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# MELETEMATA

## STUDIES IN AEGEAN ARCHAEOLOGY PRESENTED TO MALCOLM H. WIENER AS HE ENTERS HIS 65th YEAR

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# CHARACTERIZATION STUDIES OF BRONZE AGE POTTERY FROM ELEUSIS*

## Introduction

In recent years the application of inter-disciplinary methods of ceramic analysis has become one of the most useful tools for the study of ceramic technology, production, and exchange in the Aegean Bronze Age. The combination of "traditional" archaeological studies with scientific analyses has been applied to the material from several sites in the Peloponnese,[1] the Cyclades,[2] and Crete[3] and has demonstrated both the usefulness of such methods and the need for the expansion of the known databases with the inclusion of material from other sites. At Eleusis, the old and new excavations have brought to light extensive Bronze Age ceramic material (approximately 17 000 EH, MH, and LH vases and sherds), that could become an excellent source of information about the technology of ceramic production, the nature and degree of craft specialization, and the exchange networks

* The director and the members of the Eleusis Archaeological Project would like to express their gratitude to INSTAP and personally to Malcolm H. Wiener, for the financial support the project has received over the years.

1 M. ATTAS, *Regional Ceramic Trade in Early Bronze Age Greece, Evidence from Neutron Activation Analysis of Early Helladic Pottery from Argolis and Korthia* (Unpublished Ph.D. Dissertation, McGill University, 1982); M. ATTAS, L. YAFFE, J.M. FOSSEY, "NAA of Early Bronze Age pottery from Lake Vouliagmeni, Perakhora, Central Greece," *Archaeometry* 19 (1977) 33-43; M. ATTAS, F. WIDEMANN, P. PONTES, K. GRUEL, F. LAUBENHEIMER, J. LLRES, "Early Bronze Age ceramics Lerna in Greece, Radiochemical Studies," *Archaeo-Physika* 10 (1979) 14-28; M. ATTAS, J. FOSSEY and L. YAFFE, "An Archaeometric Study of Early Bronze Age Pottery Production and Exchange in Argolis and Korinthia (Corinthia), Greece," *JFA* 14 (1987) 77-90; P.P BETANCOURT, G.H. MEYER and J.B. RUTTER, "The Ceramic Petrography of Early Pottery from Lerna," in C.C. KOLB and I.M. LACKEY (eds), *A Pot for All Reasons, Ceramic Ecology Revisited* (1988) 73-80; H. MOMMSEN, E. LEWANDOWSKI, J. WEBWER and Ch. PODZUWEIT, "Neutron activation analysis of Mycenaean pottery from the Argolid, The search for reference groups," in R.M. FARQUHAR, R.G.V. HANCOCK and L.A. PAVLISH (eds), *Proceedings of the 26th International Archaeometry Symposium (Toronto)* (1988) 165-171; S.M.A. HOFFMAN, F.J. ROBINSON, E.B. FRENCH, "Report on the Perlman/Asaro analysis of selected Nichoria sherds," in W.A. MCDONALD and N.C. WILKIE (eds), *Excavations at Nichoria. Southwest Greece* II. *The Bronze Age Occupation* (1992); H. MOMMSEN, T. BEIER, D. HEIMERMANN, A. HEIN, ITTAMEIER and Ch. PODZUWEIT, "Neutron activation analysis of selected sherds from Prophitis Ilias (Argolid, Greece); a closed Late Helladic II settlement context," *Journal of Archaeological Science* 21 (1994) 163-171 and the contributions in J. RUTTER, "The Pottery of Lerna IV," *American School of Classical Studies at Athens* (1995) 663 ff.

2 S. VAUGHAN, "Appendix 2, Petrographic Analyses of Mikre Vigla Wares," *BSA* 84, (1989) 150-159; ID., "Petrographic Analysis of the Early Cycladic Wares from Akrotiri on Thera," in D.A. HARDY *et al.* (eds), *Thera and the Aegean World* III. 1 (1990) 480-487; V. KILIKOGLOU, C.G. DOUMAS, A. PAPAGIANNOPOULOU, E.V. SAYRE, Y. MANIATIS and A.P. GRIMANIS, "A Study of Middle and Late Cycladic Pottery from Akrotiri" in D.A. HARDY (ed.), *Thera and the Aegean world* III.1 (1990) 441-448; S.J. VAUGHAN, V. KILIKOGLOU and A. PAPAGIANNOPOULOU, "An interdisciplinary study of Middle Cycladic White Wares from Akrotiri on Thera," *Mat. Res. Soc. Symp. Proc.* 352 (1995) 445-452.

3 D.E. WILSON and P. DAY, "Ceramic Regionalism in Prepalatial Central Crete, the Mesara Imports at EM I to EM IIA Knosssos," *BSA* 89 (1994) 1-87; T.M. WHITELAW, P.M. DAY, E. KIRIATZI, V. KILIKOGLOU and D.E. WILSON, "Pottery traditions at Myrtos Fournou Korifi, Crete", in R. LAFFINEUR and P. BETANCOURT (eds), *TEXNH, Craftsmen, Craftswomen and Craftmanship in the Aegean Bronze age, Aegaeum* 16, 265-274. Some specimens also in R.E. JONES, " Greek and Cypriot Pottery," *A Review of Scientific Studies* (1986).

of which Eleusis was a part.[4] In order to study these issues more fully and supplement the archaeological study of the material, the authors have undertaken a series of scientific analyses on a large sample of Bronze Age sherds from the site. These analyses were conducted in the NCSR Demokritos and the Fitch Laboratory of the British School at Athens, with funding provided by INSTAP; they included petrographic and chemical analyses on a sample of 180 sherds and electron microscopy on a sample of twenty sherds. The sherds were selected in such a way that they would be representative of the groups identified in the "traditional" archaeological study, briefly described below.

**Archaeological groups**

The macroscopic study of the material led to the identification of eleven main groups of pottery and several subgroups from the Early, Middle, and Late Bronze Age and a tentative distinction between local and imported groups of pottery, on the basis of three sets of criteria:[5]

- technology (fabric, clay color, non-plastic inclusions, and surface treatment),
- morphology (shapes and typology),
- decoration (modes and styles of decoration).

The following groups and subgroups were identified:

**A. Early Helladic Pottery**

In total approximately 100 EH sherds are now known from the old and new excavations. The main groups are the following:

*AI. Red or black Urfirnis* is the largest group (approximately 80 sherds) and dates to the EH II.

*AII. Faience ware* is rare (only five sherds) and dates to the EH II.

*AIII. Light-on-dark* (Aghia Marina style) are also few (four sherds) and date to the EH III.

*AIV.* Two lug handles from the EH stratum appear to be *Cycladic.*

**B. Middle Helladic Pottery**

*BI. Matt-Painted Pottery(MP)*

In total, approximately 4000 MP sherds have been found in the old and new excavations. The sherds have been classified into four classes, briefly described below. Noteworthy is the high percentage of sherds with gold mica, which amounts to more than half of the total number of Matt-Painted sherds and cuts accross all fabric classes.

BIa. Yellow-white ware. It is the largest subgroup, representing 46.2% of the total number of matt-painted sherds. The fabric ranges from semi-fine to medium coarse and

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4 For the old excavation see: A. SKIAS, *Ephemeris* (1898) 28 ff.; ID., *Ephemeris* (1912) 1 ff; K. KOUROUNIOTES and G.E. MYLONAS, "Excavations at Eleusis," *AJA* 37 (1933) 271 ff, G.E. MYLONAS, *Prehistoric Eleusis* (1932); ID., "Eleusis in the Bronze Age," *AJA* 36 (1932) 104 ff; ID., "Eleusiniaka," *AJA* 40 (1936) 415 ff; ID., *Eleusis and the Eleusinian Mysteries* (1961) summary of Bronze Age: 23-54; ID., *The West Cemetery at Eleusis (Library of the Athens Archaeological Society* 81, 1-3 [1975] in Greek). For the new excavation see: M.B. COSMOPOULOS, "The Early and Middle Helladic Pottery from Eleusis," *AJA* 97 (1993) 344-345 (abstract); ID., "The University of Manitoba excavations at Eleusis: An Interim Report," *EMC-CV* XXXIX (1995) 75-94 ID., "The University of Manitoba Excavations at Eleusis," *AJA* 99 (1995) 341 (abstract); ID., "Recherches sur la stratigraphie préhistorique d'Eleusis: travaux 1995," *EMC-CV* XL, 1-26; ID., *Praktika* (1994) 45-60; ID., *Praktika* 1995 (in press). The final results of the analyses will be included into Cosmopoulos' book on Bronze Age pottery from Eleusis, to be published by the Athens Archaeological Society. A brief presentation of the preliminary results was given in the poster session of the 99th Annual Meeting of the AIA, Chicago, December 28, 1997 (*AJA* 102, 373-4).

5 For a detailed description of the methodology see COSMOPOULOS 1993 (*supra* n. 4).

approximately 20% have gold mica. Their surfaces are slipped and burnished or slipped and polished.

BIb. Red/pink or red/orange ware. It is the second largest subgroup, representing 34.3% of the total. The fabric is in general semi-fine to fine and the surfaces burnished or slipped and burnished. Approximately 15% of the sherds of this category have gold mica.

BIc. Green ware. It represents 11.1% of the total. Mostly semi-fine fabric, surfaces are slipped and burnished or slipped and polished or just smoothed. Approximately 11% of this ware has gold mica.

BId. Brown/black ware. It represents 8.4% of the total. The fabric ranges from coarse to semi-fine and fine and approximately 10% has gold mica. Surfaces are polished or slipped and polished or slipped and burnished.

*BII. Grey Minyan Pottery*

Approximately 3600 sherds belong to the Grey Minyan Ware. The following subgroups have been distinguished:

BIIa. Light grey clay. It represents approximately 35% of the total grey minyan pottery. Fabric fine to medium coarse. Surfaces are polished or slipped and smoothed.

BIIb. Medium grey clay. The largest category of grey minyan pottery (approximately 48%). Fine fabric with polished surfaces.

BIIc. Dark grey clay. It represents approximately 13% of the total number of grey minyan sherds. Semi-fine to medium coarse fabric with polished or smoothed surfaces. Commonly decorated with grooves or ridges.

BIId. Red imitation of Grey Minyan pottery. Fabric medium coarse to coarse fabric, with coarse inclusions. This group is small (appr. 4% of the total Grey Minyan).

*BIII. Yellow Minyan*

A small number of Yellow Minyan sherds (approximately 300) have been recovered. Fine fabric, surfaces polished.

*BIV. Bichrome (Cycladic?)*

Approximately 20 sherds have red-and-brown decoration that appears to be of Cycladic origin. Fine to semi-fine fabric.

*BV. Red-Slipped Cycladic.*

Approximately 40 sherds and one bowl with Cycladic red or dark brown slip. Fine to semi-fine fabric.

**C. Late Helladic Pottery**

The following groups of pottery were distinguished:[6]

*CI. LH I-II pottery.*

Decorated pottery, subdivided into two groups:

CIa. Fine fabric, lustrous light brown slip and lustrous black or red paint.

CIb. Semi-fine fabric, matt light brown slip and matt black or dark brown paint.

*CII. LH IIIA1-IIIA2 pottery*

Decorated pottery subdivided into two subgroups:

CIIa. Fine fabric, lustrous light brown or yellow slip and lustrous black paint.

CIIb. Semi-fine fabric, matt light brown slip and matt black, brown or red paint.

CIIc. Plain undecorated pottery with fine, light brown fabric.

6 The quantitative analysis of the LH pottery is now being completed.

*CIII. LH IIIB1-IIIB2 pottery*

CIIIa. Decorated semi-fine to medium coarse pottery, matt light brown slip and matt brown paint.

**Petrographic analysis**

The samples for analysis by petrography were selected so as to represent the range of fabrics already identified in the archaeological study and were analysed in order to verify the results of the hand specimen examinations. Several samples were taken from each fabric group, so as to assess the degree of internal variation. Although petrography is not suited to the analysis of fine-grained fabrics, we deemed it preferable to select the same samples for both NAA and petrography, in order to allow direct comparison of the scientific results.

For petrography, the samples were removed as small chips (between 2 to 3 cm sq in size). Thin sections were made from these chips using the facilities in the Fitch Laboratory of the British School at Athens. The petrographic analysis focused on the composition (grain identification based on reference literature, and frequency of occurrence) and texture (grain size and shape) of inclusions in the ceramic fabrics. These data allowed discrimination both in terms of the geology of the source regions, and in terms of the coarseness of the paste, which may in turn relate to the size of particular vessels, methods of their manufacture, and the preferences of the potters. Comparison with data (from geological maps and journals) on the regional geology in the vicinity of Eleusis, and in other parts of Greece, were used to isolate those fabrics that were likely to be local, and those that were likely to be imported.[7] Furthermore, the samples from Eleusis were compared against material from other sites, including Lerna, Kirrha, Orchomenos and the Athens Acropolis wells, to determine whether correlations that may further identify the origins of imported ceramics could be made. The following petrographic groups were identified:

*Petrographic Group I*: It is characterised by the presence of volcanic rock fragments and represents about 40% of the samples. It includes the majority of the MH Matt-painted wares, a number of coarse wares but also some of the Early Helladic samples (e.g. EH Urfirnis). Some variability present within this group could reflect products of different geographical origin (characterised by the presence of different volcanic rocks) or differential use of the raw materials from a specific area. Aegina is one probable source for this pottery.

*Petrographic Group II*: This is a silicate group, consisting of fine-grained fabrics with inclusions that are not indicative of origin. It represents approximately 50% of the samples and includes the majority of the MH Grey Minyan wares, most of the EH Urfirnis samples and almost all the LH samples. Some degree of variability is evident within this broad group, too; its large chronological span being surely one of the main reasons.

*Petrographic Group III*: The third group is characterized by schist inclusions and appears to be comprised of several subgroups, probably reflecting a variety of sources. It encompasses sporadic samples of various types; coarse wares, red slipped ware, Matt-painted and EH samples (which further suggest that these fabrics include material of various sources). Some of the samples included in this group could be of cycladic origin (i.e. red slipped ware or Early Helladic sherds of cycladic-style).

Apart from the above main groups, there are minor ones (e.g. Serpentine group related to a small number of Matt-painted samples).

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7 In summer 1996 a non-systematic attempt by Cosmopoulos and Kilikoglou to identify local sources of clay by interviewing modern potters and inspecting possible locations that could be used to supply clay proved unsuccessful, something that could be expected given the destruction of the Eleusinian landscape by industrial and residential construction.

## Chemical analysis

*Neutron Activation Analysis*

The external surface of the sherds selected for Neutron Activation Analysis (NAA) was cleaned with a tungsten carbide drill-bit, and a piece of about 300 mg was cut from each of them. Then samples were ground and dried at 110°C overnight. For the analysis, samples were irradiated in batches of 10 (8 samples and 2 reference materials of 120 mg each) at the "Demokritos" swimming pool reactor at a flux of $3x10^{13}$ n. $cm.^{-2}.sec^{-1}$. Eight days after irradiation samples and reference, materials were counted for the g-spectra in order to determine the concentrations of *Sm, Lu, U, Yb, As, Sb, Na, Ca, La.* The same samples were counted again two weeks later to get data from isotopes with longer half-lives in spectra with lower background. The following elements were determined: *Ce, Th, Cr, Hf, Ca, Sc, Rb, Fe, Co, Ta, Eu.*

At the second stage of the analytical work, the collected data were standardized and subjected to statistical treatment in order to investigate possible groupings. As it has already been mentioned, the first goal of the work was the characterization of the various fabrics that exist within the samples from Eleusis. Therefore, the preliminary grouping by cluster analysis was compared to the petrographic and hand specimen examination data. Statistical analysis was fed back with the latter and the various groups were reconsidered. At this level, principal component analysis was used for the refinement of the original groups.[8]

The last stage of work was the comparison of the final groups to available databases for Argolid Corinth, Attica, Boeotia, and Aigina. The known published data have two problems: a) the majority of the available data are not entirely contemporary with the Eleusis material and b) in the past data were produced by analytical techniques other than NAA, which determine different chemical elements. Neutron activation analytical data are available for Mycenaean pottery from the Argolid,[9] and for EH pottery from Corinthia.[10] Furthermore, there are comparative data for the Geometric-Hellenistic periods from Attica[11] and also unpublished analyses from the NCSR Demokritos. Neutron activation analysis indicated two main chemical groups (Pl. XIX), each containing a number of small sub-groups:

*Chemical Group I.* The first main group contains the majority of the MH matt-painted wares.

*Chemical Group II.* The second main group includes MH grey minyan sherds.

*Scanning Electron Microscopy*

The micromorphology of fabric and surface of sherds was examined using a Philips 515 Scanning Electron Microscope coupled with the energy-dispersive system EDAX 9900. The procedure allowed the study of such technological aspects of the samples as degree of vitrification of the clay matrix, paints, surface treatment, degree of adherence of the paint to the body, and firing temperature. The results are presented in Table 1.

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8 V. KILIKOGLOU, M.T. KARAYANNIS, A.P. GRIMANIS, "Neutron Activation and Statistical Analysis of Pottery from Thera, Greece," *Journal of Radioanalytical and Nuclear Chemistry, Articles* 142 (2) (1990) 347-355; V. KILIKOGLOU and A.P. GRIMANIS, "Chemical Characterization of Bronze Age Pottery from Greek South Aegean Islands by INAA," *Journal of Radioanalytical and Nuclear Chemistry, Articles* 168 (2) (1993) 297-306.

9 MOMMSEN *et al.* (*supra* n. 1) 1988 and 1994; HOFFMAN *et al.* (*supra* n. 1) 1992.

10 ATTAS *et al.* (*supra* n. 1) 1977 and 1979.

11 D. FILLIERES, C. HARBOTTLE, E.V. SAYRE, "Neutron activation analysis of figurines, pottery and workshop materials from the Athenian Agora, Greece," *JFA* 10 (1983) 55-69.

| Ware | Samples | Calcareous | Firing Temperature | Surface |
|---|---|---|---|---|
| Matt-Painted ware (MH) | 12 | medium to high | 800°C to >1080°C | Mn black; oxidation atmosphere |
| Grey Minyan (MH) | 6 | low to medium | 800°C to 1080°C | Burnished reduction atmosphere |
| Yellow Minyan (MH) | 1 | medium | 850°C to 1050°C | burnished |
| Coarseware (MH) | 3 | low | <750°C to 750°C | |
| | 1 | non | 800-900°C | |
| Red Slipped Cycladic (MC) | 1 | non | <750°C | Burnished; oxidation atmosphere |
| Painted Pithoi (LH) | 4 | medium | 800°C to 1050°C | Fe-reduction black; Fe red; oxidation-reduction-oxidation atmosphere |
| Bichrome Cycladic (MC) | 2 | medium to high | 800°C to 850°C | Mn black; Fe red oxidation atmosphere |
| | 1 | low to medium | 1050°C to 1080°C | Mn black; Fe red oxidation atmosphere |
| Urfirnis (EH) | 1 | medium | 1000°C to 1080°C | Fe-reduction black; burnished surface; vitrified with bloating pores |
| | 1 | medium | 800°C to 850°C | Fe red; oxidation atmosphere burnished surface; no vitrification |

Table 1: Results of SEM analysis of Bronze Age samples from Eleusis

## Conclusion

The first chemical and petrographic groups indicate that the MH Matt-Painted pottery was, almost in its entirety, imported, apparently from Aigina. The same appears to be true also for some of the coarse ware, which does not seem to have been manufactured locally. Another possible source of imported pottery was the Cyclades, where the red-slipped and bichrome pottery seem to originate (Petrographic Group III). On the other hand, we do not know the origin of the EH Urfirnis and the MH Grey Minyan Ware (Chemical and Petrographic Group II). The full study of the issues of local production, craft specialization, and ceramic exchange will be conducted after the completion of the physicochemical analyses. It is hoped that these will contribute towards the study of the social and economic factors that led to the growth and development of one of the most important religious centers of the ancient world.

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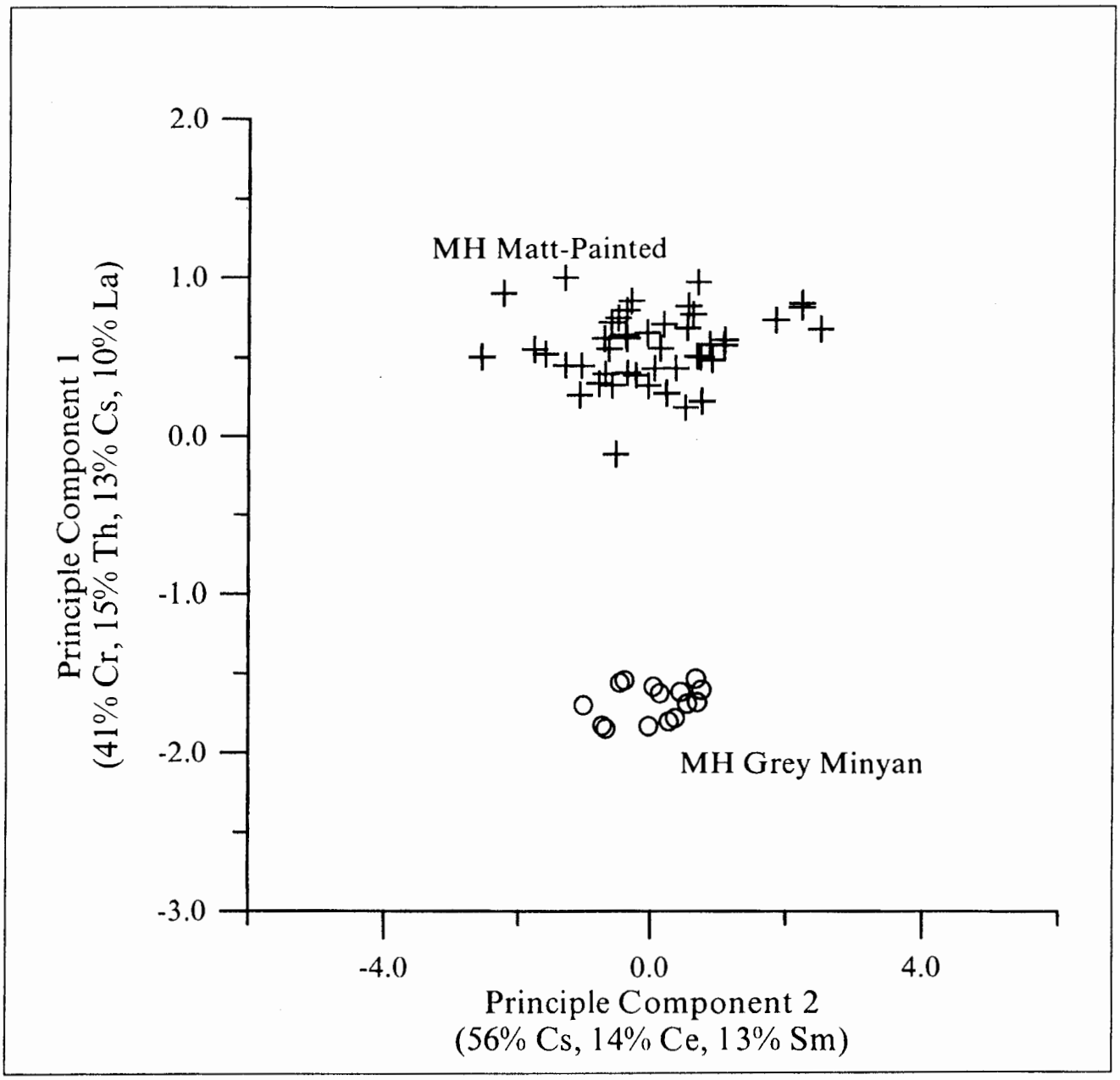
ILLUSTRATION

Pl. XIX Composition of main chemical groups.


2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
0.0
4.0
Principle Component 1
(41% Cr, 15% Th, 13% Cs, 10% La)
Principle Component 2
(56% Cs, 14% Ce, 13% Sm)
MH Matt-Painted
MH Grey Minyan