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GODDESSES, SNAKE TUBES, AND PLAQUES

Analysis of Ceramic Ritual Objects from the LM IIIC Shrine at Kavousi

ABSTRACT

Ceramic ritual objects from the Late Minoan IIIC (ca. 1175–1050 B.C.) shrine at Kavousi, Crete, were analyzed by thin-section petrography and scanning electron microscopy. The authors investigate aspects of the objects' production technology, drawing on the extensive comparative data available in the study area. It appears that potters manufactured these items as sets, in different locations around the Isthmus of Ierapetra, utilizing different raw materials, paste recipes, and firing conditions. These contrasting technologies relate to those used in the manufacture of cooking pots and to a range of jug/jar types, indicating that objects considered specialized may have been made by different groups of potters in the same area.

PROVENANCE, TECHNOLOGY, AND POTTERS' TRADITIONS

The physicochemical analysis of pottery has been employed regularly in the study of prehistoric Crete and the Aegean to elucidate questions of both provenance and technology.[1] Chemical analysis has succeeded in isolating compositional divisions on the island of Crete that have proved invaluable

1. We are grateful to the Greek Archaeological Service and the American School of Classical Studies at Athens for permission to sample ceramics from Kavousi. Our work has been facilitated by Metaxia Tsipopoulou, the late Nikos Papadakis, and Costis Davaras on behalf of the 24th Ephorate of Prehistoric and Classical Antiquities. Leslie P. Day and the late William D. E. Coulson, the codirectors of the Kavousi Project (G. C. Gesell, Executive Director), were most generous in their support of our work. We are grateful to them for discussion regarding fabrics and also to the following colleagues in the Kavousi team for their observations on ceramics at the site: Kevin Glowacki, Donald Haggis, Nancy Klein, Margaret Mook, and Lee Ann Turner.

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in early studies of exchange and trade.[2] Studies of ceramic technology, primarily by scanning electron microscopy (SEM), met with some success. Notable among these have been the analysis and reconstruction of decorative techniques[3] and the study of firing technologies.[4]

More recently, ceramic petrography (PE) has offered additional possibilities for the scientific study of archaeological pottery. In the favorable geological conditions of Crete, PE has been used to narrow clay sources down to geological types and sometimes to specific locations. Yet its contribution has been not only in the field of provenance, but also in providing information on the technology of a ceramic. It is this sort of detail that dovetails with the renewed interest in the study of technology contextualized in social relations of the past.

Such new-found capabilities in ceramic analysis allow us to address questions more complex than the reconstruction of exchange relations through joining points in space. The approach works on a variety of levels and it is now acknowledged generally that a tailor-made integration of different suitable analytical techniques is the best strategy in many cases. These often revolve around the application of chemical (neutron activation analysis [NAA], X-ray fluorescence [XRF], and inductively coupled plasma emission spectroscopy [ICP-AES]), mineralogical (PE, X-ray diffraction [XRD]), and microstructural techniques, such as SEM, to give a view of the many aspects of pottery production, exchange, and consumption.[5]

In this light, analytical studies of ceramics can elucidate a number of issues current in the consideration of Minoan material culture: the range of traditions that existed in the manufacture of ceramics, how the organization of production related to social and economic change, how finished products were exchanged, and the investigation of consumption patterns across the Minoan landscape.

Here we present a study of ritual objects—goddess figures,[6] snake tubes, and plaques—from the Late Minoan (LM) IIIC shrine at Vronda, Kavousi, in East Crete. Our aim is to characterize the different ceramic fabrics used for the manufacture of these objects in order to clarify their location and history of production. These are special objects, relatively rare, which we suggest would also have been special in the past. The story of their manufacture and how they were found together as offerings and ritual equipment in one shrine is of interest in revealing the nature of social relations not only in the ceramic landscape, but also in the sacred landscape of the Isthmus of Ierapetra.

2. For a summary of early analyses in Crete, see Jones 1986.

3. E.g., Noll, Holm, and Born 1975; Stos-Fertner, Hedges, and Evely 1979; Noll 1982; Betancourt et al. 1984; Betancourt and Swann 1989; Swann, Ferrence, and Betancourt 2000; Faber, Kilikoglou, and Day 2002.

4. Maniatis and Tite 1981; Maniatis, Katsanos, and Caskey 1982; Maniatis 1984; Kilikoglou 1994.

5. E.g., Day et al. 1999; Tite 1999; Shaw et al. 2001.

6. The use of the term "figures" follows French 1981, p. 173; for a discussion of the term "goddess" and whether these figures conventionally referred to as Goddesses with Upraised Hands (or Arms) in fact represent goddesses, see Gesell 2004, pp. 131, 143–144.

CERAMIC PRODUCTION, CONSUMPTION, AND RELIGION IN BRONZE AGE CRETE

LM III pottery has been considered a prime subject of interest in the investigation of changes in the social and economic landscape of Crete.[7] Biographies of even the most ordinary ceramics offer a variety of insights into the way objects were created and used at the end of the Bronze Age, a time thought to be one of considerable change. Until now, however, analytical work has been largely restricted to that on transport stirrup jars and other traded ceramics.

In general, studies of ceramic production have moved on from the time when anything prior to the building of the palaces was considered simple and dispersed, based around the household. We know that pottery making and exchange were more complex, even in the Early Neolithic,[8] while production in the Early Bronze Age was clearly carried out in a specific number of centers, with wide distribution of the potters' products.[9] Recently, Knappett has produced a sophisticated study of the possible links between pottery manufacture, exchange, and consumption and the politico-economic organization of the early state in the Middle Minoan period.[10] These analyses have made it clear that pottery production varied substantially over different regions and times. Another notable aspect of such ceramic studies is the evidence they provide that ritual objects were often manufactured to very high standards in both the Early and Middle Bronze Age[11] and that their patterns of exchange and consumption are similar in many ways, in spite of changes in at least the built environment at key palatial sites.[12]

Recently, others have studied ritual objects in an effort to understand the social, political, and religious landscapes of Crete, with a clear emphasis on those objects at the open-air shrines we refer to as peak sanctuaries.[13] Ceramic analysis to trace the origin of such offerings has been used to determine the sphere of influence of particular ritual sites on the island.[14] Broad changes in the relationship between sacred and natural landscapes have been posited for the Minoan period. Ritual activity is often thought to have undergone transformations of scale and organization, with Peatfield arguing that in the Middle Minoan peak sanctuaries we see ritual sites that represent a popular religious practice in a mystified countryside, which is subsequently appropriated by the palatial elite by the Neopalatial period.[15] Thus we have the close relationship between the peak sanctuary of Juktas and the palace at Knossos, a case of centralization that may break down upon the destruction of the palaces. Does cult or ritual become less centralized and more town-centered in the Postpalatial period? How would we expect this to be represented in the material culture found in shrines of this period?

While we do not expect a complete reflection in material culture of the nature and organization of ritual, clearly there are links that might usefully be investigated to further our knowledge of society at this crucial transitional phase. If material culture sets are deposited or used in shrines as part of ritual activity, the location of their manufacture may give some indications as to spatial organization and movement over the landscape.

7. E.g., Pålsson Hallager 1985; Borgna 1997.
8. Tomkins and Day 2001; Tomkins, Day, and Kilikoglou 2004.
9. Day, Wilson, and Kiriatzi 1997.
10. Knappett 1997.
11. Wilson and Day 1994, pp. 70–82; Faber, Kilikoglou, and Day 2002.
12. Day and Wilson 1998, 2001.
13. Rethemiotakis 1997; Karetsou and Kourou 1997.
14. Maniatis et al. 1992.
15. Peatfield 1987.

THE SHRINE AT KAVOUSI AND ITS RITUAL EQUIPMENT

Recent excavations at Vronda near the modern village of Kavousi have revealed a LM IIIC settlement comprising a complex of domestic buildings, a shrine (building G), and a pottery kiln. Although the site contains some earlier pottery from the Early and Middle Bronze Ages and the area was later used extensively for the placement of graves during the Geometric period, its main phase of use is the LM IIIC settlement (ca. 1175–1050 B.C.). The excavation of building G, identified as a shrine by its deposit of ritual objects, which is our interest here, has been presented in a series of preliminary reports.[16]

The shrine comprises two rooms with benches along their east walls. There was a substantial scatter of broken fragments of ritual objects outside the building to the south and west of room 1. Numbering over 4,000 sherds in all, the deposit contained figures of the Goddess with Upraised Hands, snake tubes, plaques, and kalathoi. It is likely that much of this deposit was created when, in the Late Geometric period, grave 19 was dug into room 1. Prior to this, many of the goddess figures and their ritual equipment may have been grouped on and in front of the bench of room 1. A few fragments were found in room 1 itself, mostly in the northeast corner outside grave 19; a second group of ritual equipment was discovered in room 2, some of it intact or nearly so, though none was in situ on the floor.[17] Through painstaking work, many of these ritual vessels have now been reconstructed (Fig. 1), studied in terms of their fabric and technology of construction,[18] and compared to other similar assemblages on the island. There are more than 26 separate Goddesses with Upraised Hands, while parts of at least 37 plaques and 33 snake tubes exist.

Macroscopic examination makes it clear that the fabrics of the goddess figures, snake tubes, and plaques vary considerably. All three types of object are made in a range of fabrics, which are present also in the domestic ceramic assemblage, notably in cooking pots and storage jars. One goddess, snake tube, and plaque occur in the same distinctive micaceous red clay, while another goddess, snake tube, and plaque are made from a light-colored, calcareous clay with frequent sandy inclusions. This gives the impression that there existed sets of objects, comprising a goddess figure with associated, matching ritual equipment.

GODDESS FIGURES, SNAKE TUBES, AND PLAQUES

The ceramic ritual equipment found at Vronda bears comparison with deposits from a variety of similar shrine sites of the LM IIIB and IIIC periods. It is to the earlier period that the geographically close deposit of Gournia belongs. Gournia lies some 10 km west of the shrine at Kavousi. Situated near the top of the west side of the ridge running through the town, the shrine contained at least three goddess figures and five snake

16. Gesell, Day, and Coulson 1988, pp. 289–290; Gesell, Coulson, and Day 1991, pp. 161–163; Gesell, Day, and Coulson 1995, pp. 78–82.

17. Gesell, Day, and Coulson 1995, p. 80.

18. Gesell 1995; Gesell and Saupe 1997.

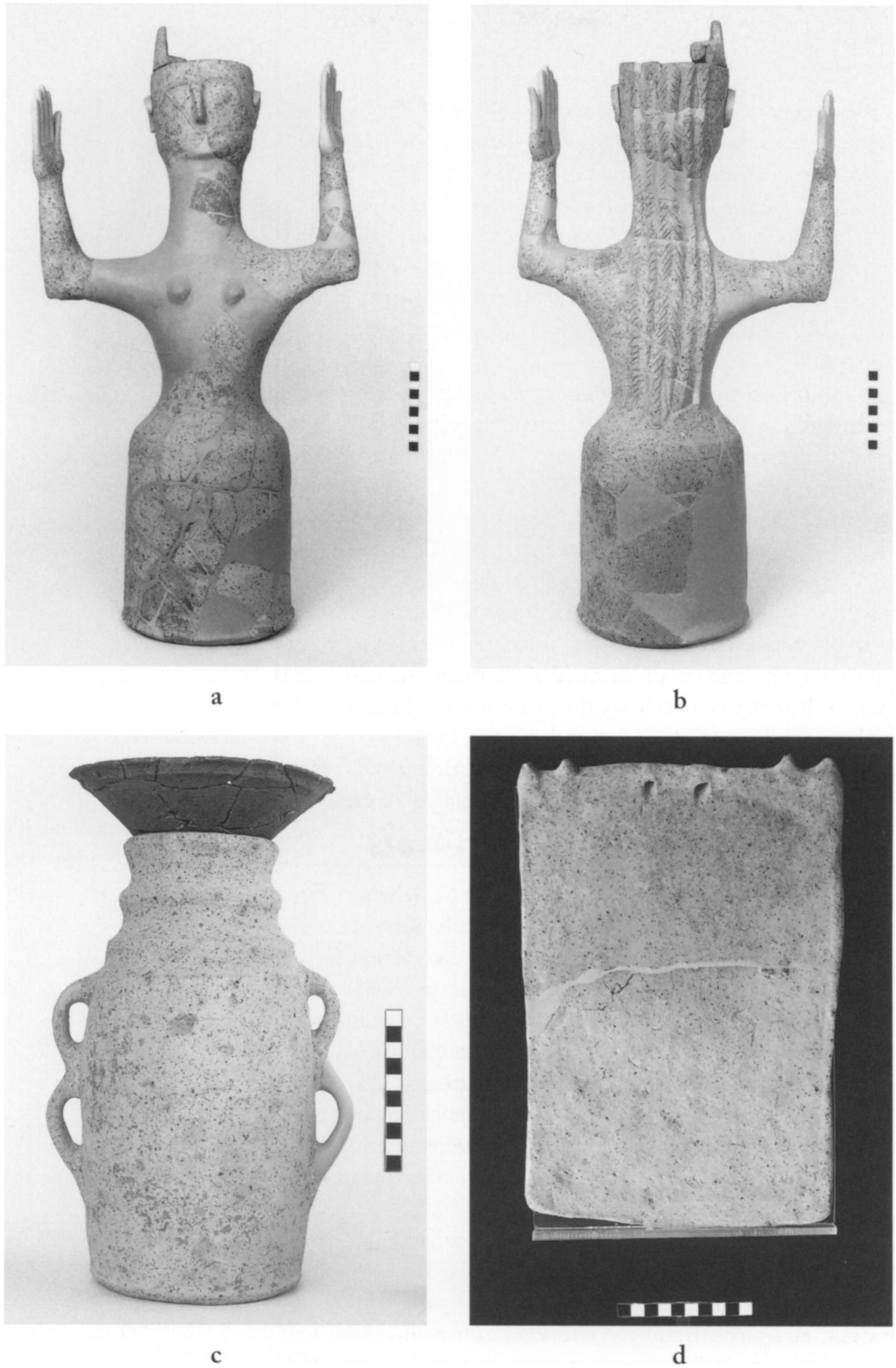


Figure 1. Ritual objects from Kavousi: (a, b) goddess figure 1, front and rear views; (c) snake tube 4 with kalathos; (d) plaque 2

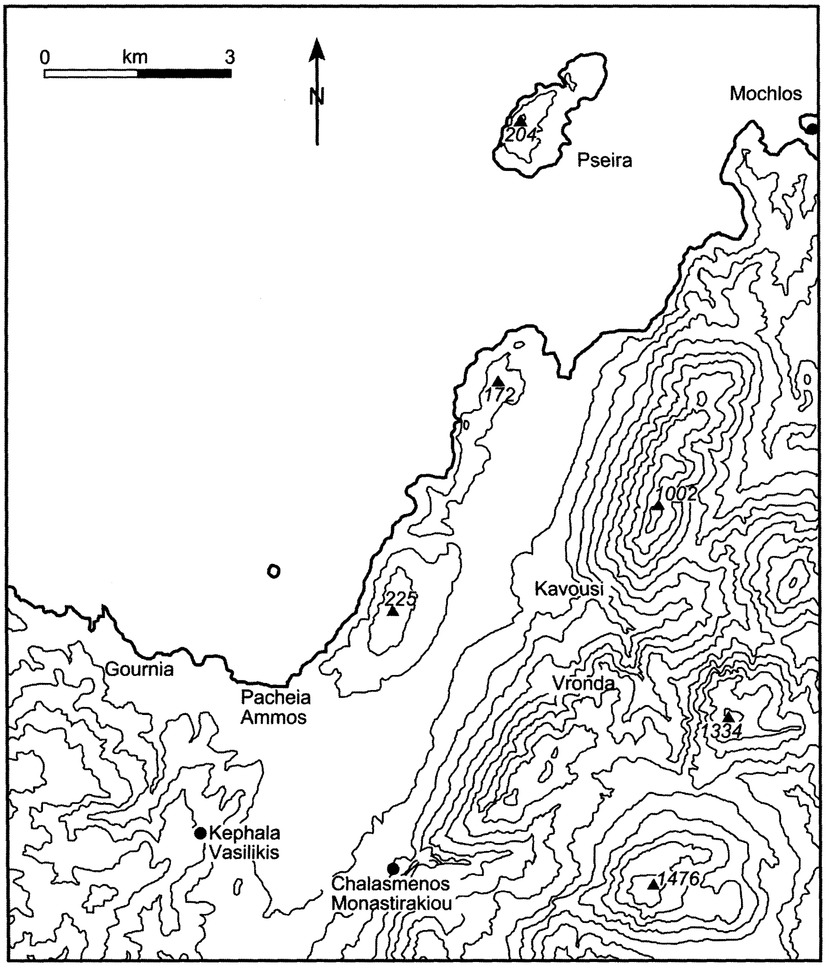


Figure 2. Map of the Kavousi area, showing sites mentioned in the text

tubes, of which the best-preserved goddess and one snake tube are of the same poorly fired red clay.[19] Since the present study was carried out, further examples of shrines with Goddesses with Upraised Hands have been found at Kephala Vasilikis[20] and at Chalasmenos Monastirakiou,[21] the locations of which are shown in Figure 2. Other close typological parallels for the goddess figures, snake tubes, and plaques were found farther afield in Gazi, Kannia, Karphi, Knossos, and Prinias.[22]

All the goddess figures are similar in dress and pose, but they differ in details. They stand on their cylindrical skirts with upper arms outstretched to front or side, bent at elbow so that the forearms and hands are raised.[23] The construction techniques are also similar; the larger sections of the skirt, torso, and head were thrown on the wheel.[24] Details of modeling and decoration, however, vary from potter to potter and the ritual symbols on the figures' tiaras vary from site to site. The most common symbols are snakes and birds but horns of consecration, palettes, and, at Gazi, poppy heads appear. The last item suggests the use of opium in the ritual.

The distinctive features of snake tubes, ritual stands for holding bowls (kalathoi) filled with offering material,[25] are also similar from shrine to shrine. They are cylinders thrown on the wheel, with ringed top, beveled

19. Hawes et al. 1908, pp. 47–48.
20. Eliopoulos 1998.
21. Tsipopoulou 2001.
22. Gesell 1985, pp. 41–56.
23. Gesell 1985, pls. 43–49.
24. Gesell and Saupe 1997.
25. Gesell 1976; Gesell 1995, pls. 140–149.

bottom, and opposing serpentine handles. Most are open at the bottom. Differences occur in the number of rings, the number of loops on the handles, and the ritual symbols. Snakes, birds, a bull's head, an *agrimi,* and horns of consecration occur.

The plaque is a flat rectangular slab of clay; most of those preserved at the top have suspension holes for hanging the plaque from the wall or ceiling.[26] The technique of making them varies. Some are rolled with a frame left at the top, while others have a separate frame attached on all four sides. A few have traces of paint, while others have relief decoration. One from Karphi is topped with a head. It is likely that all displayed a ritual scene like those from Kannia.[27]

The goddess figures from Kavousi fit into the general pattern, that each was part of a ritual assemblage, together with a snake tube and plaque, belonging to a shrine. It is also clear that this assemblage, as suggested by those found earlier at Gazi, was a matching set, not only in the way that it was used, but also in the way that it was produced. At Gazi each of the five goddess figures was associated specifically with an offering vessel.[28] One goddess is made from a characteristic fabric that is the same as that of her accompanying plaque; the fabric of a second goddess matches that of her snake tube. The fabric of a third goddess, on the other hand, was different from that of her snake tube, but both objects were covered with the same red paint so that the surface appearance of their fabric was the same. The fabrics of the fourth and fifth goddesses matched those of a pedestal bowl and a cylindrical vessel. It has been suggested that each pair was brought to the shrine as a set.[29] At Kavousi, too, it is apparent that goddess figures often have the same fabric as plaques and snake tubes.

Were there, then, only a restricted number of locations where these ritual ceramics were produced? Certainly the figures throughout the island follow a general typological and technological pattern, but they vary in fabric and in details of style and construction, suggesting that their production was more widespread. An alternative scenario then arises, that these special objects might have been produced by itinerant potters, an explanation that has been popular in consideration of ancient Cretan ceramic production due to the presence of itinerant storage jar makers in the recent past.[30] It is through the analyses presented in this article that we hope to choose between these alternative explanations, to reveal more about ceramic production in the area of the Isthmus of Ierapetra at this time, and to provide information on the use of the shrine at Kavousi.

The Kavousi shrine assemblage breaks down into clearly differentiated fabrics that relate to fabric types used in the quantification of the whole ceramic assemblage at both the Vronda and Kastro sites. Thus the analysis of the ritual objects and the choice of samples are based on very large numbers of recorded sherds and vessels.

26. Gesell 2001.
27. Gesell 1985, pl. 108.
28. Gesell 1985, pp. 69–71.
29. Gesell 1985, p. 44.
30. Voyatzoglou 1974; Day 2004.

RITUAL CERAMICS AND POTTERY PRODUCTION IN THE ISTHMUS OF IERAPETRA

Most of the figures and associated objects discussed above are essentially coarse ware, manufactured from fabrics normally associated with storage jars and cooking vessels. They bear little relation to some of the fine wares found on earlier ritual sites in Central and East Crete or, indeed, to the fine wares of the LM IIIC period. The issue here is to find the provenance of the raw materials. If it is not possible to identify their specific geographical locations, one can nevertheless gain an appreciation of the general nature of the geological materials present in the pastes.

Macroscopic examination suggests that the goddess figures and other objects are made from at least two fabrics familiar from groups of storage jars and two or more other fabrics normally found in cooking vessels at Kavousi. A goal of the project was thus to compare the fabrics within the two categories (jars and cooking pots) and to characterize any differences in production methods between the two in order to relate them to technological traditions or practices. Ultimately this can tell us much about how many groups of potters may have been involved in the production of such objects.

We already know much about pottery production in the Isthmus of Ierapetra, mainly in the periods from Early Minoan (EM) I to LM I. Here, perhaps more than any other area of the Aegean, macroscopic, petrographic, and chemical study of ceramics has played an important role. Minoan ceramics have been analyzed from Kalo Chorio, Kavousi, Gournia, Mochlos, Pseira, and sites discovered by the Vrokastro Survey and the Kavousi Survey (Fig. 2). Best known are the granitic/dioritic ceramics, commonly referred to as Mirabello fabrics, that have their origin in this area[31] and that seem to have a wide currency across East Crete. They appear as early as the Early Neolithic period.[32] Other fabrics manufactured from metamorphic raw materials have also been recorded.[33] The Kavousi Survey coarse-ware fabric series has been extended and applied to the excavations at Kavousi, while the Vrokastro Survey has also produced a detailed fabric typology.[34] Analyses of material from Kavousi, as well as a fabric series used in the quantification of Neopalatial levels at Mochlos, have been published.[35] These studies have shown that a number of production centers existed in the area of the Isthmus that are notable for the longevity of their activity.

THE ANALYTICAL PROGRAM

The questions addressed here involve aspects of both provenance and technology of the relatively coarse ceramics. Analytical techniques are required that characterize raw materials and provide information on their manipulation and the nature of the firing process. To fulfill these requirements, a combination of petrographic analysis and scanning electron microscopy is best suited. The former technique, as described above, provides information on the geological and possibly the spatial origin of the raw materials through comparative work both with geological material and samples of other archaeological ceramics from neighboring, often

31. Betancourt et al. 1979; Betancourt 1984; Day 1995, 1997; Whitelaw et al. 1997.

32. Tomkins and Day 2001.

33. Betancourt and Myer 1995.

34. For Kavousi, see Haggis and Mook 1993; Haggis 2005; Mook 2005. For Vrokastro, see Hayden 2003, 2004, 2005.

35. Day, Joyner, and Relaki 2003; Day et al. 2005.

TABLE 1. ANALYZED SAMPLES OF RITUAL OBJECTS AND COMPARATIVE MATERIAL

Sample	*Description*	*Sherd No.*	*Trench*
Ritual Objects			
Kavousi 93/1	goddess 7	3180	V8802.3
Kavousi 93/2	snake tube 3	–	V9904.2
Kavousi 93/3	goddess 2	–	V9904.1
Kavousi 93/4	plaque 5	3871	V8817.2
Kavousi 93/5	goddess 24	1491	V8812.7
Kavousi 93/6	goddess 17	1607	V9314.1
Kavousi 93/7	snake tube 1	3484	V8906.7
Kavousi 93/8	goddess 16	–	V8905/8906/8907
Kavousi 93/9	snake tube 17	3762	V8905.4
Kavousi 93/10	plaque 1	–	V9904.2
Kavousi 93/11	snake tube 11	1616	V9306.4
Kavousi 93/12	snake tube 13	1708	V8305.4
Comparative Material			
Gournia 88/1	Neopalatial amphora with painted lily pattern		
Kavousi 93/13	cooking vessel, LM IIIC		
Kavousi 93/14	cooking vessel, LM IIIC		
Kavousi 93/18	cooking vessel, LM IIIC		
Kavousi 93/25	horned kalathos, LM IIIC		
Kavousi 93/66	pithos, MM		
Kavousi 93/102	body sherd, EM		
Lasithi 88/9/3	water jar from modern kiln site at Vainia		
Lasithi 88/95	clay sample of terra rossa from Aphendis Christos, Kalo Chorio		

contemporary, sites. The SEM, through examination of the microstructure of a ceramic, allows the investigation of firing conditions, specifically the equivalent firing temperature and atmosphere. This information supplements macroscopic study of the techniques used in the construction of these objects,[36] and also aids in the reconstruction of specific practices or recipes used in selecting and manipulating raw materials. The latter can be useful in defining traditions of pottery manufacture,[37] which can reveal much about both the organization of the craft during different periods and about human groups within an area.

Twelve samples of the ritual ceramics were analyzed by both PE and SEM, along with roughly 200 ceramic samples from the Kavousi excavations. These are representative of a much larger number of samples that are firm members of the same macroscopic fabric groups. Comparative samples from the material examined from Kavousi and nearby sites are presented here to show the direct link between the fabrics used for the goddess figures and other objects and those used in utilitarian pottery (Table 1). The comparative vessels include examples of Neopalatial, Protopalatial, and especially Prepalatial date. Together they indicate the nature and source of a variety of fabrics, as it can be shown that the production locations or raw-material sources in the Ierapetra region spanned the Bronze Age and beyond.

36. E.g., Maniatis, Katsanos, and Caskey 1982.

37. Whitelaw et al. 1997; Livingstone Smith 2000; Day 2004.

THIN-SECTION PETROGRAPHY

Thin sections of the ritual ceramics and comparative material were examined with a polarizing microscope and described using a modified version of the system proposed by Whitbread.[38] The analyses reveal information not only on the geological origin of the raw materials, but also on the ways in which those raw materials were mixed, tempered, and fired. Detailed descriptions are provided in the Appendix, while comments on those descriptions are included in the text below. Here it will suffice to consider each description in turn, followed by a short summary of the results.

Group 1: Frequent Low-Grade Metamorphic Rocks

Kavousi 93/11 (snake tube 11), 93/18 (cooking vessel)

The fabric in group 1 corresponds to type XVI in the Kavousi coarse-ware fabric series (Fig. 3:a, b). It is characterized by a wide range of very low-grade, low-grade, and rare medium-grade metamorphic rock fragments, set in a groundmass rich in mica laths and quartz grains. The fabric is coarse-grained, appearing to be bimodal, with coarse metamorphic rock fragments set in a finer-grained groundmass. The aplastic inclusions indicate an origin for this fabric in the Phyllite-Quartzite series (Fig. 4), which hosts a range of mainly low-grade metamorphic rocks[39] and which runs east from the area of Kavousi.[40] The red-firing clay is optically active, which suggests a relatively low firing temperature. Kavousi 93/18 has a ribbon of orange clay running parallel to the vessel margins within the red-firing base clay, while areas of finer-grained clay are visible within Kavousi 93/11. These textural features may suggest that the fabric is the product of mixing two or more clays, a practice common in modern pottery of East Crete.[41] The same distinctive fabric occurs in cooking vessels of LM IIIC at Kavousi and is taken to be a product made either around Kavousi or in the area to the east that hosts the Phyllite-Quartzite series.

Group 2: Acid Igneous Rocks

Kavousi 93/5 (goddess 24), 93/14 (cooking vessel)

The macroscopic fabric of goddess 24 corresponds to type XXV in the Kavousi coarse-ware fabric series (Fig. 5:a). With a red-firing matrix, it contains frequent inclusions of acid igneous rocks, mostly granite. These rocks are characteristic of those fabrics referred to in the literature as Mirabello fabrics (see above) and occur as intrusions into limestone along the southern edge of the Gulf of Mirabello, roughly from Kalo Chorio to Pacheia Ammos, with another group of intrusions around the village of Kapistri, northwest of Kentri (Fig. 4).[42] In addition, the constituent minerals and rock fragments of granite and diorite occur in both Neogene deposits and Quaternary alluvium within the Isthmus area.[43] As the red-firing groundmass of these fabrics contains the same mineral constituents in the

38. Whitbread 1986, 1989, 1995.
39. Wachendorf et al. 1974.
40. Papastamatiou et al. 1959; Durkin and Lister 1983.
41. Blitzer 1984, pp. 146–148; Day 2004, pp. 129–132.
42. Baranyi, Lippolt, and Todt 1975.
43. Day 1995, pp. 159–161; 1997.

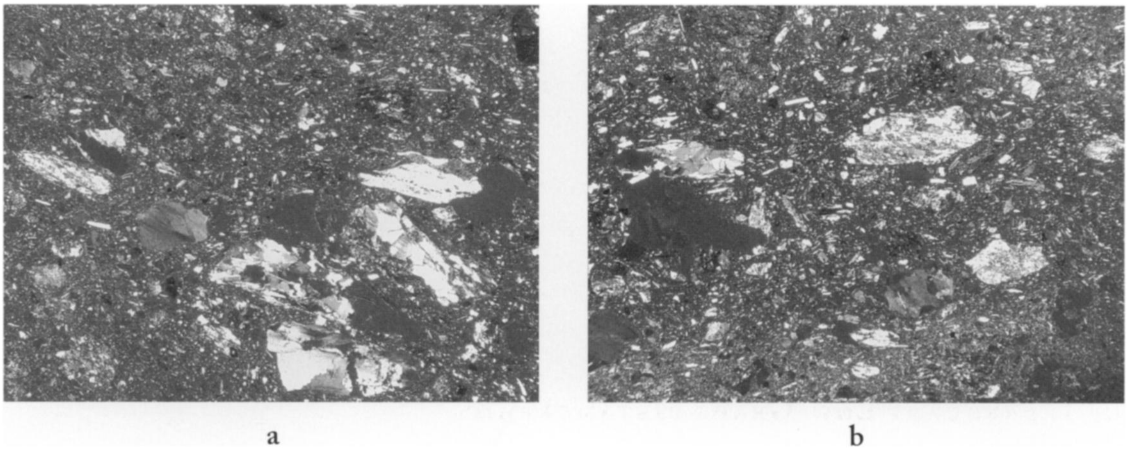


Figure 3. Photomicrographs of (a) Kavousi 93/11 (snake tube 11) and (b) Kavousi 93/18 (cooking vessel), group 1, with low-grade metamorphic rocks in a mica-rich groundmass. Crossed polars, horizontal dimension 7.4 mm

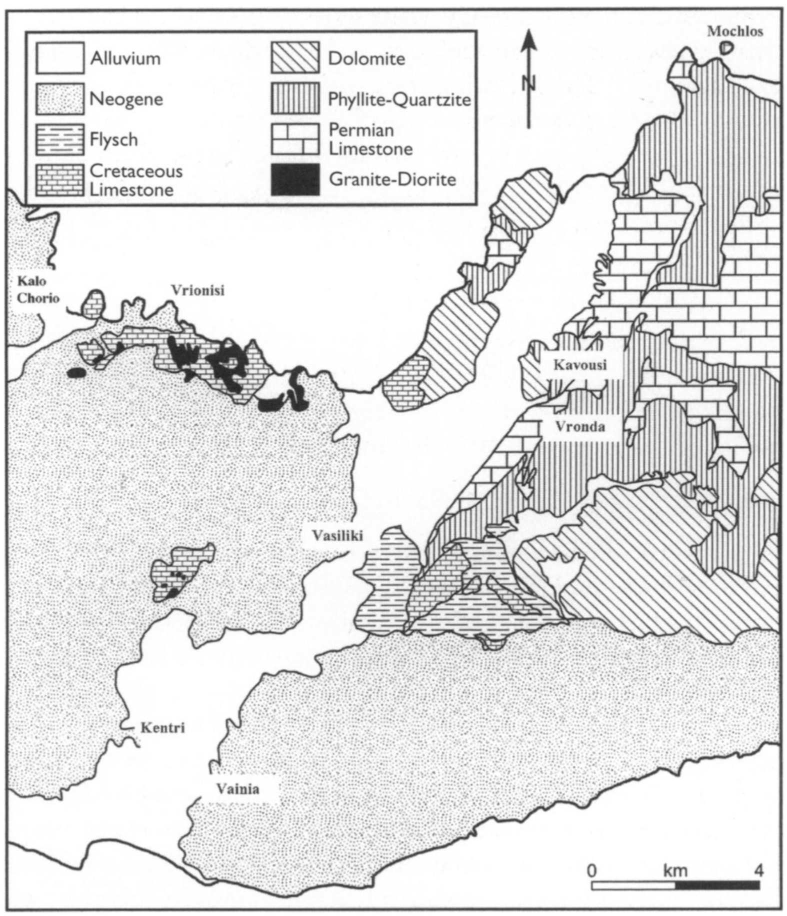


Figure 4. Geological map of the study area. After Papastamatiou et al. 1959; Fortuin 1977, enclosure I

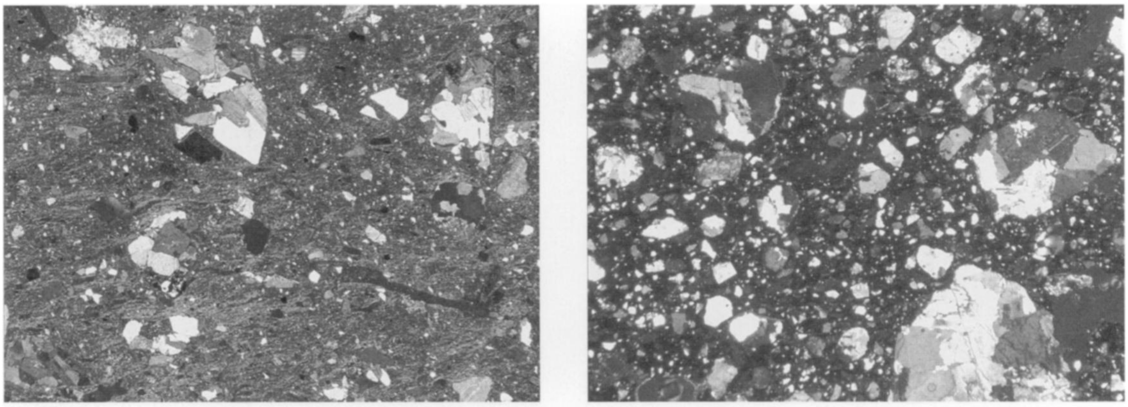


Figure 5. Photomicrographs of (a) Kavousi 93/5 (goddess 24), group 2, illustrating acid igneous rock temper; and (b) Lasithi 88/95, terra rossa sample from Aphendis Christos, Kalo Chorio. Crossed polars, horizontal dimension 7.4 mm

form of large aplastics, it is clear that this fabric has its origin within the Isthmus area, exploiting the terra rossa soils as part of the clay recipe (Fig. 5:b). This fabric is essentially that of the red cooking-vessel fabrics that have a long history in the area.[44] Although these fabrics usually have been considered low calcareous, recent work with micropaleontology has shown that they are often mixed with calcareous, marine Neogene deposits.[45]

Group 3: Common Sand Inclusions

Kavousi 93/1 (goddess 7), 93/3 (goddess 2), 93/7 (snake tube 1), 93/10 (plaque 1), 93/12 (snake tube 13)

The distinctive group 3 fabric corresponds to types X and XI in the Kavousi coarse-ware fabric series, which are very common in pithoi and jugs/jars of LM IIIC (Fig. 6:a, b). It is the fabric most commonly used for ritual objects from the shrine. One of its main macroscopic characteristics is the variation between those samples with red inclusions and those with mainly gray. It was assumed that such variations were due to firing atmosphere and that the different colored inclusions are of essentially the same composition. The ritual ceramics examined are identical in petrographic terms to a wide range of jar samples of LM IIIC date from Kavousi examined by the authors.

The fabric is characterized by large, well-rounded, aplastic inclusions of low-grade metamorphic rocks (phyllite and slate), sedimentary rocks (sandstones and siltstones), and fine-grained igneous rocks (basic volcanics?), set in very fine-grained base clay. The grain-size distribution is bimodal. There is evidence for clay mixing in all these samples. Kavousi 93/3 displays thin ribbons of calcareous clay within a red-firing base clay, and similar features of a dark red clay within a more orange-red base clay are also visible. This suggests that a calcareous clay and a red-firing clay may have been mixed together intentionally, although Neogene clays from the Vrionisi area on the south side of the Gulf of Mirabello have been shown to display such characteristic heterogeneity and specifically characteristic clay pellets, even without clay mixing. It is clear, however, that this fabric

44. See Whitelaw et al. 1997 for EM examples; Myer, McIntosh, and Betancourt 1995, pp. 144–145; Day 1997, p. 226.

45. Quinn 1999, pp. 346–356; Tsolakidou et al. 2002.

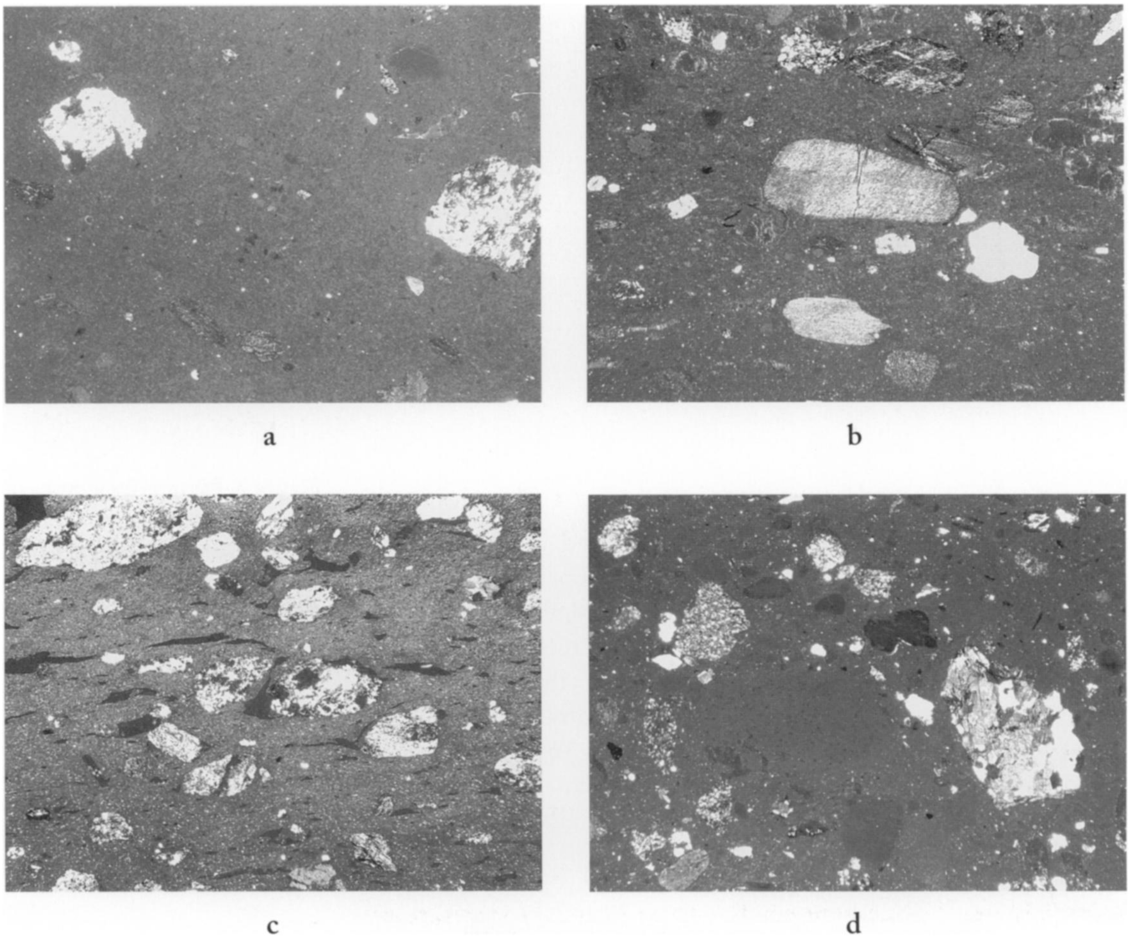


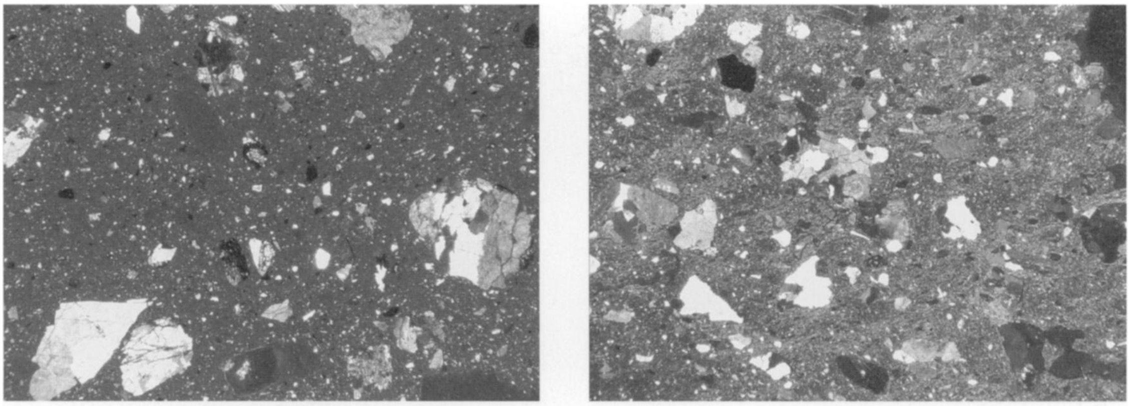
Figure 6. Photomicrographs of (a) Kavousi 93/1 (goddess 7) and (b) Kavousi 93/10 (plaque 1), group 3, illustrating common sand inclusions in a fine matrix; (c) Gournia 88/1 (Neopalatial amphora), illustrating the same sand inclusions seen in group 3; and (d) Kavousi 93/66 (MM pithos), illustrating rounded inclusions of schist and phyllite, as in group 3, with granodiorite rock. Crossed polars, horizontal dimension 7.4 mm

comprises a clay or clay mix tempered with water-rounded sand and that there is a marked consistency in examples of the fabric.

Fabrics similar to this have been noted in the LM I period within the area of Gournia (Fig. 6:c). In that case, their similarity both in terms of technology and the mineralogy of inclusions caused difficulty, in purely analytical terms, in separating them from sand-tempered ceramics from sites in the western Mesara Plain in southern Crete.[46] They do, in fact, resemble Mesara examples very strongly, perhaps leading to an incorrect assessment of provenance in some cases. Although their petrology indicates that they are compatible with metamorphic series, their clay groundmass appears to have as its basis fine, calcareous Neogene clay. In short, the fabric is very similar in nature to the calcareous Mirabello jar fabrics, but with rounded metamorphic sand temper instead of added angular, igneous rock fragments.

Sample Kavousi 93/66 from the Kavousi-Thriphti Survey helps to solve this problem. A trickle-painted storage jar of Middle Minoan date, it has features both of this fabric and also of those, such as group 4 (below), that have igneous inclusions in a fine, calcareous matrix. It contains fragments of granodiorite very similar to those seen in group 4 and coarse, rounded grains of siltstone, sandstone, and low-grade metamorphic rocks (phyllite

46. Day 1995, pp. 157–159.



a b

Figure 7. Photomicrographs of (a) Kavousi 93/6 (goddess 17), group 4, illustrating granodiorite inclusions in a fine calcareous matrix; and (b) Kavousi 93/102 (EM body sherd), illustrating a similar fabric.
Crossed polars, horizontal dimension 7.4 mm

and slate) that are found commonly in this group (Fig. 6:d). In addition, this fabric has common coarse grains of mudstone (red and dark brown varieties) and rare angular chert grains. The base clay appears fine-grained and is reminiscent of the Mirabello-type group groundmass, but the fine fraction is more sparsely distributed despite being composed of similar grains (biotite and monocrystalline quartz). This sample, then, provides the link between these two fabrics and shows that fabric group 3 has its origin in the area of the Isthmus. Although we cannot yet pin down the exact source of the sand inclusions, it seems that the base clay originates in the area of the Isthmus itself, rather than in the metamorphic series to the east.

Group 4: Granodiorite Inclusions in a Calcareous Matrix

Kavousi 93/6 (goddess 17)

The group 4 fabric corresponds to a finer version of Kavousi coarse-ware type XXII, and is characterized by the occurrence of medium/coarse-grained, acid to intermediate igneous rock fragments, probably granodiorite, and grains of the constituent minerals (Fig. 7:a). The latter comprise plagioclase feldspar, alkali feldspar, quartz, and amphibole that has almost all altered to biotite mica. The groundmass is composed of red-firing clay with fine grains of the constituent minerals of the granodiorite. There are streaks of very fine clay within the base clay, having the same color, which may indicate heterogeneity of the clay. The fabric is akin to calcareous granitic/dioritic fabrics found in the Early and Middle Minoan periods,[47] which also display the textural features noted (Fig. 7:b). It has been argued previously that rather than comprising evidence for clay mixing, they may be a natural feature of some gray clays within the Isthmus area. The aplastic inclusions clearly indicate a source similar to that for group 2. The difference between the two groups, however, lies in the technology of the clay mixes and firing, one (group 4) being mainly used for jar fabrics and the other for cooking wares.

47. Myer 1984; Day 1995; Whitelaw et al. 1997.

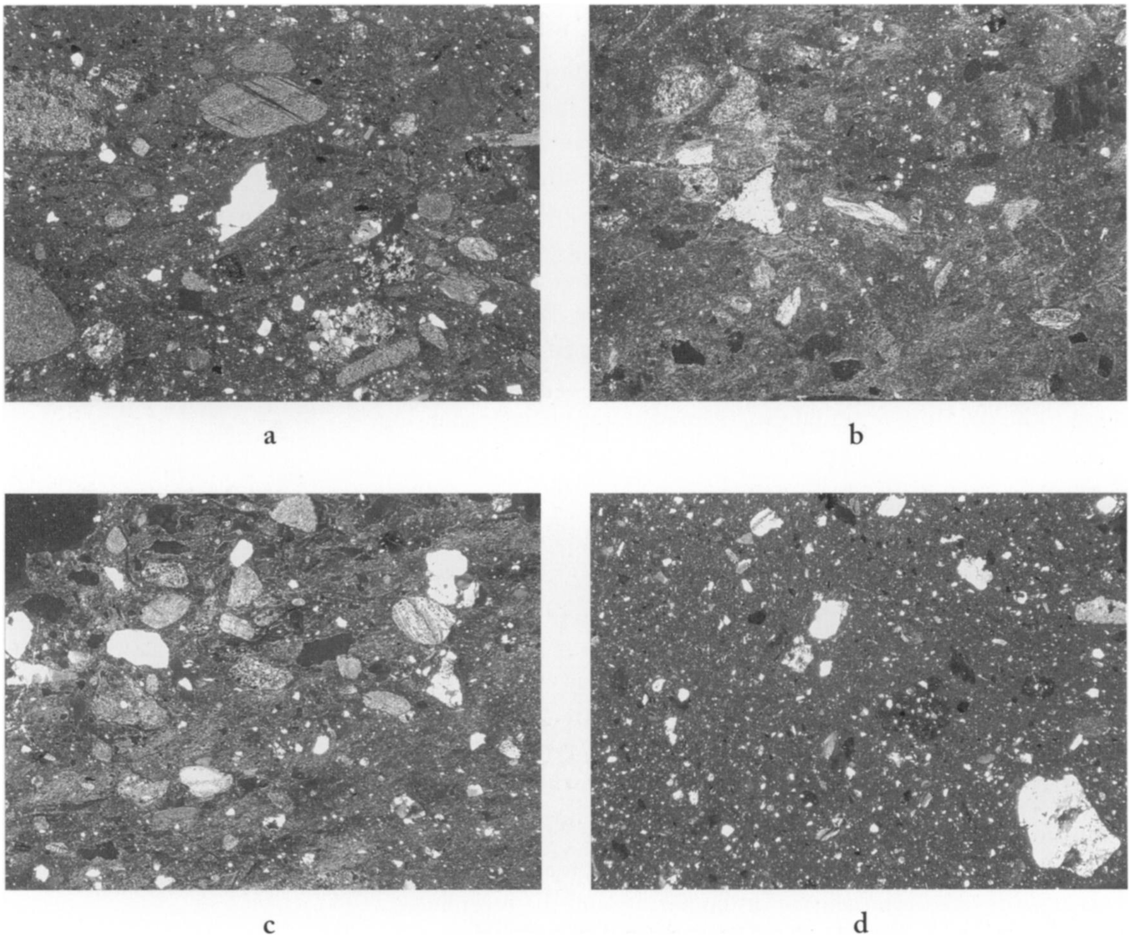


Figure 8. Photomicrographs of (a) Kavousi 93/2 (snake tube 3) and (b) Kavousi 93/9 (snake tube 17), group 5, illustrating phyllite inclusions in quartz-rich matrix; (c) Kavousi 93/8 (goddess 16), group 5, illustrating striations suggesting clay mixing; and (d) Lasithi 88/9/2/34, a modern water jar manufactured in the village of Vainia, illustrating textural concentration features from clay mixing. Crossed polars, horizontal dimension (a–c) 7.4 mm and (d) 3.7 mm

Group 5: Phyllite Group

Kavousi 93/2 (snake tube 3), 93/4 (plaque 5), 93/8 (goddess 16), 93/9 (snake tube 17), 93/13 (cooking vessel), 93/25 (horned kalathos)

The group 5 fabric corresponds to type IV in the Kavousi coarse-ware fabric series and is characterized by the presence of large, elongate grains of metamorphic rock fragments, principally phyllite (Fig. 8:a–c). In addition, there are grains of siltstone and sandstone that show signs of partial metamorphism. These large inclusions are set in a finer-grained groundmass of monocrystalline quartz and a red-firing clay, giving the appearance of a bimodal grain-size distribution. The base clay appears to be homogeneous in some of the samples (Kavousi 93/4, 9, 13, and 25) and shows evidence for clay mixing in others (Kavousi 93/2 and 8). There are areas of a more calcareous, finer-grained clay within the red-firing base clay, which may either represent the intentional mixing of different clays, or use of a heterogeneous clay source (cf. Fig. 8:d). The groundmass is optically active, indicating a relatively low firing temperature. This group is consistent in its nature and resembles closely a fabric common in cooking vessels from LM I onward.

Summary of Petrographic Analyses

The fabrics identified within the ritual ceramics of Kavousi are all familiar from components of the utilitarian ceramic assemblage. They comprise well-defined, separate groups. Moreover, groups such as 3 and 5 demonstrate notable consistency *within* a fabric group and marked differences *between* groups, thus increasing our confidence that they represent the products of different production locations. It is likely that they were all manufactured either in the area of the Isthmus or from areas geologically dominated by the Phyllite-Quartzite series, to the east of Kavousi. Before progressing to a detailed assessment of their technology (using SEM), it is worth noting that three of the five groups analyzed (groups 1, 2, 5) are normally considered to be cooking-vessel fabrics, primarily comprising red-firing, coarse fabrics. The other two (groups 3, 4) are common jar fabrics. The fabrics bearing a resemblance to cooking ware and jar fabrics respectively show distinctly different paste recipes.

SCANNING ELECTRON MICROSCOPY

The microstructures of 17 samples were examined with a scanning electron microscope (SEM), coupled to a microanalysis system (EDAX), for estimation of the extent of vitrification. Chemical composition of the samples combined with the degree of vitrification of the clay minerals can provide a reliable estimate of the equivalent firing temperature.[48] Other information can be derived from a SEM-EDAX examination, including the type of clay used, its degree of refinement or tempering, and the morphology, chemistry, and quality of decoration.[49] All these parameters assess the technology employed in producing the pottery and provide grounds for discussing the suitability of raw materials used in the final product.

SEM has been applied quite extensively to pottery from a variety of Aegean sites and chronological periods, with an emphasis on the Bronze Age. In Crete, Noll and coworkers concentrated on the decorative technology of Middle Minoan pottery, while Maniatis and Matson, respectively, determined firing temperatures and characterized slips for Early Minoan White-on-Dark ware from East Crete.[50] More systematic studies have been carried out on Early Minoan pottery for all of the main wares and types.[51] Similarly, and on a larger scale, a recent major project examined ca. 200 samples of Middle Minoan polychrome pottery by SEM.[52] The results of these studies are used for comparisons with the present findings.

Terracotta statues from a LM IB/LH II sanctuary in Ayia Irini, Kea, also studied by SEM,[53] may at first appear to provide the closest parallel to the Kavousi material, but closer inspection shows just how different their production technologies were. The Kea statues were all low-fired, made with low calcareous clays, and divided into two groups according to their firing temperatures. In addition, technological studies have been carried out on material similar to that from the Kavousi shrine, namely, the Middle Minoan clay figurines from peak sanctuaries in Crete, including Kophinas in the Asterousia Mountains.[54] It was found that most of these figurines were made in the wider area of the Mesara Plain; the rest could be divided

48. Maniatis and Tite 1981.
49. Kilikoglou 1994.
50. Noll, Holm, and Born 1975; Noll 1982; Maniatis 1984; Matson 1984.
51. Kilikoglou 1994; Whitelaw et al. 1997.
52. Faber, Kilikoglou, and Day 2002.
53. Maniatis, Katsanos, and Caskey 1982.
54. Maniatis et al. 1992.

TABLE 2. SEM DATA FOR RITUAL OBJECTS AND COMPARATIVE MATERIAL

Sample	*Description*	*Petrographic Fabric*	*CaO (wt%)*	*Vitrification*	*Atmosphere*	*Firing Temperature (°C)*
Kavousi 93/11	snake tube 11	group 1: low-grade metamorphic	<3	NV/IV	O/R	~750
Kavousi 93/18	cooking vessel	group 1: low-grade metamorphic	<3	V	O/R	800–900
Kavousi 93/5	goddess 24	group 2: acid igneous	<3	NV/IV	R	~750
Kavousi 93/14	cooking vessel	group 2: acid igneous	<3	NV	R	<750
Kavousi 93/1	goddess 7	group 3: sand	7–9	V_c-	O	800–850
Kavousi 93/3	goddess 2	group 3: sand	7–9	V_c-	O	800–850
Kavousi 93/7	snake tube 1	group 3: sand	7–9	V_c-	O	800–850
Kavousi 93/10	plaque 1	group 3: sand	7–9	V_c-	O	800–850
Kavousi 93/12	snake tube 13	group 3: sand	7–9	V_c-	O	800–850
Kavousi 93/66	pithos	cf. group 3: sand	4–6	V_c-	O	800–850
Kavousi 93/6	goddess 17	group 4: granodiorite	7–9	IV	O	750–800
Kavousi 93/2	snake tube 3	group 5: phyllite	<3	NV	R	<750
Kavousi 93/4	plaque 5	group 5: phyllite	<3	NV	R	<750
Kavousi 93/8	goddess 16	group 5: phyllite	<3	NV	R	<750
Kavousi 93/9	snake tube 17	group 5: phyllite	<3	NV	R	<750
Kavousi 93/13	cooking vessel	group 5: phyllite	<3	NV	O/R	<750
Kavousi 93/25	horned kalathos	group 5: phyllite	<3	NV	R	<750

CaO values are given with an approximation because the sections analyzed were not polished.
Abbreviations: NV: no vitrification, IV: initial stage of vitrification, V: extensive vitrification, V_c-: incomplete vitrification (calcareous structure), O: oxidation, R: reduction (after Maniatis and Tite 1981).

into a relatively large number of chemical groups reflecting many different areas of provenance. SEM study on the same material revealed low firing temperatures, the majority below 800°C, suggesting the use of open fires rather than kilns.

The SEM data for the present study are summarized in Table 2. Our aim was to investigate the very clear fabric groupings resulting from thin-section petrographic analysis in order to determine the manner of ceramic production. The estimation of firing atmosphere was based on a combination of macroscopic and microstructural characteristics. Freshly fractured surfaces of the samples were examined with a Philips 515 SEM, connected to an EDAX 9900 analysis system. What is remarkable about the results is the consistency within each group in firing temperature, atmosphere, and calcium content. These are very clear and well-formed groups in both SEM and PE terms.

Petrographic Group 1

Both samples in group 1 (Kavousi 93/11, 93/18) are characterized by their coarse clay, a feature that produced rough fracture surfaces with very limited areas of clay that were free of inclusions—vital for estimating firing temperature. The majority of the inclusions present in the clay mass

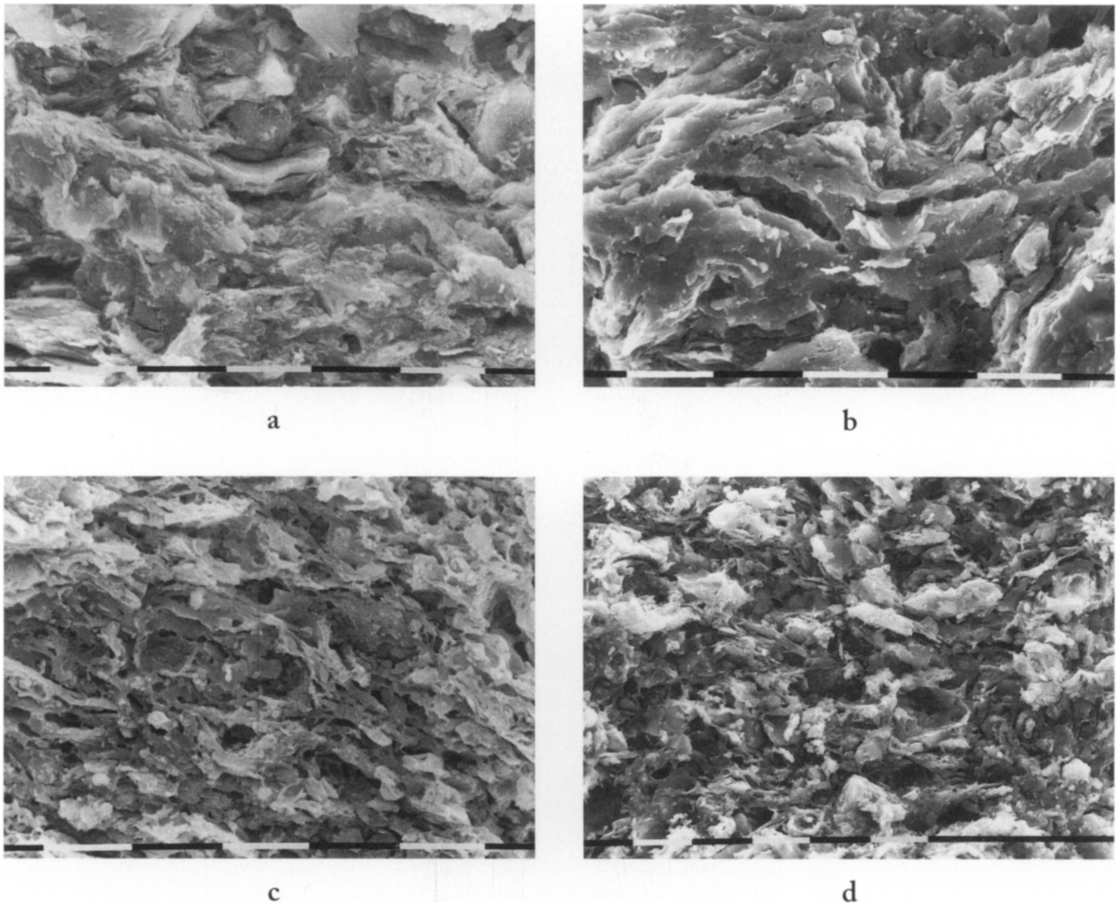


Figure 9. SEM photomicrographs of (a) Kavousi 93/11 (snake tube 11), group 1, illustrating initial stages of vitrification (IV) in pockets and micromorphology with no vitrification (NV); (b) Kavousi 93/18 (cooking vessel), group 1, illustrating higher-fired, vitrified (V) body; (c) Kavousi 93/7 (snake tube 1), group 3, illustrating incompletely vitrified (V_C-) micromorphology; and (d) Kavousi 93/66 (MM pithos), illustrating incomplete vitrification (V_C-), similar to group 3 examples. Bar = 10μm

are quartz, K-feldspars, and biotite (rich in Fe, K, Mg), with magnesium present in great quantity, a characteristic of this fabric. Both samples fired to dark brown as a result of the relatively high iron content and most likely an atmosphere that was not completely oxidizing. The estimated firing temperatures for these samples, however, differed from one other. Kavousi 93/11 exhibits initial vitrification only in limited areas, while no vitrification was detected in the majority of the fracture surface (Fig. 9:a). A marginal temperature of initial vitrification is assumed (~750°C). The cooking vessel (Kavousi 93/18) was fired higher (800–900°C), exhibiting an extensive network of glass as a result of vitrification of the clay minerals (Fig. 9:b).

Petrographic Group 2

Group 2 is also a low calcareous group, made of coarse clay containing frequent rock fragments of quartz-feldspars-amphiboles. Both samples (Kavousi 93/5, 93/14) exhibit no vitrification or very few signs of initial vitrification (Fig. 10:a) and, accordingly, temperatures of around 750°C or below are estimated. At such low temperatures complete oxidation is difficult to achieve and, therefore, both samples fired to dark brown colors.

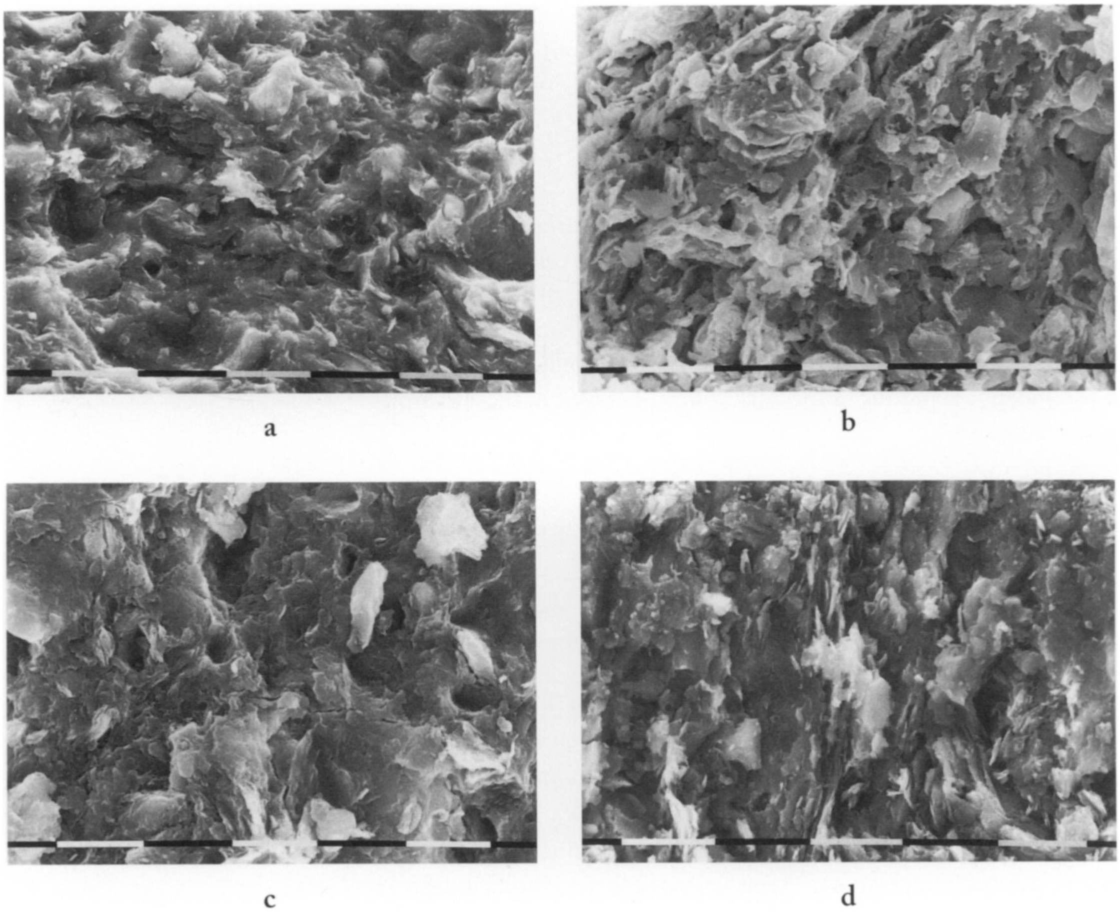


Figure 10. SEM photomicrographs of (a) Kavousi 93/14 (cooking vessel), group 2, illustrating low-fired body, no vitrification (NV); (b) Kavousi 93/6 (goddess 17), group 4, illustrating incomplete vitrification; (c) Kavousi 93/8 (goddess 16), group 5, illustrating low-fired body, no vitrification (NV); (d) Kavousi 93/13 (cooking vessel), group 5, illustrating low-fired body, no vitrification (NV). Bar = 10μm

Petrographic Group 3

Group 3 is also extremely consistent on technological grounds. All of the ritual objects in this group were made with a calcareous clay containing ~8% wt% CaO. The presence of calcium and the objects' exposure to relatively high firing temperatures resulted in the formation of cellular microstructures characterizing clays fired over 800°C (e.g., Kavousi 93/7; Fig. 9:c). As the glass filament network was not completely developed in all samples, we can assign temperatures of around 800–850°C. Due to the light color of the clay bodies, it can be surmised that an oxidizing atmosphere was predominant during their firing. The comparative pithos sample (Kavousi 93/66) exhibited the same technological features with the exception of being slightly less calcareous and in some areas forming a coarser vitrification microstructure (Fig. 9:d).

Petrographic Group 4

In technological terms (level of Ca and firing) the sample representing group 4 (Kavousi 93/6; Fig. 10:b) is very similar to the members of group 3 and especially to the comparative sample Kavousi 93/66. Both 93/6 and 93/66 contain a slightly coarser glass filament network than is typical of group 3. In some areas of its ceramic body, however, Kavousi 93/6 exhibits only initial stages of vitrification and therefore it should be assigned an overall temperature of 750–800°C.

Petrographic Group 5

Group 5 is a coarse fabric with very rough fracture surfaces, due to the large number of inclusions. The clay in all samples is low calcareous and the firing temperature consistently low (<750°C) (Fig. 10:c, d). As mentioned above, given the low firing temperature, a relatively reducing atmosphere is likely to have existed; combined with the low calcareous nature of the clays, this atmosphere produced the dark colors observed in these samples (dark brown to gray).

SYNTHESIS OF ANALYTICAL RESULTS

The results from PE and SEM form a clear picture of the production of these distinctive groups of pottery. The consistency in their raw materials and firing seems to confirm that, indeed, they were produced as sets of ritual ceramics: goddess figures, snake tubes, and plaques. All three types of objects appear in petrographic groups 1, 3, 4, and 5, while 20 of 26 goddess figures, 24 of the 33 snake tubes, and 27 of the 37 plaques can be classified within petrographic fabric group 3 (see Table 3).

Although it is clear that the ritual objects are produced primarily in one fabric (macroscopic fabric XI,[55] represented by petrographic group 3), they do not represent the products of one local workshop specializing in the production of religious objects. The various fabrics were produced by potters in quite different locations, employing varied technologies of production. There are those that exploited low calcareous clays and used low firing temperatures and those that tempered calcareous clays and fired them at relatively higher temperatures. Such a contrast between two very different conceptions of a ceramic paste has been noted for EM IIB[56] and it seems that in LM IIIC, as during the earlier period, these two traditions produced primarily cooking pots and jug/jar repertoires, respectively.

With their fabrics identical to those of everyday utilitarian objects, these ritual ceramics were almost certainly made in the same workshops that produced the normal range of coarse-ware pottery. But where were such workshops located? We shall discuss this first by reference to geological deposits and their distribution, and then within the context of work on resource thresholds for ceramic raw materials.

The first observation that can be made is that the clay matrix and aplastics of group 5 and perhaps group 1 derive from low-grade metamorphic deposits, probably the Phyllite-Quartzite series, which is common in the area immediately to the east of the Isthmus of Ierapetra (Fig. 4). Phyllite-based fabrics have a long history in this area, with a significant proportion of pottery from Kavousi and Mochlos deriving from these deposits in the Early Bronze Age,[57] as well as from Mochlos during the Neopalatial period.[58] In fact, the site of Vronda itself is situated on deposits of the Phyllite-

55. Haggis and Mook 1993, pp. 275–276; Mook 2005, p. 171.
56. Whitelaw et al. 1997.
57. Day et al. 1999.
58. Betancourt and Myer 1995; Day, Joyner, and Relaki 2003.

TABLE 3. FABRIC GROUPS FOR RITUAL OBJECTS

Macroscopic Fabric Type	*Petrographic Fabric*	*Goddess Figures*	*Snake Tubes*	*Plaques*
IV	group 5	1	4	2
XI	group 3	20	24	27
XVI	group 1	1	1	6
XXII	group 4	1	1	2
XXV	group 2	1	1	0
XXVI	–	0	2	0
Others	–	2	0	0
Total		26	33	37

Macroscopic fabric types are defined in Haggis and Mook 1993.

Quartzite series and indeed has a potter's kiln dated to LM IIIC.[59] It is likely that the ceramics produced in this updraft pottery kiln exploited the nearby phyllite deposits, although the link between the Kavousi kiln and the group 5 fabrics is less clear. Similar fabrics could have been produced in other geologically similar locations.

In contrast, the aplastic inclusions found in groups 2 and 4 are associated with deposits that occur as intrusions into the limestone on the southern border of the Gulf of Mirabello. These granitic and granodioritic rocks have a restricted distribution that should give a good indication of where the temper for group 4 was obtained. The constituent minerals of these igneous rocks are also present in the terra rossa deposits of the Ierapetra depression (Fig. 4) and it may be that this is their origin in the case of group 2. Analyses of modern ceramics from the village of Vainia, whose potters use a mix of terra rossa and a nearby marl,[60] show the presence of granodiorite-derived minerals (Fig. 8:d).[61] The aplastics of these two fabric groups clearly originated on the west side of the Isthmus of Ierapetra. In the case of group 2, it is likely that the aplastic component was already present in the red bed deposits that surely formed a major part of the clay mix (from the alluvial deposits around the Ierapetra depression or Kalo Chorio area; see Fig. 5:b).

Group 4 differs in its clay matrix, being based on a fine, calcareous Neogene clay that was high fired. Such deposits are found across a broad area, mostly to the west of the Isthmus, with those around Vrionisi being some of the most suitable for pottery production, along with those in the vicinity of Vasiliki and Vainia (Fig. 4).[62]

Having a similar base clay, pithos sample Kavousi 93/66 demonstrates also that its dominant metamorphic sand grains have a geographical association with the area of the granodiorite outcrops, as both types of inclusion are present in the same fabric. It is not immediately clear where these metamorphic rocks originate, but in examples of the closely comparable

59. Gesell, Day, and Coulson 1988, pp. 290–293.
60. Blitzer 1984.
61. See also Gifford and Myer 1984; Myer 1984.
62. Dermitzakis 1969; Fortuin 1977; Gifford and Myer 1984; Hein, Day, and Kilikoglou 2004.

group 3 they are associated with altered igneous rock fragments, suggesting a possible link to the ophiolitic outcrops in the area of Gournia.

Arnold's influential Exploitable Threshold Model[63] has often been used effectively in assessing probabilities of the location of pottery workshops in relation to their raw materials. It offers us at least a general guideline concerning the common proximity of production sites to their clay sources. Although no workshops or kiln structures have been found in the area of the granodiorite outcrops, both the clays and aplastics contained in the pottery give a clear indication of at least two areas for the production of the goddess figures and the associated ritual ceramics. A strong argument can be made that at least four of the fabric groups represent quite different clay recipes and ways of firing. In summary, they are as follows:

1. fine calcareous clay with granodiorite aplastics (relatively high fired, west of Isthmus);
2. fine calcareous clay with rounded metamorphic sand inclusions (relatively high fired, west of Isthmus, but separate from above);
3. low calcareous phyllite fabric (relatively low fired, east of Isthmus);
4. low calcareous micaceous, metamorphic fabric (relatively low fired, east of Isthmus, but distinct from above fabrics).

All of these fabrics are common in the normal coarse-ware assemblage of Kavousi and represent pottery from different production locations. In addition to their varying origins, they also display distinctly different technologies.

SPECIAL OBJECTS AND SPECIALIST POTTERS?

Clearly then, we are not faced with the specialist production of what appear to be rather special ritual objects, let alone their centralized production. On the contrary, our analyses point to potters from different traditions in different locations producing similar equipment for religious use. The objects may still be special to both producer and consumer, but they take their place within the normal material bounds of pottery manufacture.

This, however, does not mean that the production of a cult figure or vessel might not have been acknowledged as a special occasion. The creation of a Zhikile pot (a representation of a deity) by the Ngwazla caste potters of the Mafa in Northern Cameroon takes place in the same space and with the same raw material as the other repertoire of the potters. However, the figure of a god is the subject of more input from the potter's husband and the rites and libations associated with such a figure are more elaborate than they would be in an ordinary day's work.[64]

Similarly, in 20th-century East Crete, many potters interviewed claimed to have special pots that nobody else knew how to make. These were commonly "justice cups" and large jars with birds that acted as fountains—vessels that required special care in their manufacture and were

63. Arnold 1985, pp. 20–60.
64. David, Sterner, and Gavua 1988; David 1990.

used as trick cups or as vessels of display. Although the potters in each case claimed the unique nature of their creation, in fieldwork by Day this story was heard repeatedly from a variety of individuals belonging to either of the main traditions, the Thrapsano potters or the Kentri potters.

Can we envisage a similar situation with potters around the Isthmus of Ierapetra during LM IIIC? Were the striking goddess figures, snake tubes, and plaques special items that most potters had in their repertoire? Were the complex figures shaped in similar ways by distinct groups of potters, despite differences in the way those potters manufactured utilitarian pottery? Were these figures as much a chance for the potters to show off their skills within their community as they were for display at the shrine in which they were deposited?

Although the locations and traditions of production are distinct, the whole range of products from these centers is common at Vronda. In consumption terms we would consider them a normal part of the domestic repertoire of the site. Therefore, it is difficult to argue that, in the case of ritual objects from these production centers, their differing microprovenance indicates the presence at the shrine of people from different communities. It is not as yet clear whether the objects traveled with other products and were obtained at Kavousi, or individuals themselves brought such sets across the landscape to that place of worship.

These are questions of great interest, addressing issues of how people and objects moved around the landscape on an everyday basis and on special occasions. The analyses presented here offer a way forward. The analysis of the ritual ceramics now known from Kephala Vasilikis and Chalasmenos Monastirakiou would certainly shed further light on our ability to trace the routes of people and objects around the Isthmus region at this time.

APPENDIX
PETROGRAPHIC FABRIC DESCRIPTIONS*

GROUP 1: FREQUENT LOW-GRADE METAMORPHIC ROCKS

Kavousi 93/11 (snake tube 11), 93/18 (cooking vessel)

Microstructure

There are very few voids in these samples, comprising few megavughs, common macro- and mesovughs, and common mesoplanar voids. The voids have a crude long axes parallel orientation with the vessel margins and are generally single- to double-spaced. The elongate aplastic inclusions have a crude long axes parallel orientation with the vessel margins, but the micas within the groundmass have a random orientation.

Groundmass

Homogeneous throughout the sections. The color varies from orange-brown to mid-brown in PPL and from red-orange to red-brown in XP (×25). The micromass is optically active to optically moderately active.

Inclusions

$c{:}f{:}v_{10\mu m}$ = ca. 30:65:5
Coarse fraction = 3 mm to 0.2 mm (granules to fine sand)
Fine fraction = 0.2 mm or less (fine sand and below)

The inclusions appear to have a bimodal grain-size distribution; the coarse inclusions are set in a finer-grained groundmass. Inclusions are poorly sorted.

Coarse Fraction

Dominant to frequent
Metamorphic rock fragments: mainly very low to low-grade, very rarely medium-grade metamorphism. There are a variety of different types: clinozoisite-rich rock fragments,

* The descriptions below follow Whitbread 1986, 1989, 1995. Common abbreviations are as follows: a = angular; c:f:v = coarse:fine:void ratio; PPL = plane polarized light; r = rounded; sa =subangular; sr = subrounded; wr = well rounded; XP = crossed polars.

epidote-biotite quartz schist, amphibole-biotite-clinozoisite-quartz schist, biotite-clinozoisite-quartz schist, clinozoisite-biotite-opaques-quartz schist, biotite-rich rock fragments, amphibole-biotite-opaques-clinozoisite-quartz-titanite rock fragment, chlorite or anthophyllite-biotite schist (some possibly with accessory tourmaline?), chlorite biotite schist, clinozoisite feldspar rock fragment, altered feldspar-titanite-biotite replaced amphibole-clinozoisite rock fragment, amphibole-rich rock fragments, and garnet-banded biotite quartz rock fragment. Generally elongate to slightly elongate, sa–sr. Size = <2.5 mm; mode = 1 mm long dimension.

Common to few

Polycrystalline quartz: inequigranular, sometimes with a sheared appearance and/or sutured grain boundaries. Size = <3 mm; mode = 0.8 mm long dimension.

Monocrystalline quartz: equant to slightly elongate, straight extinction. Size = <1 mm; mode = 0.4 mm long dimension.

Muscovite mica: laths. Mode = 0.3 mm.

Few

Chlorite: laths and pseudomorphs. Mode = 0.2 mm.

Very few

Opaques: mode = 0.2 mm.

Biotite mica: lath, possibly replacing amphibole? Size = 0.5 mm long dimension.

Rare

Siltstone: composed of rounded grains of monocrystalline quartz set in a clay-rich matrix. Some hematite staining present. Slightly elongate, sr. Size = <0.9 mm long dimension.

Very rare to absent

Orthopyroxene: approximately equant, sa. Size = 1.05 mm long dimension. Poikilitically enclosed small, rounded grains of garnet. Some marginal alteration.

Plagioclase feldspar: laths, some are heavily saussuritized and others are fairly fresh; polysynthetic twinning still visible, slightly bent. Size = 1.3 mm long dimension.

Amphibole

Epidote

Alkali feldspar

Fine Fraction

Frequent

Monocrystalline quartz: approximately equant, sa–sr. Straight extinction common. Mode = 0.04 mm long dimension.

Muscovite mica: laths. Mode = 0.1 mm long dimension.

Few

Biotite mica: laths. Mode = 0.1 mm.
Clinozoisite: equant.
Metamorphic rock fragments: as above. Mode = 0.1 mm long dimension.

Few to rare

Opaques: equant.

Rare

Chlorite: pseudomorphs and laths.
Epidote
Amphibole
Polycrystalline quartz
Titanite (sphene)
Plagioclase feldspar

Very rare to absent

Microsfossils: calcareous. Foraminifera, shell fragments.
Calcimudstone (micrite)
Alkali feldspar

Textural Concentration Features (Tcfs)

Textural concentration features, or tcfs, are few to rare in these samples. They are dark brown in PPL and dark red-brown in XP (×100), with sharp to diffuse boundaries, high optical density, subrounded to rounded and discordant with the micromass, although the aplastic inclusion range appears to be very similar. The aplastic inclusions comprise monocrystalline quartz and/or clinozoisite and epidote. Mode = 0.3 mm long dimension. They are probably clay pellets.

GROUP 2: ACID IGNEOUS ROCKS

Kavousi 93/5 (goddess 24), 93/14 (cooking vessel)

Microstructure

There are very few voids in these samples. There are common mesovughs and planar voids, and rare macroplanar voids, and very rare megavughs. The voids are open- to double-spaced. They have a crude orientation with their long axes parallel to the vessel margins, as do the aplastic inclusions.

Groundmass

Homogeneous throughout the sections. The color varies from orange-brown in PPL, to red-brown to orange-brown to mid-brown in XP (×25).

Inclusions

$c{:}f{:}v_{10\mu m}$ = ca. 30:65:5
Coarse fraction = 2.7 mm to 0.25 mm (granules to medium sand)
Fine fraction = 0.25 mm or less (fine sand and below)

The inclusions appear to have a bimodal grain-size distribution, with coarse inclusions set in a fine-grained groundmass. Generally a–sa, and poorly sorted.

Coarse Fraction

Dominant

Acid igneous rock fragments: composed of quartz, alkali feldspar, plagioclase feldspar, and occasional muscovite/and or biotite mica, amphibole, and microcline. Interlocking igneous texture is evident. Medium to coarse-grained, possibly granite or microgranite. Generally slightly elongate, sa. Size = <2.5 mm; mode = 0.5 mm long dimension. Feldspars tend to be partially saussuritized. Rare myrmekite in some grains.

Common to few

Biotite mica: laths. Size = <0.8 mm; mode = 0.4 mm long dimension.
Plagioclase feldspar: laths with polysynthetic twinning; some show simple twinning as well. Partially saussuritized in most cases. Size = <0.5 mm; mode = 0.3 mm long dimension.
Monocrystalline quartz: slightly elongate, sa. Size = <0.6 mm; mode = 0.3 mm long dimension.

Few

Polycrystalline quartz: inequigranular. Slightly elongate, sa–sr. Size = <0.8 mm; mode = 0.5 mm long dimension.
Alkali feldspar: approximately equant, sa–sr. Partially saussuritized; some grains show simple twinning. Size = <0.75 mm; mode = 0.5 mm long dimension.

Very rare

Anti/perthite: approximately equant, sa. Size = 2.7 mm and 0.55 mm long dimension.

Very rare to absent

Garnet(?): high relief, pale brown and isotropic, in sample 93/5.
Amphibole: green with altered margins (biotite), in sample 93/5.
Limestone: sparite with sparse monocrystalline quartz inclusions, irregular shape, in sample 93/5.
Chlorite pseudomorphs: rounded, amorphous, in sample 93/5.
Opaques: in sample 93/5.

Fine Fraction

Frequent

Monocrystalline quartz: equant, a–sr. Mode = 0.1 mm long dimension.

Common

Plagioclase feldspar: laths. Mode = 0.1 mm long dimension.
Biotite mica: laths. Mode = 1 mm long dimension.

Few

Opaques: equant.

Few to very few

Amphibole: green.
Alkali feldspar

Rare

Chert: slightly elongate, r.
Epidote: equant.
Limestone: equant and rounded.
Calcite
Muscovite mica: laths.

Very rare

Myrmekite
Titanite (sphene)
Chlorite

Very rare to absent

Clinozoisite
Garnet(?): in sample 93/5.

Textural Concentration Features

There are very few tcfs in these samples. In sample 93/14 there are rounded areas with a different clay particle orientation, visible in XP. They are orange-brown in PPL and red-orange in XP (×40), with clear to merging boundaries, neutral optical density, concordant with the micromass, usually well rounded, with a range and spacing of aplastic inclusions similar to that seen in the base clay. Mode = 1.25 mm. They are probably clay pellets. There are also irregular longitudinal areas of finer-grained clay, which are also seen in sample 93/5. There are amorphous concentration features in sample 93/5 that are dark red-brown in PPL and XP (×40), with clear boundaries and high optical density; they are discordant with the micromass and have no aplastic inclusions. Equant, sa–sr. They are probably clay mineral concentrations.

GROUP 3: COMMON SAND INCLUSIONS

Kavousi 93/1 (goddess 7), 93/3 (goddess 2), 93/7 (snake tube 1), 93/10 (plaque 1), 93/12 (snake tube 13)

Microstructure

There are common to rare voids in these samples. They are commonly meso- and microvughs, rare to absent macro- and megavughs, and rare to absent macro- and mesoplanar voids. The voids are double- to open-spaced and have a crude long axes parallel orientation with the vessel margins. The aplastic inclusions have a very crude long axes parallel orientation with the vessel margins.

Groundmass

Varies from being homogeneous in some samples (93/1 and 93/7) to heterogeneous with evidence for clay mixing in others (93/3, 93/10, and 93/12). The color varies from red-brown in PPL to dark red in XP (×25). The micromass is optically slightly active.

Inclusions

$c{:}f{:}v_{10\mu m}$ = ca. 15:80:5 to 20:75:5
Coarse fraction = 4 mm to 0.25 mm (granules to medium sand)
Fine fraction = 0.25 mm or less (fine sand and below)

The inclusions have a bimodal grain-size distribution. Coarse, well-rounded inclusions are set in a very fine grained groundmass and are moderately sorted.

Coarse Fraction

Common

Phyllite: composed of biotite and quartz. Rarely with chlorite (greenschist). Crenulation cleavage is visible in some grains. Approximately equant to slightly elongate to elongate, sr–wr. Size = <1.8 mm; mode = 0.75 mm long dimension.

Slate: elongate, sr–r. Size = <3.5 mm; mode = 0.8 mm long dimension. Can be seen to grade into partially metamorphosed siltstones.

Few to very few

Schist: composed of biotite and quartz, and chlorite and quartz (greenschist); schistocity is well defined, and sometimes folding is seen. Elongate, sr. Size = <1.9 mm; mode = 1.75 mm long dimension.

Sandstone: composed of monocrystalline quartz, both framework and matrix supported varieties, with a small amount of clay-rich and/or quartz-rich matrix. Fine-grained sandstone, quartz arenite. Some is partially metamorphosed; quartz porphyroclasts in a partially recrystallized and aligned matrix and boundaries of some of the quartz porphyroclasts are breaking down. Also some stretched quartz grains, indicating deformation during metamorphism. Sandstones mostly well sorted, a few poorly sorted. Some grade into litharenites with chert and plagioclase feldspar clasts. Equant and well-rounded grains. Size = <2.6 mm; mode = 0.75 mm long dimension.

Siltstone: partially metamorphosed. Original sedimentary lamination still visible and contains inclusions of monocrystalline quartz. Elongate grains, r. Size = <1.3 mm; mode = 0.5 mm long dimension. Packing of the grains varies from sparse to well packed.

Polycrystalline quartz: inequigranular, generally elongate, sa–sr. Usually exhibit a stretched, metamorphic texture. Size = <1.25 mm; mode = 0.75 mm long dimension.

Few to very rare

Monocrystalline quartz: generally equant, sa–sr. Size = <1.6 mm; mode = 0.3 mm long dimension.

Few to absent

Fine-grained igneous rock fragments: possibly volcanic, basalt? Texture varies from decussate to porphyritic. Variable alteration; in some, the groundmass has been devitrified. Elongate to equant. Size = <1.25 mm; mode = 0.5 mm long dimension.

Calcimudstone (micrite): generally equant and fairly well rounded, often with a dark rim around the outside (reaction rim?). Often optically inactive due to high firing. Size = 0.75 mm; mode = 0.3 mm long dimension.

Very rare to absent

Mudstone: brown

Alkali feldspar

Bright red mineral: clay concentration?

Fine Fraction

Predominant

Monocrystalline quartz: equant, sa–sr. Mode = 0.02 mm.

Few

Biotite mica: laths.

Phyllite: as above.

Opaques

Calcimudstone

Rare

Polycrystalline quartz

Very rare to absent

Chlorite: pseudomorph.
Muscovite mica: laths.

Textural Concentration Features

Tcfs are common to rare in these samples. The majority is of one type, which is gray in PPL and optically inactive, dark gray in XP (×40), with clear to merging boundaries, low optical density, equant and well-rounded to irregular, elongate shapes. They are discordant grading into concordant with the micromass; inclusions are very fine-grained monocrystalline quartz. Some merge into the micromass, suggesting that they are clay pellets, and are partially mixed into the base clay. These are seen in all the samples.

GROUP 4: GRANODIORITE INCLUSIONS IN A CALCAREOUS MATRIX

Kavousi 93/6 (goddess 17)

Microstructure

There are very few voids in this sample. Rare macrovughs, and few mesovughs, with very rare macroplanar voids. The voids have a very crude long axes parallel orientation with the micromass and are open-spaced. Aplastic inclusions have a random orientation.

Groundmass

Homogeneous throughout the section. The color is mid-brown in PPL and red-brown in XP (×25). The micromass is optically slightly active.

Inclusions

$c{:}f{:}v_{10\mu m}$ = ca. 25:70:5
Coarse fraction = 2.25 mm to 0.1 mm (granules to very fine sand)
Fine fraction = 0.1 mm or less (very fine sand and below)

The inclusions have a unimodal grain-size distribution and are poorly sorted.

Coarse Fraction

Frequent

Acid igneous rock fragments: probably granodiorite. Composed of various proportions of plagioclase feldspar, alkali feldspar, quartz, amphibole altered to biotite mica. Coarse- to medium-grained. Generally equant, sa–sr. Size = <2.25 mm; mode = 0.5 mm long dimension.

Common

Plagioclase feldspar: tabular. Polysynthetic twinning, a–sa. Size = <0.75 mm; mode = 0.25 mm long dimension.

Few

Alkali feldspar: tabular. Sometimes with simple twinning, usually partially saussuritized, sa–sr. Size = <0.6; mode = 0.2 mm long dimension.

Biotite mica: some are laths, others replace amphibole (pseudomorphs); sa–sr. Mode = 0.15 mm long dimension. Pleochroic dark brown to brown-green.

Monocrystalline quartz: straight and undulose extinction, sa. Mode = 0.15 mm.

Rare

Opaques

Mudstone: brown and gray varieties.

Amphibole: pale brown to pale yellow.

Very rare

Siltstone: composed of monocrystalline quartz and biotite mica grains in a clay-rich matrix, fairly well packed, elongate, sr. Size = <2 mm long dimension; mode = 0.75 mm long dimension.

Fine Fraction

Common

Biotite mica: laths and equant grains, sa–r. Mode = 0.04 mm long dimension. Some are an alteration product of amphibole.

Monocrystalline quartz: mainly equant, sa–r. Mode = 0.02 mm long dimension.

Few

Plagioclase feldspar: laths. Polysynthetic twinning. Mode = 0.08 mm long dimension.

Rare

Opaques

Alkali feldspar

Very rare

Muscovite mica: laths.

Chlorite

Textural Concentration Features

Tcfs are rare in this sample. They are dark brown in PPL and dark red-brown in XP (×100), with clear to diffuse boundaries, very high optical activity, discordant with the micromass, sometimes with a surrounding void, aplastic inclusions of quartz, usually equant, sr–r. Size = <0.32 mm. They are probably clay pellets.

GROUP 5: PHYLLITE GROUP

Kavousi 93/2 (snake tube 3), 93/4 (plaque 5), 93/8 (goddess 16), 93/9 (snake tube 17), 93/13 (cooking vessel), 93/25 (horned kalathos)

Microstructure

There are few to common voids in these samples, including common mega- and macroplanar voids, and very few macro- and mesovughs. The voids have a crude long axes orientation with the vessel margins in some of the samples, and a random orientation in others. They are single- to double-spaced. The elongate aplastic inclusions have a crude long axes parallel orientation with the vessel margins.

Groundmass

Homogeneous through the sections. The color varies from orange to orange-brown in PPL and from red-orange to orange-brown in XP (×25). Optically active to slightly active.

Inclusions

$c{:}f{:}v_{10\mu m}$ = ca. 20:75:5 to 25:65:10
Coarse fraction = 4 mm to 0.25 mm (granules to medium sand)
Fine fraction = 0.25 mm or less (fine sand and below)

The inclusions appear to have a bimodal grain-size distribution, with moderately well-rounded coarse grains set in a finer groundmass. Overall the inclusions are poorly sorted.

Coarse Fraction

Dominant to frequent

Phyllites: varying in grain size and composition, from mica-rich (biotite and muscovite), to mica- and quartz-rich, sometimes with chlorite. Some display crenulation cleavage; all have a phyllitic alignment of the platy minerals. Generally elongate, sa–r. Size = <4 mm; mode = 1 mm long dimension. Original sedimentary lamination is sometimes still visible.

Few to rare

Sandstone: grading into quartz-rich greywacke. Moderately sorted quartz grains set in a clay- and quartz-rich matrix, mostly fairly equant, sa–r. Size = <1.7 mm; mode = 0.5 mm long dimension. Some show evidence of being partially metamorphosed (biotite rims around the quartz grains). Some sandstone fragments contain chert. Reactionary grain boundaries indicate a partial metamorphism to psammites. Some quartz grains are elongate from stretching during metamorphism.

Siltstones: variable quantities of quartz grains in a clay-rich matrix, generally equant, sr–r. Size = <1.3 mm; mode = 0.5 mm long dimension.

Few to absent

Polycrystalline quartz: inequigranular, fairly equant, sa–sr. Size = 1.7 mm; mode = 0.5 mm long dimensions. Boundaries are either straight or consertal.

Very few to very rare

Monocrystalline quartz: approximately equant, a–sa. Size = 2.7 mm; mode = 0.4 mm long dimension.

Very few to absent

Calcimudstone (micrite): some have quartz inclusions within them. Generally equant, sa–sr. Size = <2.45 mm long dimension.

Chert: approximately equant, sa–sr. Size = <1 mm; mode = 0.4 mm long dimension.

Rare to absent

Schists: quartz-biotite mica schists; schistocity is developed. Elongate grains, sa–r. Size = <2.6 mm. Only seen in samples 93/2 and 93/13.

Very rare to absent

Altered igneous rock fragments: fine-grained. Feldspar laths within a devitrified groundmass. Approximately equant, sa. Size = 0.62 mm long dimension. Decussate texture.

Shell fragment voids: in samples 93/13 and 93/25. Size = 0.7 mm long dimension.

Alkali feldspar: laths with simple twinning and some euhedral grains. Orthoclase? In samples 93/4 and 93/13.

Chlorite: pseudomorph. Fibrous grains of chlorite.

Fine Fraction

Frequent to common

Monocrystalline quartz: generally equant, a–sr. Straight extinction mainly. Mode = 0.04 mm long dimension.

Few

Polycrystalline quartz: inequigranular to equigranular. Usually equant, sa–sr. Mode = 0.1 mm long dimension.

Few to rare

Muscovite mica: laths.
Biotite mica: laths.

Rare to very rare

Plagioclase feldspar: laths with polysynthetic twinning.
Alkali feldspar: laths sometimes showing simple twinning.
Chert
Quartz biotite phyllite rock
Clinozoisite-epidote group minerals
Opaques
Amphibole

Very rare to absent

Chlorite: pseudomorphs, fibrous.
Sandstone: well-rounded grains.

Textural Concentration Features

Tcfs are very rare to absent in these samples, with two different types. Sample 93/13 displays both types. The first is very dark brown in PPL and dark red-brown in XP (×40), with sharp to clear boundaries, very high optical density, elongate, discordant with the micromass, aplastic inclusions of quartz, biotite, and metamorphic rock fragments. Generally sr–wr. Size = 1.75 mm long dimension. Probably a clay pellet. The second type is red-orange in PPL and dark red in XP (×100), with clear to diffuse boundaries, fairly high optical density, slightly elongate, concordant with the micromass, aplastic inclusions of monocrystalline quartz, titanite (sphene) and opaques, r–sr. Probably a clay pellet. This type is also seen in sample 93/2. Tcfs are absent in samples 93/4, 93/8, 93/9, and 93/25.

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