, see Day 1999, pp. 65–67; Haskell et al. 2011, pp. 54–56. For fabric 2B from the Kommos kiln, see Shaw et al. 2001, pp. 116, 145.
65. Day 1995b, 1997; Poursat and Knappett 2005, pp. 18–19.
66. Whitbread 1995, pp. 83–106.

Fabric I: Quartz, Polycrystalline Quartz, Schist, and Microfossils

Kommos 98/12

Fabric I is characterized by the presence of very coarse- to medium-grained quartz, polycrystalline quartz, micrite, quartzite, quartz/mica schist, and phyllite inclusions and dark red-brown TFs in an orange-brown noncalcareous micromass containing abundant fine quartz, mica, and microfossils (Fig. 4:c). It appears to be related to fabric F, but differs in texture. Although the mixing of calcareous and noncalcareous material is known in West Cretan pottery, the large proportion of micrite inclusions in sample 98/12 is uncharacteristic of ceramics from this area of Crete. The provenance of fabric I remains uncertain.

Fabric J: Schist

Kommos 98/10

This sample contains a distinctive range of medium- to coarse-grained quartz, biotite, and hornblende schist fragments (Fig. 4:d). These occur along with mineral grains of metamorphic origin in a fine-grained, clay-rich micromass containing quartz, biotite, and calcite. The suite of metamorphic rock fragments in the sample appears to have been added as temper to a fine, noncalcareous base clay. Comparable samples come from EM pottery found at sites in the Asterousia Mountains to the south of the Mesara, deriving from hornblende schists in the foothills surrounding the plain.

Imported Petrographic Fabrics 1–12

Fabric 1: Quartz and Calcite

Kommos 98/33–37, 39–45, 47–49, 52, 66, 76

This fabric is characterized by the presence of calcite and well-rounded quartz inclusions, set in red-firing clay containing fine calcite, quartz, microfossils, and hornblende (Fig. 4:e). There is clear evidence of clay mixing in all samples except 98/45, which is more homogeneous. It appears that a fine, marly clay was mixed with a clay firing red-brown, which contained the rounded quartz grains. All samples are high-fired. Most of the calcareous inclusions are micritic. Their internal features have been lost during firing and the subsequent formation of secondary calcite. The size and abundance of quartz, calcite, TFs, and voids vary. Sample 98/76 contains a well-rounded basaltic inclusion; sample 98/45 has less frequent calcite inclusions.

This fabric is dominant among EJ samples from Kommos. The inclusions are compatible with those found in Egyptian ceramics, which commonly contain rounded sand-grade quartz (aeolian quartz), together with feldspar and mica.[67] The calcareous nature of the fabric could link it with the marl groups in Egypt, although its relationship with the mixed marl and Nile silt fabrics is not clear.[68] Differences between our petrographic analysis and the approach taken in comparative studies of Egyptian pottery make

67. Bourriau and Nicholson 1992, pp. 37–41.

68. For such mixed fabrics, see Bourriau, Smith, and Nicholson 2000.

it difficult to place this fabric with confidence. Nevertheless, it is more or less compatible with the marl groups described from Memphis, Saqqara, and Amarna, especially those with higher proportions of fine biotite in the matrix. Sample 98/76, containing a volcanic rock inclusion, is the only sample of this fabric classified typologically as a CJ.

Subfabric 1a: Quartz and Calcite with Chert

Kommos 98/51, 64, 73, 84

The samples in this fabric, while containing inclusions broadly similar to those found in fabric 1, also show some important differences. They contain chert, volcanic rock fragments, and ferruginous concentrations, as well as more foraminifera, less plagioclase feldspar, and markedly less hornblende (Fig. 4:f). There are textural differences as well: subfabric 1a has a finer coarse fraction that is better sorted and more densely packed. The groundmass is optically more active than that of fabric 1, reflecting a difference in firing temperature between the two groups of samples.

While the samples are petrographically similar, it appears that those of subfabric 1a may have a very different provenance from that of the main group. The presence of rounded quartz and calcite is characteristic of Egyptian fabrics, but subfabric 1a is a better match for Smith's group 1 of Canaanite jars from Israel.[69] This group is likewise characterized by rounded quartz inclusions, which are thought to have come from beach sand on the Israeli coast. It also contains fossiliferous remains and may be linked to the Jezreel Valley, in the environs of Tell Abu Hawam, specifically between Haifa and Akko.[70]

Fabric 2: Macrofossiliferous Clay Pellet

Kommos 98/56, 59, 68, 71, 72, 74, 75, 78, 80, 81, 86 (related: 98/61)

This homogeneous, well-defined fabric is characterized by the presence of large macrofossils and clay pellets, with medium-sized calcite, chert, and microfossil inclusions, set in calcareous clay with fine calcite and quartz (Fig. 4:g). The microfossils (foraminifera) occur as part of the marly base clay, whereas the macrofossils (coralline algae) may have come from a bioclastic limestone added as temper. The presence of red-brown clay pellets attests to the mixing of terra rossa with a marly clay body (e.g., sample 98/71). In this respect, fabric 2 is related technologically to fabric 3. In terms of provenance it is also clearly related to fabric 4, only differing in the relative proportion of macrofossil fragments, monocrystalline quartz grains, clay pellets, and chert.

Fabric 2 is identical to Smith's petrographic group 5 of Canaanite jars from the New Kingdom.[71] The distinctive fossils and other inclusions in this group permitted a relatively precise ascription to a source on the Lebanese coastal plain.[72] Similar fossils have been found in thin sections of tablets sent to Amarna from Amurru, which also suggests a Lebanese provenance for fabric 2.[73] Our samples correspond to the low-quartz variety of Smith's group 5, which would place them on the coastal Akkar Plain in the Lebanon/Syria region.[74]

69. Bourriau, Smith, and Serpico 2001, pp. 116–121; Smith et al. 2004, pp. 57–58.
70. Bourriau, Smith, and Serpico 2001, pp. 116–121, 140, pl. 7:22–26; Smith et al. 2004, pp. 56–58.
71. Bourriau, Smith, and Serpico 2001, pp. 132–136, 143, pl. 7:37–40; Smith et al. 2004.
72. Smith et al. 2004, pp. 71–73.
73. Goren, Finkelstein, and Na'aman 2003.
74. Smith et al. 2004, pp. 62–63, 71–73.

Fabric 3: Quartz and Clay Pellet

Kommos 98/60, 63, 67, 85 (related: 98/82)

This fabric is characterized by very coarse micrite inclusions, rounded TFs, monocrystalline quartz, and microfossils in a calcareous clay containing fine quartz and micrite (Fig. 4:h). Like fabric 1, it has abundant micrite and quartz. In comparison with fabric 2, it has fewer macrofossils and a greater abundance of monocrystalline quartz inclusions. Fabric 3 corresponds to Smith's group 2 from Aphek, Jaffa, Tel Hefer, and other sites on the Israeli coastal plain.[75] The red staining present in some of the samples derives from an iron-stained soil known as *hamra,* which occurs on the coast.[76] This group has an origin along the part of the coastal plain that borders the Carmel ridge, from Haifa to Yavneh Yam.[77]

Sample 98/82 (Fig. 5:a), which is related to fabric 3, features a large calcareous inclusion containing a coralline macrofossil body of the type seen in fabrics 2 and 4. It is possible that the bioclastic limestone inclusion is the origin of the macrofossil fragments in these two fabrics. Smith's group 5 (related to fabrics 2 and 4) and group 2 (related to fabric 3) have adjacent source areas on the Levantine coast.[78]

Fabric 4: Quartz, Chert, and Macrofossils

Kommos 98/70, 79, 83 (related: 98/61)

This fabric is characterized by the presence of coarse, rounded calcite, macrofossils, quartz, and chert inclusions set in a calcareous micromass containing microfossils, fine quartz, calcite, and opaques (Fig. 5:b). It appears to have been produced by the addition of weathered fossiliferous material and quartz temper to a fine calcareous clay. The base clay may have been prepared by the mixture of two or more materials, one of which was high in organic matter, as indicated by streaking in samples 98/70 and 98/79, and by the organic-rich TFs that occur in many sections. Fabrics 2 and 4 are closely related by their calcareous composition and the occurrence of both rounded quartz and macrofossils of coralline algae. Like fabric 2, fabric 4 is related to Smith's group 5 and is likely to have an origin in the Lebanese coastal plain.[79] Fabric 4 corresponds to the higher-quartz subgroup of Smith's group 5, which is believed to be from the coastal area between Akko and Sidon.

Sample 98/61 is related to fabrics 2 and 4 (Fig. 5:c). It contains many of their characteristic inclusions in its coarse fraction, including large coralline macrofossils, chert, several different types of clay pellets, planktonic and benthic foraminifera, and monocrystalline quartz grains. This sample has a less abundant coarse fraction than fabrics 2 and 4.

Fabric 5: Chert

Kommos 98/58, 65 (related: 98/62)

The two samples that constitute fabric 5 are composed of sand-tempered calcareous clays containing rounded chert inclusions, radiolaria, foraminifera, spinel, opaques, and rare serpentine (Fig. 5:d). Both samples have

75. Bourriau, Smith, and Serpico 2001, pp. 121–125, 140, pl. 7:27–30; Smith et al. 2004, pp. 63–64.
76. Cohen-Weinberger and Goren 2004, pp. 77–78.
77. Singer-Avitz and Levy 1992; Smith et al. 2004, pp. 58–60, 63–64.
78. Smith et al. 2004.
79. Bourriau, Smith, and Serpico 2001, pp. 132–136, 143, pl. 7:37–40; Smith et al. 2004, pp. 71–73.

a bimodal grain-size distribution, but differ in other textural and microstructural characteristics. Sample 98/58 has a greater frequency of voids, a more abundant coarse fraction, and a stronger alignment of inclusions than sample 98/65. This fabric appears to have been prepared from a mixture of calcareous and noncalcareous clay, as indicated by the ptygmatic texture in sample 98/58 and the TFs in both sections. The presence of calcite, microfossils, radiolarian chert, and serpentine inclusions links this fabric with subgroup 1.1 of Smith's group 4, which has a "high percentage of ophiolite."[80] It is thus related to fabric 7, which is linked to the ophiolite complex of the northwestern Syrian coast.[81]

Sample 98/62 is related to fabric 5, but differs in its elongate phyllite inclusions and igneous rocks, as well as the nature of its chert inclusions (Fig. 5:e). It is similar to a distinctive but problematic group of material in Smith's classification. That group was originally considered to be related to the ophiolite series and classified as subgroup 4.2.2.[82] In the new scheme, however, it is placed in a separate group (Smith's group 6) and assigned an origin in southern Cyprus.[83] It is therefore possible that sample 98/62 may also have an origin in Cyprus.

Fabric 6: Fusilinid

Kommos 98/50, 54

This highly distinctive fabric consists of two almost identical sections characterized by the occurrence of large fusilinid foraminifera (microfossils) and micrite inclusions, together with medium-sized rounded quartz, set in a dark, high-fired clay (Fig. 5:f). Both samples contain a high percentage of large vughs and elongate voids, which are aligned to the margins of the sections. They were high-fired in a reducing atmosphere. Fabric 6 is unlike that of any other transport jar sample analyzed in this project and cannot be correlated with any of the comparative material. It may be compatible with a marl mixed with large fragments of bioclastic limestone. Further comparative material should be sought in Egypt.

Fabric 7: Serpentine and Micrite

Kommos 98/55, 69

This fabric is characterized by the presence of rounded, medium- to coarse-grained serpentine and micrite inclusions (Fig. 5:g). It differs from fabric C by the presence of micritic inclusions and microfossils and matches Smith's group 4.1.1, which is characteristic of the ophiolites of the Baër-Bassit complex of northwestern Syria.[84] Ceramics with this composition have been found at Ras Shamra (Ugarit),[85] while thin-section analysis of two letters sent from Ugarit to Amarna have revealed a similar composition.[86]

80. Smith et al. 2004, pp. 65–68.
81. Cohen-Weinberger and Goren 2004, pp. 71–73.
82. Bourriau, Smith, and Serpico 2001, pp. 127–132.
83. Smith et al. 2004, pp. 68–70.
84. Bourriau, Smith, and Serpico 2001, pp. 127–132, 142–143, pl. 7:33–36; Cohen-Weinberger and Goren 2004, pp. 71–73.
85. Smith et al. 2004, pp. 60–61.
86. Goren et al. 2003.

Fabric 7 is therefore suspected to have originated on the Syrian coast north of Latheqieh, possibly around Ras Shamra.

Fabric 8: Polycrystalline Quartz and Calcite

Kommos 98/77

This fabric is characterized by medium-grained, rounded polycrystalline quartz and micrite inclusions (Fig. 5:h). It was produced by a mixture of rounded, medium-sized temper with a fine, highly calcareous, microfossiliferous clay. It is related to several other fabrics in our study; in particular, its calcareous, fossiliferous character and the metamorphic polycrystalline quartz suggest a link with sample 98/62, which is related to fabric 5 and may have originated on Cyprus. It does not, however, match any one group in Smith's classification.

Fabric 9: Quartz and Metamorphic

Kommos 98/53

This fabric is characterized by coarse- to fine-grained, rounded monocrystalline quartz, polycrystalline quartz, metamorphic rock fragments, and elongate phyllite and schist inclusions in a red, noncalcareous, fine-grained micromass with extensive clay-mixing features (Fig. 6:a). While it is not closely related to any other samples in our study, its mineralogy is compatible with the low-grade metamorphic geology of south-central Crete. We take this vessel to be Cretan and to have been misclassified in macroscopic sorting.

Fabric 10: Micaceous Quartz and Feldspar

Kommos 98/38

This fabric contains moderately well-sorted, coarse- to fine-grained, rounded quartz and feldspar inclusions in a dense, noncalcareous micromass containing fine quartz, plagioclase feldspar, and abundant mica laths (Fig. 6:b). The feldspar and quartz coarse fraction is likely to have been added as temper to a finer base clay. The presence of TFs with abundant fine micas, quartz, and plagioclase suggest that the base clay may have been produced by blending two or more different types of material. The source of the temper is likely to have been an intermediate igneous rock, and the fabric is suspected of having been produced outside of Crete.

Fabric 11: Quartz and Schist

Kommos 98/46

Fabric 11 is characterized by coarse- to very fine-grained monocrystalline quartz, polycrystalline quartz, micrite, quartzite/cataclasite, and phyllite inclusions set in a fine, noncalcareous micromass with quartz and micas (Fig. 6:c). In addition to the range of metamorphic rock fragments, the sample contains rare igneous rocks. It was clearly imported to Crete, but its origin is uncertain.

Fabric 12: Alkali Feldspar

Kommos 98/57

This fabric is characterized by the presence of very coarse- to fine-grained alkali feldspar inclusions, intermediate and acid volcanic igneous rock, schist and phyllite fragments, TFs, and opaques set in a noncalcareous clay with fine quartz, feldspar, micas, and opaques (Fig. 6:d). Many of the rock and mineral inclusions in this fabric may have originated from a dark red-brown clay, which forms the distinctive TFs. This clay may have been mixed with another, lighter clay. Although it is clearly an import to Crete, as yet we have no comparative data for this fabric.

INSTRUMENTAL NEUTRON ACTIVATION ANALYSIS

All 88 transport jar samples were analyzed chemically by INAA. The external surface of each sample was cleaned with a tungsten carbide drill bit. The sherds were then ground to a fine powder in an agate mortar and dried at 110°C overnight. Approximately 130 mg of each dry, powdered sample was aliquoted into a polyethylene vial, which was then heat-sealed. The vials were irradiated in batches of 10, along with two reference samples, at a thermal neutron flux of 5×10^{13} n.cm^{-2}.s^{-1}, in a swimming pool reactor at the National Center for Scientific Research "Demokritos" in Athens. Eight days after irradiation, the γ-spectra of the samples and reference materials were recorded in order to determine the concentrations of the elements Sm, Lu, Yb, U, As, Sb, Ca, Na, K, and La. The same samples were also measured two weeks later in order to determine the concentrations of the following isotopes with longer half-lives in spectra with lower backgrounds: Ce, Th, Cr, Hf, Cs, Tb, Sc, Rb, Fe, Ta, Co, Eu, Ba, Ni, Zr, Zn, and Nd. The full analytical data for the 27 elements analyzed in each of the 88 samples are presented in online Appendix 2.[87]

Sixteen of the 27 elements analyzed (Sm, Lu, Yb, Ca, Na, La, Ce, Th, Cr, Hf, Cs, Sc, Rb, Fe, Co, and Eu) were chosen for statistical analysis. The elements As and Sb were excluded because of their high natural fluctuation, which could introduce unrealistic variability to the data. Seven elements (U, Tb, Ta, Ba, Ni, Zr, and Nd) were not included because of their low count in the transport jar samples. Finally, K and Zn were omitted because they are not present in the comparative data sets that we have used.

A comprehensive picture of the chemical variability within the INAA dataset can be obtained by the calculation of a variation matrix using the 16 elements listed above, along with U and Ta (Table 3).[88] In a variation matrix, the variance of each element (columns) is expressed as a logarithmic ratio over that of all other elements (rows). These values are used to calculate the sum of the variances, or total variance, for each individual element when it is used as a divisor. The results provide important information about the covariance structure of the data and the effect of one elemental concentration on the others. We have also calculated the total variation (Var.T.) of the dataset from the sum of all variances divided by twice the number of elements included in the matrix. This calculation helps

87. See http://dx.doi.org/10.2972/hesperia.80.4.0511.app2.

88. On the variation matrix and the logarithmic ratio transformation of data, see Buxeda i Garrigós and Kilikoglou 2003.

TABLE 3. CHEMICAL VARIATION MATRIX FOR 18 OF THE ELEMENTS ANALYZED WITH INAA IN LATE MINOAN TRANSPORT JAR SAMPLES FROM KOMMOS

	Sm	*Lu*	*U*	*Yb*	*Ca*	*Na*	*La*	*Ce*	*Th*
Sm	0.0000	0.0201	0.0678	0.0183	0.5474	0.3619	0.0103	0.008	0.1094
Lu	0.0201	0.0000	0.0667	0.0020	0.5900	0.2868	0.0217	0.0165	0.0641
U	0.0678	0.0667	0.0000	0.0767	0.5853	0.3571	0.0690	0.0826	0.1355
Yb	0.0183	0.0020	0.0767	0.0000	0.5963	0.2897	0.0189	0.0131	0.0623
Ca	0.5474	0.5900	0.5853	0.5963	0.0000	1.1546	0.6343	0.6294	0.9052
Na	0.3619	0.2868	0.3571	0.2897	1.1546	0.0000	0.3411	0.3291	0.2490
La	0.0103	0.0217	0.0690	0.0189	0.6343	0.3411	0.0000	0.0064	0.0710
Ce	0.0085	0.0165	0.0826	0.0131	0.6294	0.3291	0.0064	0.0000	0.0687
Th	0.1094	0.0641	0.1355	0.0623	0.9052	0.2490	0.0710	0.0687	0.0000
Cr	0.8705	0.6995	0.8585	0.7107	1.3845	0.7090	0.8429	0.8360	0.6601
Hf	0.0750	0.0830	0.1839	0.0771	0.7077	0.3880	0.0816	0.0643	0.1638
Cs	0.6863	0.5770	0.5783	0.5836	1.6921	0.5137	0.6018	0.6270	0.3850
Sc	0.1209	0.0601	0.1468	0.0666	0.7064	0.1998	0.1222	0.1075	0.0918
Rb	0.4017	0.3209	0.3280	0.3281	1.3249	0.3160	0.3465	0.3549	0.1900
Fe	0.1026	0.0523	0.1211	0.0608	0.6480	0.2376	0.1136	0.0954	0.1064
Ta	0.0345	0.0516	0.1126	0.0500	0.6042	0.3482	0.0485	0.0338	0.1463
Co	0.2836	0.1854	0.3183	0.1950	0.8146	0.2754	0.2994	0.2686	0.2432
Eu	0.0080	0.0262	0.0804	0.0263	0.4899	0.3731	0.0293	0.0231	0.1405
Total	3.7269	3.1240	4.1687	3.1757	14.014	6.7300	3.6586	3.5651	3.7927
vt/	0.7716	0.9205	0.6898	0.9056	0.2052	0.4273	0.7860	0.8066	0.7582
rTotal	0.9379	0.9826	0.9585	0.9808	0.8878	0.8638	0.9627	0.9656	0.9484

	Cr	*Hf*	*Cs*	*Sc*	*Rb*	*Fe*	*Ta*	*Co*	*Eu*
Sm	0.8705	0.0750	0.6863	0.1209	0.4017	0.1026	0.0345	0.2836	0.0080
Lu	0.6995	0.0830	0.5770	0.0601	0.3209	0.0523	0.0516	0.1854	0.0262
U	0.8585	0.1839	0.5783	0.1468	0.3280	0.1211	0.1126	0.3183	0.0804
Yb	0.7107	0.0771	0.5836	0.0666	0.3281	0.0608	0.0500	0.1950	0.0263
Ca	1.3845	0.7077	1.6921	0.7064	1.3249	0.6480	0.6042	0.8146	0.4899
Na	0.7090	0.3880	0.5137	0.1998	0.3160	0.2376	0.3482	0.2754	0.3731
La	0.8429	0.0816	0.6018	0.1222	0.3465	0.1136	0.0485	0.2994	0.0293
Ce	0.8360	0.0643	0.6270	0.1075	0.3549	0.0954	0.0338	0.2686	0.0231
Th	0.6601	0.1638	0.3850	0.0918	0.1900	0.1064	0.1463	0.2432	0.1405
Cr	0.0000	1.0722	0.8451	0.5227	0.7649	0.5778	0.9614	0.3871	0.8552
Hf	1.0722	0.0000	0.8404	0.1904	0.5187	0.1665	0.0473	0.3615	0.0822
Cs	0.8451	0.8404	0.0000	0.5168	0.0991	0.5780	0.8056	0.6484	0.7378
Sc	0.5227	0.1904	0.5168	0.0000	0.2785	0.0106	0.1295	0.0730	0.1121
Rb	0.7649	0.5187	0.0991	0.2785	0.0000	0.3123	0.4776	0.4097	0.4397
Fe	0.5778	0.1665	0.5780	0.0106	0.3123	0.0000	0.1034	0.0772	0.0904
Ta	0.9614	0.0473	0.8056	0.1295	0.4776	0.1034	0.0000	0.2864	0.0373
Co	0.3871	0.3615	0.6484	0.0730	0.4097	0.0772	0.2864	0.0000	0.2578
Eu	0.8552	0.0822	0.7378	0.1121	0.4397	0.0904	0.0373	0.2578	0.0000
Total	13.558	5.1035	11.316	3.4557	7.2113	3.4539	4.2780	5.3846	3.8094
vt/	0.2122	0.5635	0.2541	0.8322	0.3988	0.8326	0.6722	0.5341	0.7549
rTotal	0.5547	0.9483	0.6019	0.9695	0.6384	0.9807	0.9372	0.8267	0.9187
S.T.V	103.526824								
Var.T.	2.875745								

to determine whether one or more groups are present in the dataset. The total variation of 2.9 in our dataset indicates that we can expect to find chemically distinct groups in the data.

From the variation matrix it is clear that the elements Ca, Cr, and Cs introduce the highest variation when used as a divisor. In comparison, Lu, Yb, Sc, and Fe produce the lowest individual variance values and the lowest total variance. This means that the variance in these elements is probably natural or due to mixing or tempering, rather than to alteration or contamination. Scandium (Sc) has the second lowest variability in the dataset and is a lithophilic, immobile element. We therefore chose to express the concentration of each of the 18 elements in our dataset as a logarithmic ratio over the concentration of Sc.

The logarithmic ratios of all elemental concentrations over Sc were then submitted to cluster analysis based on Euclidean distance and average linkage. The resulting dendrogram is shown in Figures 7–9. From the general structure of the dendrogram we can expect to distinguish several well-defined chemical groups, a result in accordance with high total variation in the matrix. The nine groups circled and labeled with roman numerals on the dendrogram are discussed in detail below. The mean elemental concentrations as well as the percentage standard deviations of all nine groups are presented in Table 4. The dashed line that separates the dendrogram into two slightly unequal halves corresponds to the split between samples of Cretan origin (to the left of the line) and those from the Near East and Egypt (to the right). The sample numbers of the members of each group are shown in Figure 7, the correspondence between the chemical groups and the typological classification of the vessels is shown in Figure 8, and the correspondence between the chemical groups and the petrographic fabrics is shown in Figure 9.

Cretan Chemical Groups

Chemical Group I

This is the largest and most compact group in the dendrogram, containing 22 samples, of which 13 are TSJ and 7 SNA (Fig. 8). The remaining two samples (98/46 and 98/61) are classed as CJs on stylistic grounds. A close examination of sample 98/46 (see online Appendix 2) reveals that it has a lower concentration of the rare earth elements Th, Fe, and Sc than the rest of chemical group I. Since Sc was used as a divisor, its low value elevated the concentration of other elements, with the result that this sample clustered in group I.

Chemical group I contains most of the transport jar samples from petrographic fabric A, as well as individuals from Central Cretan fabrics D and E and fabrics G and J (Fig. 9). The standard deviations for most elements in chemical group I are less than 10%, except for Ca, Na, Cs, and Rb, which have standard deviations greater than 20%. This situation is indicative of marine sediments in which alkalis are selectively leached, or Na is enriched, in the case of high-fired ceramics, through the fixation of analcime. All samples with Na values close to or greater than 1% behave in this way. This phenomenon has been documented in pottery from the Minoan kiln at Kommos and may be a trademark of the site.[89]

89. Buxeda i Garrigós, Kilikoglou, and Day 2001.

TABLE 4. MEAN AND PERCENTAGE STANDARD DEVIATION OF CHEMICAL GROUPS OF LATE MINOAN TRANSPORT JAR SAMPLES FROM KOMMOS ANALYZED BY INAA

Group		*Sm*	*Lu*	*Yb*	*Ca*	*Na*	*La*	*Ce*	*Th*	*Cr*	*Hf*	*Cs*	*Sc*	*Rb*	*Fe*	*Co*	*Eu*
I	mean	4.93	0.34	2.68	6.04	0.94	27.20	59.58	9.76	362.10	4.23	5.78	20.25	89.55	5.71	33.17	1.13
	%	9.68	7.86	7.79	26.62	26.11	10.59	10.38	11.95	17.65	9.49	31.33	7.90	27.46	7.65	12.51	9.38
II	mean	4.48	0.34	2.62	6.37	0.71	24.15	57.15	9.97	607.70	3.53	2.49	23.60	51.67	6.81	45.64	1.07
	%	6.11	11.45	9.78	26.84	19.40	11.00	8.31	11.87	51.31	28.95	58.90	8.69	41.36	5.40	9.13	7.33
III	mean	5.18	0.35	2.75	3.39	1.28	28.30	63.43	10.19	347.00	4.84	3.37	17.32	73.33	5.04	29.00	1.17
	%	6.68	10.92	9.41	9.59	8.59	5.84	7.98	10.09	11.44	2.56	52.47	4.62	31.49	4.24	5.27	1.97
IV	mean	7.03	0.41	3.46	8.95	0.39	35.33	86.43	9.08	116.80	9.45	1.53	13.26	32.5	4.35	22.42	1.60
	%	14.14	11.09	10.81	27.10	28.63	15.09	12.30	7.67	13.29	3.97	26.87	10.31	15.38	7.56	18.57	17.08
V	mean	5.97	0.34	2.53	17.61	0.36	28.11	60.16	5.61	133.70	4.09	1.55	13.11	35.00	4.82	21.32	1.44
	%	21.60	22.10	21.96	17.11	16.23	23.75	25.85	25.96	18.28	22.27	29.43	22.14	24.28	20.13	23.20	22.68
VI	mean	7.16	0.38	3.03	11.47	0.53	35.49	81.86	7.90	107.50	7.26	1.31	17.05	35.00	5.50	23.65	1.71
	%	7.32	7.67	6.26	16.52	38.06	7.33	7.86	10.05	8.03	9.26	32.93	8.29	26.87	8.80	12.67	7.50
VII	mean	6.24	0.32	2.59	18.21	0.23	34.57	70.57	9.45	85.50	2.92	3.57	10.88	66.67	3.10	10.41	1.33
	%	8.37	9.65	7.60	2.69	4.95	9.88	7.82	9.62	13.90	14.12	20.43	8.92	17.32	6.61	7.98	11.93
VIII	mean	7.13	0.39	2.99	10.24	0.61	39.50	79.93	10.73	123.70	4.75	3.92	12.22	66.67	3.48	9.09	1.49
	%	2.08	2.56	2.41	9.62	29.72	3.73	2.90	1.08	5.38	1.59	9.57	1.87	8.66	0.00	5.49	4.04
IX	mean	5.16	0.34	2.76	12.51	0.28	28.55	56.60	6.02	3107.00	2.86	1.21	12.24	20.00	3.18	27.49	1.19
	%	16.87	14.78	17.93	8.82	15.15	18.08	26.24	21.28	5.28	22.54	12.86	22.99	70.71	22.49	20.09	23.70

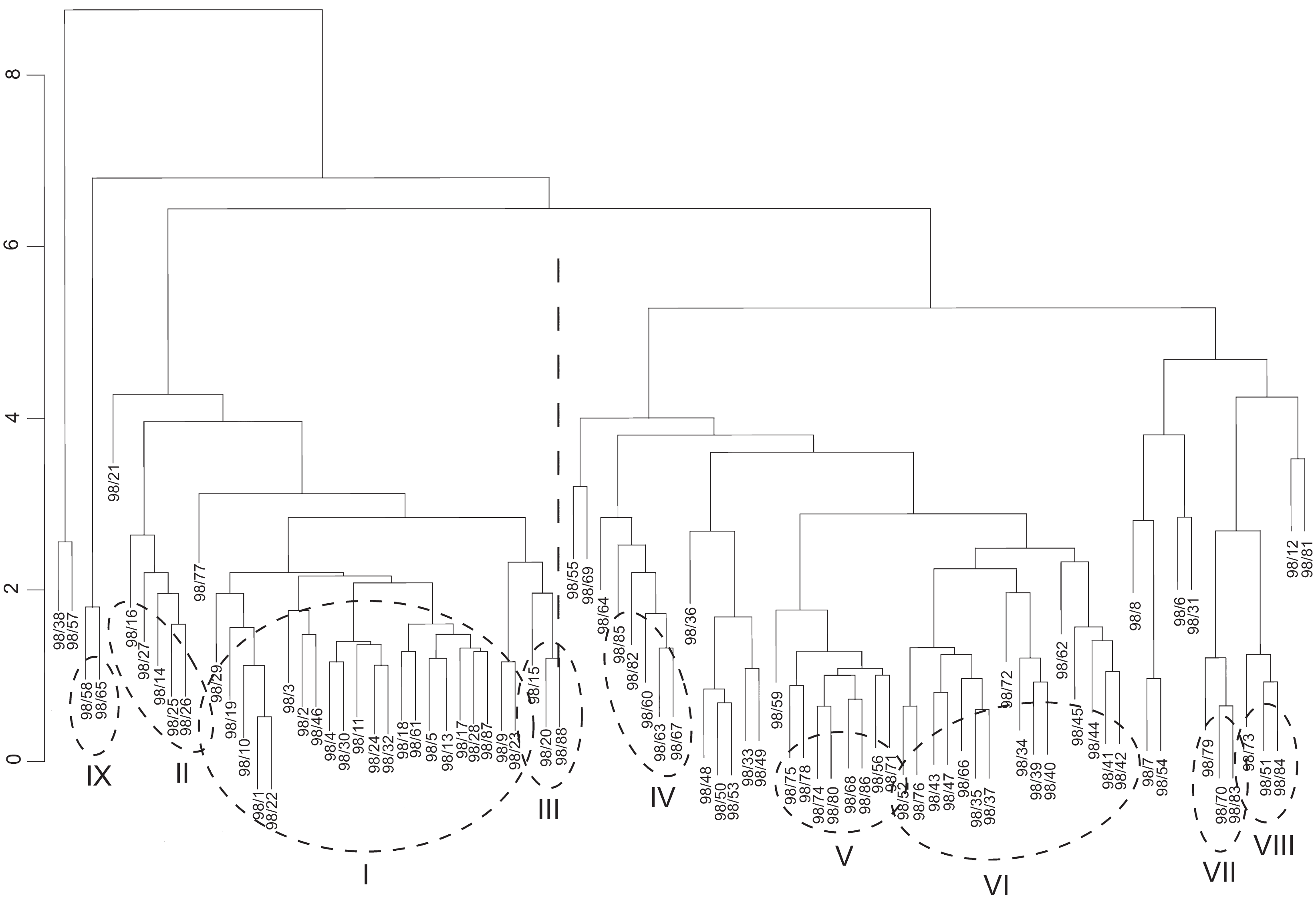

Figure 7. INAA dendrogram of LM transport jar samples with sample numbers and interpreted chemical groups. Well-defined chemical groups are circled. The vertical dashed line divides samples of Cretan origin (left) from those of Near Eastern and Egyptian origin (right). Concentrations are expressed as log-ratios over Sc.

The elemental profile of chemical group I is consistent with that of the Neogene marine sediments of Central Crete, but distinct from the reference group of pottery associated with the Kommos kiln.[90]

Chemical Group II

This group, which is related to chemical group I, consists of four SNA samples belonging to fabric A, as well as one sample (98/25) belonging to fabric C, which was later reclassified as an earlier amphora type. Chemical group II has a higher average concentration of Cr than chemical group I (see online Appendix 2). In Central Crete ultrabasic rocks, which contain Cr in the form of chromite inclusions, are abundant, and the distribution of chromite and Cr in clays can be uneven. It can therefore be safely suggested that chemical groups I and II are subgroups of a larger cluster.

Chemical Group III

Three SNA samples form the small, tight chemical group III (Fig. 8). All three belong to petrographic fabric B and are connected with igneous rocks from the foothills of the western Asterousia Mountains.

Other TSJ and SNA samples

The remaining TSJ and SNA samples do not belong to any specific cluster, but rather appear as outliers in the dendrogram (Fig. 8). Samples 98/6 and 98/31 are located on the opposite side of the dendrogram from chemical groups I, II, and III (Fig. 7). They have chemical compositions very similar to comparative material from Chania with a high concentration of light rare earth elements (see online Appendix 2). This composition is also similar to that of a group of TSJs found at Mycenae and attributed to West Crete.[91] These two samples form petrographic fabric F (Fig. 9), which is considered to be West Cretan. Sample 98/8 is also located on the right side of the dendrogram, but is more closely related chemically to East Crete than to West Crete. The two ends of the island are quite similar to each other in chemical terms, however. Samples 98/12 and 98/81 are outliers that do not match any chemical reference groups.

Imported Chemical Groups

The right side of the dendrogram consists of CJ and EJ samples (Fig. 8). The clusters here are looser than those on the left side. In general there are three larger groups (IV, V, VI), as well as at least three more groups containing two or three members each (VII, VIII, IX).

Chemical Group IV

Chemical group IV is a cluster of four samples belonging to petrographic fabric 3 (Fig. 9), which is linked to the Carmel coast of northern Israel, together with a fifth, closely related sample. This is a very compact group and one that is chemically well differentiated from the rest (Table 4).

90. Shaw et al. 2001.
91. Tomlinson 1996.

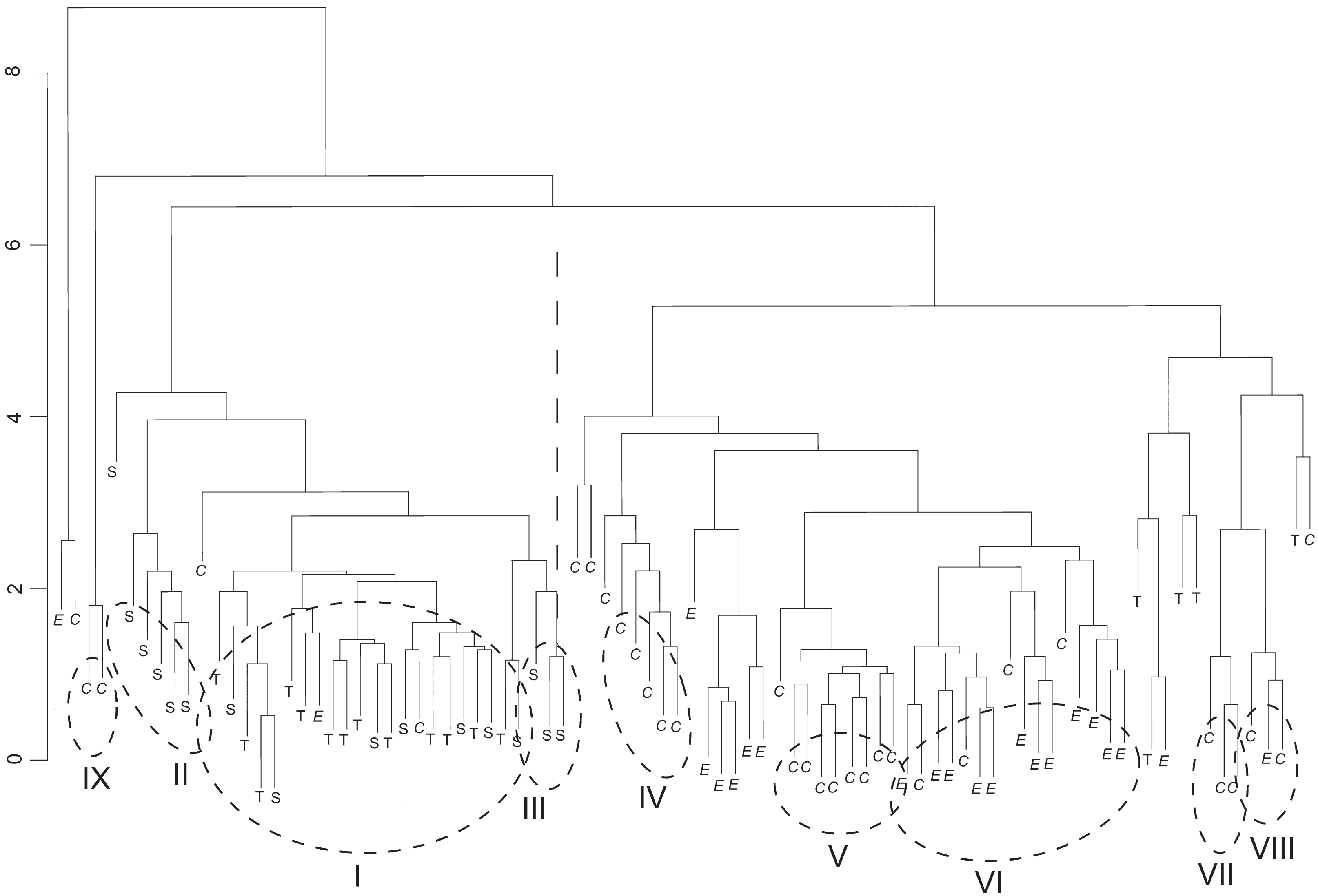

Figure 8. INAA dendrogram of LM transport jar samples with original typological classification of vessels and interpreted chemical groups. Well-defined chemical groups are circled. The vertical dashed line divides samples of Cretan origin (left) from those of Near Eastern and Egyptian origin (right). Concentrations are expressed as log-ratios over Sc. T = transport stirrup jar; S = short-necked amphora; *E* = Egyptian jar; *C* = Canaanite jar.

Chemical Group V

Chemical group V is a relatively loose group, but one composed entirely of individuals from petrographic fabric 2 (Fig. 9). It is chemically distinct from the other samples (Table 4).

Chemical Group VI

The largest chemical group on the right side of the dendrogram is group VI, which consists of 12 of the 19 EJ samples (Fig. 8). It is homogeneous and exhibits only minor variation in most elements, except for the alkalines, which show a standard deviation of over 20%, possibly due to alterations while buried (Table 4). The chemical signature of this group matches that of the amphoras from Malkata analyzed by McGovern[92] and the marl D fabric in the Vienna system, comprising amphoras from Thebes, Memphis, Amarna, and Qantir analyzed by Bourriau and her coworkers.[93] It is safe to suggest that these EJ samples from Kommos were made from the same raw materials as the Egyptian vessels in those studies. McGovern suggests that they were produced in the area of Thebes and transported to the Delta region for filling, whereas Bourriau argues for a likely source in the Memphis region.[94]

Chemical Groups VII and VIII

Two small groups of three samples each appear on the far right side of the dendrogram. Chemical group VII is composed of members of petrographic fabric 4 (Fig. 9), which may come from the Lebanese coast. Despite the small number of samples, the group is relatively tight and the average values have low standard deviations (Table 4). Next to this cluster is chemical group VIII, composed of samples from petrographic fabric 1a (Fig. 9). This is also a tight group with very low standard deviations.

Chemical Group IX

On the far left side of the dendrogram are two very distinctive CJ samples (98/58 and 98/65), which we have labeled chemical group IX (Fig. 7). This group corresponds to petrographic fabric 5 (Fig. 9), and its most distinctive chemical characteristic is its high Cr concentration (Table 4). Its likely origin lies in coastal Syria among the ophiolite series, which would account for the elevated Cr levels.

Other CJ and EJ Samples

Four EJ samples of petrographic fabric 1 (98/33, 36, 48, 49) form a loose cluster, along with samples 98/50 and 98/53, between chemical groups IV and V in the dendrogram (Fig. 7). The chemical profile of this group, when compared to that of chemical group VI, exhibits minor differences in most elements except Na, which is twice as abundant. Another loose cluster of two samples (98/55 and 98/69) is located just to the right of the line dividing Cretan from imported ceramics (Fig. 7). Both samples are members of petrographic fabric 7 (Fig. 9) and are chemically distinct from the rest of the samples, although the chemical affinity between the two samples is low compared to that of the more tightly clustered groups discussed above.

92. McGovern 1997.
93. Bourriau 2004.
94. McGovern 1997; Bourriau 2004. See also Cohen-Weinberger and Goren 2004, pp. 84–85, with references, for a comparison of the results of petrographic analysis with INAA data and interpretation.

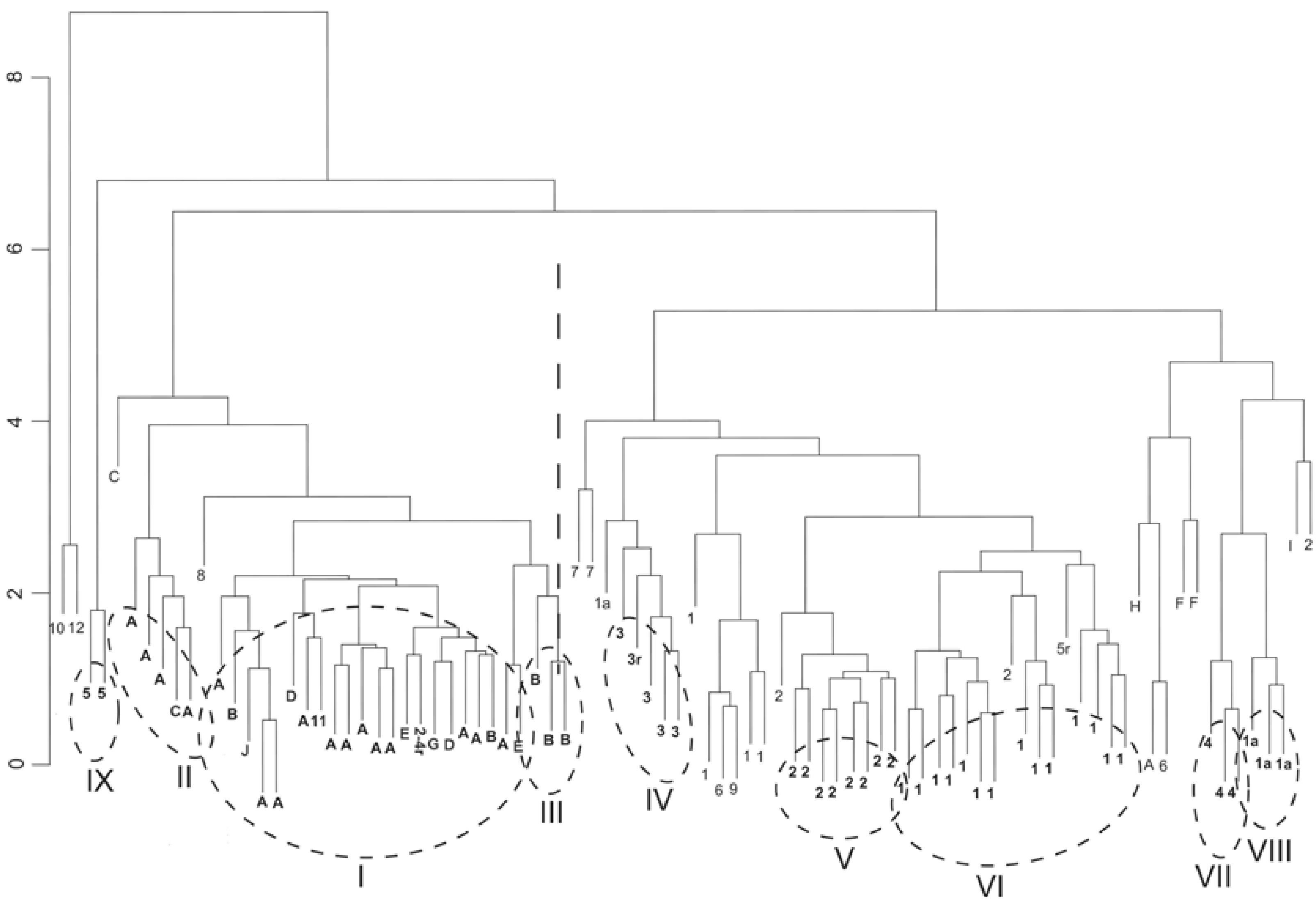

Figure 9. INAA dendrogram of LM transport jar samples with petrographic fabric classification and interpreted chemical groups. Well-defined chemical groups are circled. The vertical dashed line divides the samples of Cretan origin (left) from those of Near Eastern and Egyptian origin (right). Concentrations are expressed as log-ratios over Sc.

THE PROVENANCES OF THE TRANSPORT JARS FROM KOMMOS

Petrographic and chemical analyses of the Late Minoan transport jars from Kommos have provided us with two different lines of evidence with which to address the question of provenance. Although the two analytical techniques are concerned with different compositional characteristics, their results correspond closely with one another, as well as with the typological classification of the transport jars (Figs. 8, 9). For example, both chemistry and petrography confirm the split between the Cretan TSJ and SNA samples and the imported CJ and EJ samples. This agreement is one of the clearest to have appeared in any analytical study of Minoan ceramics, and it demonstrates the potential benefits of a combined application of the two techniques in a "mixed-mode" approach.[95] The analysis of the petrographic and chemical data within the context of the comparative material described above has allowed us to distinguish local and imported transport jars at Kommos and to suggest a geographical provenance for each group.

Cretan versus Non-Cretan Ceramics

The 88 samples can be clearly separated into Cretan and non-Cretan vessels on the basis of the petrographic classification and the INAA cluster analysis. The resulting groups range from well-defined clusters of samples that are petrographically and chemically homogeneous and can be closely linked to geology and/or comparative material, to unique samples that lack clear comparative data but can nevertheless be ascribed to a general area.

The typological distinction between the TSJ and SNA samples, which are considered to be products of Crete,[96] and the non-Cretan CJ and EJ samples is evident in both datasets. This split is particularly visible in the petrographic classification, where fabrics A–J consist of TSJ and SNA samples, while fabrics 1–12 consist of EJ and CJ samples. Chemically, the Cretan TSJ and SNA samples form tighter clusters in the INAA dendrogram than the imported CJ and EJ samples. Both sets of samples, however, contain several distinctive chemical groups, a fact that has implications for the provenance of the vessels. Some 27 of the 31 TSJ and SNA samples and 47 of the 53 CJ and EJ samples appeared on opposite sides of the INAA dendrogram (Fig. 8), confirming the broad chemical distinction between Cretan and non-Cretan material.

With the exception of sample 98/53, which is taken to be Cretan, the petrography of the 88 transport jars also supports the broad division between Cretan and non-Cretan samples, as suggested by their typological classification. We have found it useful to structure the following commen-

95. Mixed-mode statistical analysis was conducted on some of the chemical and petrographic data in collaboration with the GEOPRO Training and Mobility Network funded by the European Commission. See Beardah et al. 2003; Moustaki and Papageorgiou 2004; Baxter et al. 2008. The last of these demonstrates that when both chemical and petrographic aspects of the composition are included in the same statistical procedure, the data may show new structure and clearer groupings than when either dataset is considered separately.

96. Rutter 1999.

tary by petrographic fabric, adding observations on the typological and chemical properties of each group. Other comments will be found in the general discussion that follows.

Cretan Transport Jars

Fabric A: Main South-Central Cretan

Of the total of 17 pieces assigned to this petrographic fabric, 10 are TSJs and 6 are SNAs. The date range for the former is LM II–IIIB, that for the latter LM IIIA2–IIIB. Both shapes were evidently produced contemporaneously within the western Mesara during the 14th and 13th centuries, but the local production of TSJs clearly anticipated that of SNAs by as much as a century or more. The dearth of LM IIIA1 TSJs is a result of the fact that the samples included only one piece of that date in any fabric. Nine of the ten TSJs in fabric A were placed in chemical group I by INAA (the single exception, sample 98/7, is a chemical outlier), while the six SNAs were divided between chemical groups I and II.

Fabric B: Medium/Coarse Igneous

A total of five samples were assigned to this fabric, all of them from SNAs of LM IIIB date. Two of the five were assigned to chemical group I, but the other three separated out into the tightly clustered chemical group III. This petrographically (and, to a lesser extent, chemically) distinct set of samples provides interesting evidence for what may be a second workshop engaged in the production of SNAs in the western Mesara during the 13th century.

Fabric C: Serpentine

The two members of this fabric, both originally identified as SNAs, were sampled from body sherds. The earlier, LM IIIA2 vessel (sample 98/25) has comparatively thin walls and may in fact belong to an oval-mouthed amphora, or perhaps even to an undecorated TSJ. The later, LM IIIB vessel (sample 98/21), however, has too slim and thick-walled a lower body profile to belong to a stirrup jar or earlier oval-mouthed amphora; although it is atypical for a SNA in bearing the impressions of what appear to be three diagonally transverse string marks on its exterior,[97] it is difficult to imagine to what other shape such a fragment could belong, especially in view of its very close resemblance in profile to the more fully preserved SNA from which sample 98/19 was taken.[98] In chemical terms, both jars would be considered Central Cretan products.

Fabric D: Fine Calcareous Phyllite

These two TSJ samples are early (LM II). Their mineralogy is very distinctive, with no clear parallels in the comparative material. They are based on common Neogene marls, however, so their chemical composition unsurprisingly falls within chemical group I. After the conclusion of the analysis they were identified macroscopically as products of the island of Gavdos, which is compatible with the analytical profile.[99]

97. Rutter 2006a, p. 555, no. 67a/22, pls. 3.78, 3.93:e.

98. Rutter 2006a, p. 569, no. 75/6, pls. 3.83, 3.94:c.

99. Our thanks to K. Kopaka and C. Papadaki for this identification. The two TSJs are both unusual in their painted decoration, though only 98/13 is substantially preserved. The latter was published as a Gavdiot import in Rutter 2006b, pp. 672–674. Sample 98/3 was not identified as Gavdiot in Rutter 2006b.

Fabric E: Metasedimentary

The two samples of this fabric were originally identified as SNAs. Although they have a distinct petrographic composition, they fall into chemical group I, and are therefore thought to be Central Cretan products. The shape of both vessels has been reconsidered since the sampling: sample 98/18 is in fact a necked amphora that is arguably the immediate typological ancestor of the SNA, dating from LM IIIA2 Early, while sample 98/23 comes from a large closed vase, probably another amphora of pre-SNA type. This, then, may represent an early SNA fabric.

Fabric F: Quartzite, Phyllite, and Schist

Petrographically, these two vessels are clearly products of West Crete, matching both West Cretan control groups and the TSJs from Mycenae deemed to be West Cretan. Typologically, sample 98/31, as a LM IIIA2 Early light-on-dark TSJ, is clearly West Cretan. Sample 98/6, however, is cream-slipped over a red-firing clay and was for this reason originally thought likely to be an East Cretan import.[100] The comparatively early date of this piece—LM IA Final, a period before and during which the number of documented TSJs is still comparatively small—suggests that it may be an early West Cretan TSJ.

Fabric G: Phyllite, Siltstone, and Chert

Sample 98/5, from a TSJ fragment found in a LM IIIB context, is worthy of comment as an example of a common Central Cretan TSJ fabric that seems not to be local to the western Mesara (judging from its rarity at Kommos relative to fabric A).

Fabric H: Phyllite

Watrous suggested that the source of TSJ sample 98/8, dated to LM IIIA1, was East Cretan.[101] The East Cretan origin suggested by both the petrographic and chemical analysis is welcome confirmation of this.

Fabric I: Quartz, Polycrystalline Quartz, Schist, and Microfossils

TSJ sample 98/12, dated to LM IIIA2, is a false neck and handle fragment in a fabric that is clearly not local to Kommos. Although possibly related to petrographic fabric F, this sample is not closely identifiable with any particular region of Crete by petrography, chemistry, or typology.

Fabric J: Schist

The distinctive fabric of TSJ sample 98/10 is not matched by anything noteworthy in its chemistry (group I) or decoration (linear body and handle fragment). This piece comes from one of the later LM IIIB contexts in Building P and is chiefly of interest for further expanding the range of discrete, probably South Cretan petrographic fabrics attested in TSJs at Kommos during this period.

100. The vessel is published in Rutter 2006a, p. 429, no. 29/5, as an "import from unknown Minoan production center." See Haskell 2005, p. 208, for the significance of the pale slip and red clay body.

101. *Kommos* III, pp. 31, 153, no. 520, pl. 18.

The Provenances of Cretan Transport Jars

The samples of demonstrable Cretan origin have been classified into six fabrics and four unique samples, which can in most cases be assigned a specific provenance on the island. Several fabrics correspond to known petrographic groups of stirrup jars and other vessels.[102] The main south-central Cretan fabric A is known from several analyses in the western Mesara. The fact that both TSJ and SNA samples belong to this fabric clearly indicates that transport jars of these two types share an area of production, if not an exact location. Chemical analysis confirms the compositional similarity between these samples (chemical groups I and II), as well as their relationship to other ceramics from the Mesara. However, it also demonstrates that they differ chemically from the reference group established for the LM IA kiln at Kommos.[103] The INAA results highlight the possible separation of some SNA samples from fabric A (chemical group II). This grouping may represent variation in the origin of the sand inclusions in these samples, which was not picked up in petrographic analysis, or may simply reflect the uneven distribution of Cr within the south-central Cretan source area.

It is not possible to pinpoint the exact origin of the SNA and TSJ samples in fabric A because of the wide variability in this common fabric. The range of sand-sized inclusions in the samples, however, is compatible with an origin at one or more locations in south-central Crete. In particular, the presence of fine volcanic rock fragments suggests that this fabric may have been produced in the western Mesara (Fig. 10). The elemental profile of chemical groups I and II, to which most of the samples of fabric A belong, is closely related to that of the Neogene marine sediments on Crete.

The medium/coarse igneous fabric B is a variant of the main south-central composition represented by fabric A. The samples belonging to this smaller fabric all come from SNAs. They are also chemically distinctive (chemical group III). The mineralogy of the samples and their similarity to Minoan ceramics found at Moni Odigitrias and Ayia Kyriaki suggest that their raw materials originated somewhere in the foothills of the Asterousia Mountains, south of the Mesara Plain, not far from Kommos (Fig. 10).[104]

The two other fabrics represented among the SNAs, the serpentine fabric C and the metasedimentary fabric E, may also be related to fabric A. The samples belonging to these fabrics cluster with or near chemical groups I and II. While both fabrics could, on the basis of their petrography, come from a number of places in central and eastern Crete, they are not incompatible with the Mesara (Fig. 10).

Thus, the petrographic and chemical analyses of the SNA samples in fabrics A, B, C, and E and in chemical groups I, II, and III indicate that they originate from one or more locations in the Mesara Plain. We have studied 13 different samples of this type of jar from several levels at Kommos and can conclude with confidence that they were a local product.

The majority of the TSJ samples from Kommos, which belong to the main south-central Cretan fabric A, are also likely to have been produced in the Mesara. The compositional similarity between TSJ and SNA samples in fabric A and chemical group I (Fig. 9) strongly suggests that they were

102. For stirrup jars, see the groups in Haskell et al. 2011.

103. For the kiln, see n. 37, above. These differences, however, in no way rule out the possibility of production within the Kommos area, since there is a substantial chronological gap between the sampled jars and the kiln, which went out of use before the end of LM IA.

104. For red-firing schist-related fabrics at Kommos, see Shaw et al. 2001, pp. 117–119, 152–155.

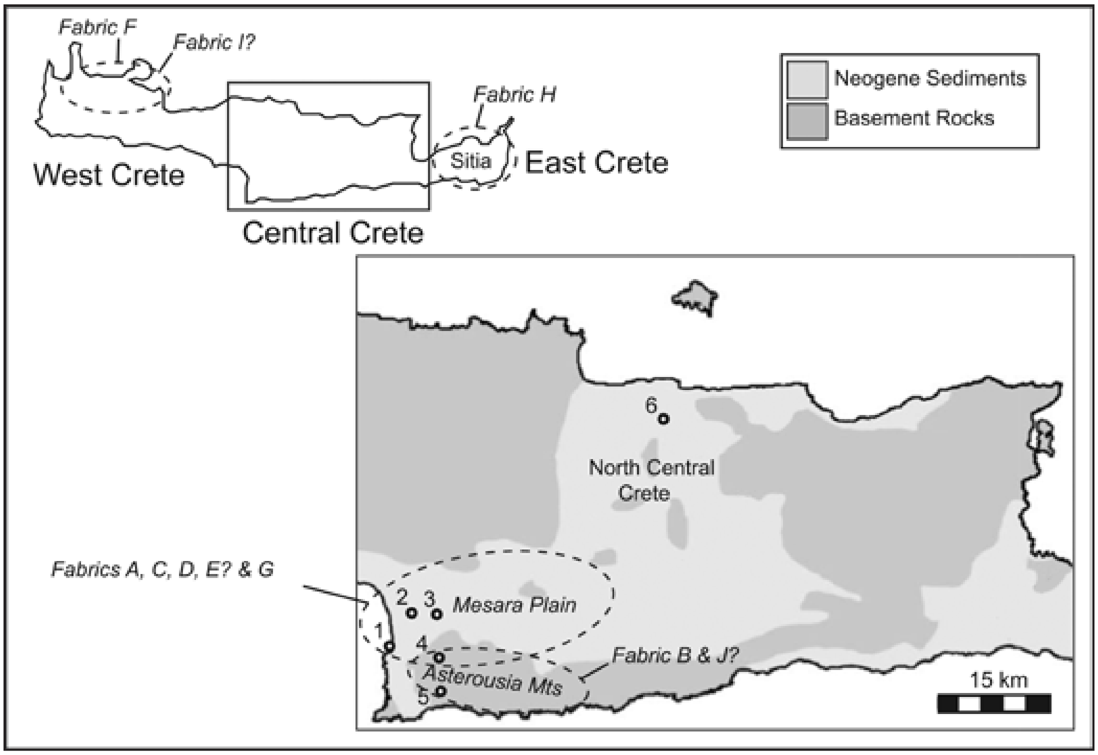

Figure 10. Map showing proposed provenances of Cretan LM transport jars from Kommos. 1 = Kommos, 2 = Ayia Triada, 3 = Phaistos, 4 = Moni Odigitrias, 5 = Ayia Kyriaki, 6 = Knossos. P. S. Quinn

produced from the same raw materials, perhaps even at the same location. The INAA data do indicate some differences between the two vessel types within fabric A, as shown, for example, by the SNA samples that form chemical group II. Most of the other TSJ and SNA samples in fabric A, however, are indistinguishable from one another in composition. The TSJ samples belonging to the fine calcareous phyllite fabric D, the phyllite, siltstone, and chert fabric G, and the schist fabric J are also compatible with an origin in the geological series of Central Crete, clustering as they do within chemical group I. Fabric D may have been produced from metamorphic rock and calcareous Neogene sediments, both of which occur in the Mesara, as well as in other areas of Crete. Fabrics G and J are compatible with a source in the Mesara and have parallels among other Minoan ceramics from this area.

While the majority of the TSJs from Kommos analyzed in this study are likely to have been produced in the Mesara, four samples may have originated elsewhere on the island. These are the samples that constitute the quartzite, phyllite, and schist fabric F, the phyllite fabric H, and the quartz, polycrystalline quartz, schist, and microfossil fabric I. Petrographically and chemically, fabric F matches samples from West Crete, specifically in the Chania Plain (Fig. 10). The related fabric I, which cannot be placed with certainty, may also have originated in the west of the island (Fig. 10). Fabric H is compatible with several locations on Crete where outcrops of phyllite-quartzite rock occur, but the best matches are in East Crete. It is worth noting that, with the exception of fabric D, the four possible non-Mesaran TSJ samples are all located at the opposite end of the dendrogram from the rest of the TSJ samples from Kommos.

Imported Transport Jars

Fabric 1: Quartz and Calcite

The chronological range of fabric 1 at Kommos extends from LM IB to LM IIIB, with over half of the sampled pieces coming from LM IIIA contexts of the 14th century. Most of these vessels are represented by only one or two small fragments found in construction fills. It is thus quite likely that many of the complete vessels actually arrived at Kommos in the course of the 15th century during the LM II–IIIA1 phases of the Monopalatial era, when Knossos, on present evidence, was the only functioning palatial center on Crete. Nothing about the two flasks included in this fabric (samples 98/34 and 98/44) distinguishes them in any way from the larger jars that represent the remainder of the sampled Egyptian imports. The INAA results correlate particularly well with the petrographic assignments. Of the 18 members of fabric 1, 14 were assigned to chemical group VI, and the remaining four were considered to be related to that group (Fig. 9).

Subfabric 1a: Quartz and Calcite with Chert

Subfabric 1a is a particularly tight grouping from all perspectives and may originate in the Jezreel Valley of Israel. The four samples assigned to this subfabric come from CJs recovered from LM IIIA2 Early (samples 98/51, 64, 84) and LM IIIB (sample 98/73) contexts, the last a tiny fragment from what could well be a much earlier vessel. Three of the four samples are assigned to chemical group VIII (the exception is the chemical outlier 98/64), and that group in turn includes only the three samples assigned to this petrographic subfabric.[105]

Fabric 2: Macrofossiliferous Clay Pellet

This fabric contains 11 samples, all of them CJs and eight of them also assigned to and accounting for all members of chemical group V (Fig. 9). Within this petrographic fabric, samples 98/72 and 98/81 are chemical outliers, which indicates a probable difference in provenance. The date range of the fabric is LM IIIA2 Early–IIIB.

Fabric 3: Quartz and Clay Pellet

The four members of this fabric are all assigned to chemical group IV, along with a single related sample (98/82) (Fig. 9). The chronological range is once again LM IIIA2 Early–IIIB.

Fabric 4: Quartz, Chert, and Macrofossils

The three samples in this fabric are also linked chemically as the three members of chemical group VII. All these pieces come from LM IIIA2 Early contexts. They have links with Smith's group 5, which has its origins in the Lebanese coastal plain between Akko and Sidon (Fig. 11).

Fabrics 2 and 4 Related Sample

Sample 98/61 is chemically distinct from both fabrics 2 and 4. It may originate on the Lebanese coastal plain (Fig. 11). Found in a LM IIIB context,

105. After the conclusion of the sampling program, the visiting Syro-Palestinian specialist M. Serpico identified eight additional examples of this fabric among inventoried CJ fragments from Kommos.

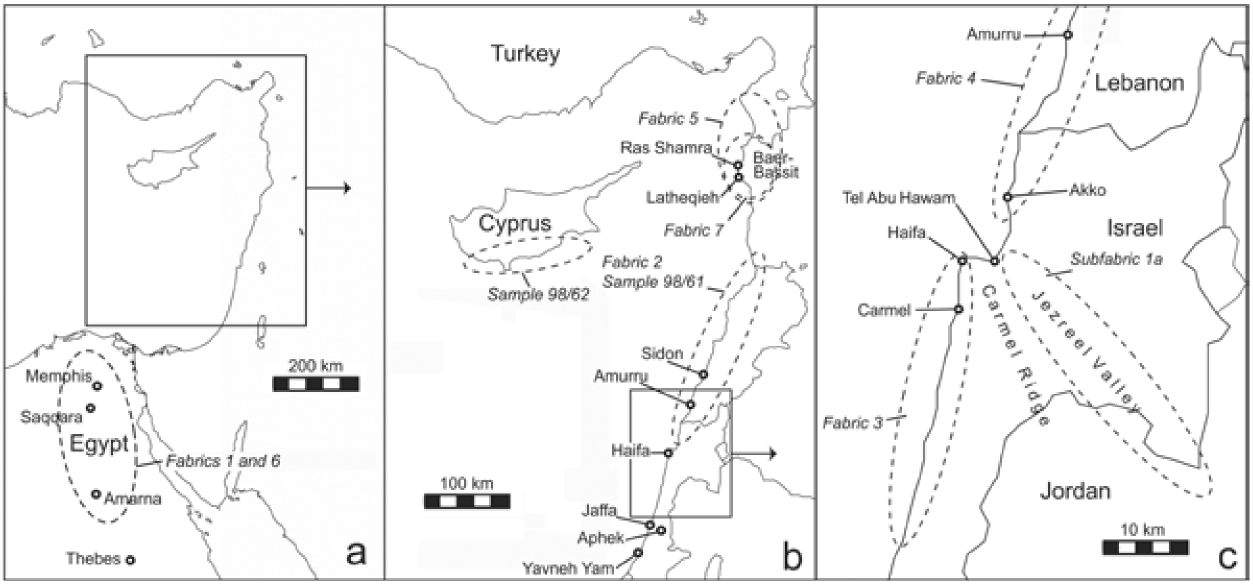

Figure 11. Map showing proposed provenances of non-Cretan LM transport jars from Kommos.
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the lower body fragment that was the source of this sample is extremely heavily worn, suggesting that the original CJ to which the sherd belonged may have been considerably earlier in date.

Fabric 5: Chert

The two samples of fabric 5 are chemically similar, and are the only two samples in chemical group IX (Fig. 9). Their date is LM IIIA2–IIIB. Sample 98/65 was taken from a base fragment of a Syrian flask or spindle bottle, a significantly smaller one-handled shape quite different from the shoulder-handled CJs that constitute the bulk of Syro-Palestinian ceramic imports to Kommos.

Fabric 5 Related Sample

The chemical composition of this sample (98/62) does not appear to be linked with that of any other sampled CJ from Kommos. It could have originated in Cyprus if the similarities noted above are valid. The fragment from which the sample was taken was recovered from a LM IIIA context.

Fabric 6: Fusilinid

These two EJ samples are virtually identical petrographically but not particularly close chemically. One of the samples (98/54) comes from a LM IB Early context, the earliest at the site to have furnished an Egyptian import. The second vessel (98/50), preserved as a large number of sherds, comes from a LM IIIA2 Early building fill.

Fabric 7: Serpentine and Micrite

These samples, from vases found in the same LM IIIA2 Early floor deposit in House X, are only loosely related both petrographically and chemically, but may nevertheless be assigned an origin along the northern Syrian coast in the neighborhood of Ras Shamra (Fig. 11). Sample 98/55 is from a fully restorable vessel and was presumably imported to Kommos not long before being abandoned on the floor ca. 1370.

Fabric 8: Polycrystalline Quartz and Calcite

This sample is a chemical outlier of unknown provenance.

Fabric 9: Quartz and Metamorphic

The pale-slipped and burnished, medium-coarse closed shape from which sample 98/53 was taken is certainly an import to Kommos, but analysis suggests it comes from another Minoan center of production.[106]

Fabric 10: Micaceous Quartz and Feldspar

The single example of this distinctive fabric was considered to be of Egyptian origin when the pale-slipped jar was sampled in 1998. It is as unique chemically as it is petrographically, and is among the comparatively few CJs to have been recovered at Kommos from a LM II context.[107]

Fabric 11: Quartz and Schist

Petrographically, this sample is clearly an import to Crete, and it is also a chemical outlier. The rim fragment preserves traces of a handle attachment on the upper neck, and thus belongs to a rather different large closed shape than the standard shoulder-handled CJ. It was found in a LM IIIA2 Early context.[108]

Fabric 12: Alkali Feldspar

Like the single examples of the two previous petrographic fabrics, the sole representative of fabric 12 is also a chemical outlier. It is clearly an import to Crete.

The Provenances of Imported Transport Jars

Among the samples of non-Cretan CJs and EJs, several petrographic and chemical groups are evident. Comparison with previously published ceramic analyses from contemporaneous archaeological sites and/or the geology of potential source areas make it possible to draw some conclusions about the provenances of these groups.

The majority of the EJ samples from Kommos fall within the quartz and calcite fabric 1, which is equivalent to the homogeneous chemical group VI (Fig. 9). Mineralogically and chemically these samples match comparative material from Egypt, particularly marl fabrics described from the Memphis region of the Nile Delta (Fig. 11:a). The highly distinctive fusilinid fabric 6, formed by two EJ samples containing large fusilinid foraminifera, may also come from the Nile area of Egypt (Fig. 11:a). Petrographically, these samples are unlike those from any other analyzed transport jars, either from Kommos or from other sites represented in the comparative data. They seem to have been produced in Egypt by the

106. Visiting Near Eastern ceramic specialists have been unanimous in rejecting this piece as either Egyptian or Syro-Palestinian, although when sampled it was considered to be an Egyptian import.

107. Both the Egyptian and Syro-Palestinian ceramic specialists who examined this sample recently agreed that it belonged to a CJ and was not Egyptian.

108. While the jar was considered to be Egyptian during the sampling in 1998, it has been subsequently reclassified as Syro-Palestinian (Rutter 2006a, p. 580, no. MI/UP/1).

addition of bioclastic limestone to a marly paste such as that used for the manufacture of fabric 1.

Samples belonging to subfabric 1a, while petrographically similar to the Egyptian ceramics in fabric 1, are chemically distinct and form a separate cluster in the dendrogram (chemical group VIII). These samples bear more similarities to fabrics described from other Canaanite jars in Israel than to the marl fabrics of Egypt. In particular, they provide a petrographic match for fabrics thought to originate in the Jezreel Valley near modern Haifa (Fig. 11:c).

The homogeneous compositional group of CJ samples represented by fabric 3 and chemical group IV can also be ascribed a provenance in northern Israel. This group corresponds petrographically to fabrics described from the New Kingdom sites of Aphek, Jaffa, and Tel Hefer. The origin of such fabrics is thought to be a stretch of the northern Israeli coast south of Haifa (Fig. 11:c).

Fabrics 2 and 4 comprise well-defined groups of CJs that are further confirmed by their chemistry. Related by the presence in both of rounded quartz and distinctive coralline macrofossil inclusions, these fabrics have also been recognized in CJs from the New Kingdom and attributed to a source on the Lebanese coastal plain. The striking similarity between this comparative material and fabrics 2 and 4 suggests that the Lebanese coast may be the origin of many of the imported CJs found at Kommos. More precisely, it is possible that the samples of fabric 4 may have originated in the southern part of this large coastal area, between Sidon and Akko (Fig. 11:c).

The two CJ samples that form fabric 5 are chemically very distinct from all other samples in this study. Petrographically, they have parallels in a Canaanite fabric thought to have originated in the ophiolite complex of the northern Syrian coast. Fabric 7 likewise contains inclusions that may have come from this ophiolite complex and can be linked to fabrics found in the same area, notably at the coastal site of Ras Shamra (Fig. 11:b).

Sample 98/62, which is related petrographically to fabric 5, is chemically very different from these Syrian samples. It can be distinguished from fabric 5 by the nature of its chert inclusions and the presence of additional fragments of igneous and metamorphic rocks. In this respect it resembles the fabric of a previously published Canaanite sample that has been ascribed to southern Cyprus (Fig. 11:b).[109] Another CJ sample, 98/77 of fabric 8, is related petrographically to sample 98/62 and may also have originated in Cyprus, although its chemistry is very different.

Fabrics 10, 11, and 12 are single CJ samples that bear no petrographic resemblance to any other material known from Kommos, Crete, or elsewhere. Fabrics 10 and 12 are also chemically very different from other samples in our analysis. All three samples are clearly non-Cretan, but at present we cannot place them with any confidence. Sample 98/53 in fabric 9 is also problematic. It was originally sampled as an Egyptian import, but its petrography suggests that it may have originated in south-central Crete. Other discrepancies in our petrographic and chemical assessment of the provenance of the imported transport jars at Kommos are the existence of a CJ sample within the otherwise uniformly Egyptian fabric 1 and chemical group VI.

109. Smith et al. 2004, pp. 68–70.

DISCUSSION

The analysis of Late Bronze Age transport jars from Kommos has shown excellent agreement between chemical and petrographic data, each set complementing the other. Along with a remarkable correspondence between the petrographic and chemical groups in this study and those published previously, this agreement has enabled us to make confident statements of provenance, and even to identify possible misclassifications of individual samples.[110] General assumptions based on archaeological evidence alone, such as a north-central Cretan origin for TSJs as opposed to a presumed source in the Mesara for SNAs, have been challenged, and a new picture has emerged with surprising detail.

The 16 pieces originally sampled as SNAs have been reduced to no more than 13, and possibly as few as 12 or 11, by the elimination of pieces that were certainly (samples 98/18, 23, 26) or possibly (samples 98/25 and, much less likely, 98/21) misidentified. The unambiguously identified SNAs are distributed within just two petrographic fabrics (A and B) and three chemical groups (I–III).

One of the petrographic fabrics (B) and one of the chemical groups (III) are restricted to the LM IIIB period; neither these nor chemical group II are represented among the 18 TSJs sampled and analyzed as part of this project. The analysis of the SNA samples demonstrates that there was more than one production center in south-central Crete, and, in the case of the fabric most frequently encountered (fabric A), shows that the same raw materials were used in the production of TSJs and SNAs.

The picture of TSJ sources that emerges from this program of petrographic analysis and INAA is one of great interest. Rather than being linked to the north-central part of the island, the majority of the TSJ samples have been shown to be broadly local to the western Mesara. These include examples presumably from the same workshops as the main SNA group. The vessels extend chronologically from LM II to the time of the effective abandonment of Kommos in later LM IIIB, a span broader than that documented in most previous analyses.[111]

The remainder of the sampled TSJs represent six different petrographic fabrics and four different chemical groups, with no single combination of the two sets of analytical groupings represented by more than two samples; these include a characteristic LM II fabric identified as a product of Gavdos[112] and vessels of LM IIIA2 Early date imported from West Crete. The only Cretan site from which TSJs have been published in numbers roughly equivalent to those now published from Kommos is the coastal center of Chania.[113]

The 18 samples of non-Cretan fabric 1 belong to imported Egyptian transport vessels (two flasks, two necked jars, and 14 probable amphoras). These, together with the two amphora samples of fabric 6, likewise considered Egyptian, represent roughly half of the total number of Egyptian ceramic imports so far identified in LM IB–IIIB contexts at Kommos. Apart from the fusilinid foraminifera, which set the two representatives of fabric 6 apart petrographically, and the atypical chemical composition of one of these samples (98/54), there is no evidence for subdivisions within

110. See n. 11, above.
111. Haskell et al. 2011.
112. See n. 99, above.
113. Hallager and Hallager 2000, pp. 144–146; 2003, pp. 214–217.

this corpus of almost 20 analyzed samples. The two flasks, the two necked jars, and the abundant amphoras occur in the same fabric, which is familiar from petrographic and chemical comparative material found in Egypt.

The 34 samples now considered to belong to Syro-Palestinian transport vessels (one spindle bottle and 33 CJs) represent exactly half of the 68 Late Bronze Age Syro-Palestinian imports thus far inventoried from LM IB and later contexts at Kommos.[114] Several fully restorable CJs have been found in LM IIIA2 Early floor deposits in House X, as well as in the court in front of Building P in a somewhat later LM IIIA2 context. These discoveries of imported CJs in what are, in effect, contexts of primary use at Kommos confirm the broader picture of their chronological distribution provided by all of the recovered CJ fragments at the site, namely that the peak period of their importation was the 14th century. Yet it is also clear that the earliest CJs to appear at Kommos had arrived before the end of the Neopalatial era (two from LM IB contexts, neither sampled for analysis), and that the bulk of those inventoried (a total of 37 pieces) come from contexts of the Monopalatial era (LM II–IIIA2 Early), when a Knossian administration dominated Central Crete and perhaps utilized Kommos as its principal southern outlet for intercultural exchange.[115]

Petrographic and chemical analyses have been able to identify groups of CJs that were produced in several regions of the Levantine coast, as well as distinctive fabrics from coastal Syria and probably Cyprus. The links between the CJ groups at Kommos and those published by Smith's team are remarkably close and allow us to posit well-defined geographical areas of origin. Almost half (30) of the 65 imported CJs inventoried from Kommos belong to just three fabric categories, which have been assigned by the Cambridge Amphora Project to production zones in the northwestern Jezreel Valley (Smith's group 1 = our subfabric 1a and chemical group VIII), along the coast of northern Israel south of Haifa (Smith's group 2 = our fabric 3 and chemical group IV), and along the Lebanese coast further to the north (Smith's group 5 = our fabrics 2 and 4 and chemical groups V and VII). The production zone of a fourth group of CJs, only about half as popular at Kommos as any of the preceding three, has been identified as the Syrian coast in the neighborhood of Ras Shamra (ancient Ugarit) (Smith's group 4 = our fabrics 5 and 7 and chemical group IX). Notwithstanding the popularity of these four Syro-Palestinian fabrics at Kommos, one of the more striking features of the corpus of CJs from the site is its overall heterogeneity. Among the 33 sampled CJs, a total of 12 distinct, petrographically defined fabric types are represented, most of them also exhibiting discrete patterns of chemical composition as well.

Overall, then, this analysis of the principal types of transport jar present at Kommos in the Late Bronze Age has revealed a wealth of information. The area of the Mesara has been shown to have hosted the production not only of SNAs, but also of TSJs, the latter over a longer period of time. Petrographic fabrics representing production from the same raw materials have demonstrated that at least some of the SNAs and TSJs shared a production location.

Turning to the imported Egyptian amphoras and other shapes, we note a remarkable uniformity of composition, perhaps reflecting their origin at

114. Rutter 2006b, pp. 649–653. About 10% of this total (n = 7) occur as kick-ups in historical levels, a clear indication that the dates of the contexts in which these and other similar pieces have been found are simply termini post quos and do not necessarily constitute reliable dates for the arrival of such imports at Kommos, much less for their actual dates of production at various centers in the Levant. This caveat is particularly applicable to the examples of such containers recovered in the form of small fragments within chronologically mixed building fills.

115. Rutter 2006b, pp. 684–687; 2006c.

a single location over a long period of time. Although both petrography and chemistry suggest a provenance in the Memphis region, further work in Egypt is required to be more confident about the origins of this specific fabric. In contrast to the EJs, the CJs from Kommos represent a variety of sources that have been isolated with some precision, and their origins, from a number of locations along the Syro-Palestinian coast, reveal maritime trade connections between Kommos and specific areas of the Levant.

Comparative evidence also enables us to speculate about the probable contents of these jars. While there is reason to believe that TSJs may have been used for the transportation of perfumed oils,[116] we have as yet little indication of what the SNAs may have held. Hieratic inscriptions on Egyptian amphoras from the Nile Delta indicate that they held wine, but what of the Canaanite jars, with their variety of origins? The work of the Cambridge Amphora Project holds the key to such questions, and their data correspond well to the fabrics identified in this study. Through an array of techniques, Serpico and others have shown that those CJs with origins on the Lebanese and Syrian coasts carried resin, probably terebinth resin, while those from the coastal region of Israel and the Jezreel Valley usually contained oil.[117] The integrated physical and chemical analysis of coarse-ware pottery fabrics has thus provided a window on the movement of various goods and commodities around the eastern Mediterranean, as well as the place of the harbor of Kommos in that activity.

116. Shelmerdine 1984.
117. Bourriau, Smith, and Serpico 2001, pp. 140–144, with references.

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