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CHEMICAL ANALYSIS OF POTTERY AND CLAY FROM CARTHAGE

BY

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SECTION 1.1

INTRODUCTION AND RESEARCH GOALS

Walking across the tilled ground or through the remaining olive groves, the modern visitor to Carthage is likely to notice the sherds of pottery which litter the ground. Many are a bright red-orange color with a smooth and shiny surface. This comes as no surprise to those familiar with the material culture of the Roman world. Actually, one would be surprised not to find a bit of Samian ware where the Romans lived. The variant used and made in North Africa is known as African Red Slip. Red-gloss pottery first appeared in the Eastern Mediterranean, but commercial production began in Italy during the 1st century A.D. Production rapidly spread to Gaul. Various fabrics were produced at least until the 7th century.(1)

Red-gloss pottery from the Italian and Gaulish workshops has furnished scholars with an ample supply of material for study.(2) Excavations at numerous European manufacturing sites and studies of distribution patterns have revealed an organizational complexity and a scale of production unparalleled in the ancient Mediterranean. The manufactories shared many features of modern serial production. Shapes were reproduced with moulds and decoration was achieved by combining motifs from prefabricated stamps. Tally lists, recorded on rejected vessels, named the workers assigned to various tasks and registered the quantities of production.(3) The workshops were clustered at manufacturing centers. Potters identified their wares with stamped trademarks, a practice

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1. Goudineau (1968); Comfort (1940); and LRP.
2. Oswald and Pryce (1920); Comfort (1940).
3. One inventory lists 166,000 vases of the same form. Pucci (1983) 110.

rarely adopted by other groups of Roman craftsmen.(4) Distribution of the pottery from these manufactories(5) was apparently controlled by middlemen, negotiatores. The ceramics were shipped considerable distances, and in some instances accounted for a significant portion of the cargo in merchant vessels.(6)

The terminology used to describe this pottery includes several different words which are often used synonymously. The fact that relief decoration appears on numerous bowls has led to the use of "terra sigillata". The earliest known production center in Italy was located at modern Arezzo, hence, "Arretine" has been employed in other instances. The generic term "Samian Ware" has been popular for many years among English speaking archaeologists. Latin authors who speak of "vasa samia" provided the precedent for its use. A recently published inscription from an inventory at La Graufesenque indicates the verb samiare was the term used by potters themselves, probably to describe burnishing (polishing) the pottery. Samian is, therefore, quite appropriate for describing the Roman's china.(7)

Technically speaking, Samian Ware is a variety of red-gloss pottery. The term "gloss" is essential to distinguish it from pottery coated with a vitreous glaze. The lustrous coating is a clay slip which has only partially

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4. Hermet (1934); King (1980); Labrousee (1975); Vertet (1975). Peacock (1982) 115-128, provides a concise, comprehensive synthesis.
5. The term manufactory is used to distinguish between the modern industrial plant and manufacture which did not benefit from the use of machinery. Peacock (1982) 9-10. Some of the Samian manufactories occasionally employed 30-60 workmen. Since these installations are comparable in size to many modern enterprises, the term "factory" may be appropriate in the the context of Roman pottery production.
6. Pucci (1983).
7. King (1980).

vitrified.(8) The physical properties vary considerably between production centers and throughout the long history of red-gloss manufacture. The coating of African Red Slip (ARS) is, generally speaking, inferior in quality to its Italian and Gaulish counterparts. Although glossy, the slip is much thinner and less lustrous than the red-gloss made in Gaul. The terminology used by Italian archaeologists (terra sigillata chiara) to describe certain categories of the late Roman ceramics recognizes this difference. While Samian from Europe has been examined in numerous laboratories, ARS has not been analyzed. The physiochemical properties of the surface finish, therefore, may not correspond with the sintered coating of Samian. This uncertainty and the obvious visual characteristics of the surface, are arguments which favour the use of "red slip" for describing the pottery of North African origin.

Until the middle of this century, the late Roman red-gloss pottery was neglected in favour of the more elaborately decorated Samian. Italian archaeologists excavating in Italy and Spain recovered large quantities of red-gloss pottery and developed classification systems which include African, Gaulish and Near Eastern fabrics.(9) It is recognized that the publication of Late Roman Pottery by John Hayes established the basis for further study. He provided a synthesis of earlier work and a comprehensive typology. Excavations at Carthage, conducted within the framework of an international Unesco campaign,

8. See Chapter 2, Section 1.
9. LRP. 13-18, 287-300. Another review of the scholarship on ARS is provided in Carandini (1983) 158-162.

have revived interest in the site(10) and have furnished an abundance of African Red Slip.(11)

Currently available evidence indicates that ARS manufacture began in North Africa during the 2nd century in modern Tunisia which corresponds approximately to the Roman Province of Africa Proconsularis. The earliest production centers were apparently located in the southern and central regions of the country, but by the 3rd century manufacture was established near the northern coast.(12) Workshops in this area have been found at Oudna and quite recently at Mahrine.(13) The prodigious quantities of ARS from the excavations at Carthage have left no doubt in the minds of specialists that the "classic types of ARS, specifically Lamboglia's TS chiara A and D series" must have a "North Tunisian origin".(14) These fabrics were exported throughout the Mediterranean littoral and beyond, as far as the British Isles.(15) The frequency with which ARS of the A and D varieties occurs at Carthage certainly gives weight to the supposition that this pottery was made in "the vicinity" of Carthage.(16) The workshops, if they existed within the city proper or adjacent to the urban area, have not been located.

Given the wide distribution of ARS and the relative similarity of the fabrics, the present investigation was undertaken to determine whether or not chemical composition could be used to distinguish different varieties of

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10. The research has been reported at international colloquia. Pedley (1980), Cahier des études anciennes XVI-XVIII. Bibliographies of excavation reports are furnished by J. Humphrey in AJA 84:1 (1980) 75-87. See also CEDAC Bulletin 4 (1971) 56-60.
11. ECBM I,2. CMICH I, II and IV. See also Actes CCC.
12. LRP 296-298. Carandini (1983) 147-151.
13. Mackensen (1985); Carandini (1983) 146.
14. Hayes (1976) 84.
15. Distribution maps are provided by Hayes in LRP 453-456.
16. Hayes (1976) 84-85.

material from Carthage. The abundances of chemical constituents provide separation criteria which are considerably less subjective than the obvious physical attributes of pottery which are commonly used to identify a particular fabric. The chemical "fingerprint" of a fabric can be used to trace the source of manufacture. This study also attempted to use the analytical data to test the assumption that the ARS recovered at Carthage was produced locally.

Several groups of ARS and associated ceramics from excavations within the Roman city were examined using direct current plasma emission spectrometry. Abundances of nine chemical componants, including major constituents and trace elements, were obtained for two hundred samples of pottery. These data, when subjected to statistical analysis, provided distinct patterns of chemical composition for individual groups of ARS. The compositions of local clays were compared with the chemical parameters established for the ceramic groups in order to assess the likelihood that the pottery was made in the vicinity of Carthage. Data from approximately one hundred samples of argillaceous soil constituted the raw material inventory. These clay samples represent major deposits at Carthage and at several other sites in northern Tunisia.

The approach to this research was essentially the same as what several laboratories have perfected for examining Greek pottery and Roman red-gloss ceramics manufactured in Italy and Gaul.(17) Chemical composition, determined by a variety of instrumental techniques, has been used to separate pottery from different production centers.(18) Provenience studies are by no means confined to the ceramics of the Greco-Roman world. Their utility has been proven by

17. The activities of the CNRS staff, particularly M. Picon (see bibliography) are particularly noteworthy.
18. Prag et al. (1974); Stern and Descoeudres (1977); Wilson (1976).

investigators working with archaeological material of the prehistoric cultures in the Near East and others studying ceramics of the ancient Americas.(19)

Whenever possible, reference groups, consisting of ceramic samples from workshops located by archaeological excavation, have formed the basis for comparison. When appropriate ceramic material was unavailable, similarities between clay deposits and ceramics have been utilized to suggest the origin of production.(20) This approach is, of course, more difficult. Ultimately one can never exclude the possibility that clays from two different locations might have identical compositions; and variations within a single clay source can cause confusion. These limitations, generally recognized by those who have attempted such investigations, permit the exclusion of sources whose chemical compositions do not match the ceramics in question, but they prevent a positive indentifica-tion of the actual source. Furthermore, it has been pointed out that when evaluating potential sources one must consider other evidence such as distribution patterns.(21) Ultimately, matching elemental abundances cannot be considered an absolute indicator of origin, but it adds considerable weight to other arguments which favour a particular source of manufacture.

Archaeological interpretation often relies on data which cannot meet the rigorous demands of modern scientific inquiry, conducted under the ideal conditions obtainable in a laboratory. The best one can achieve in certain situations is a plausible explanation. This is true for provenience studies. They can provide strong support for reasonable suppositions, within the

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19. Wilson (1978); Bishop et al. (1982); Peacock (1970); Abascal et al. (1982).
20. Schneider et al. (1979); Hancock (1984); Birgül et al. (1979); Abascal et al. (1974) and Hammond et al. (1976). This source identification technique has been used for other materials as well. Craddock et al. (1983); Michels (1982) and Boulle and Peisach (1979). See below: Section 3.1.
21. Wilson (1978); Stern and Descoeudres (1977) and Lemoine et al (1982).

limits imposed by the data, but they cannot furnish absolute proof. That is the context in which the results of this research must be evaluated.(22)

22. Lemoine et al. (1982) 57-59.

SECTION 1.2

THE SAMPLE POPULATION

The pottery which provided material for chemical analysis was recovered during excavations conducted on the northern edge of Roman Carthage. The project, directed by Dr. C.M. Wells, began in 1976. Excavation has ceased, but study of the results and preparation of a final report are continuing. The largest excavation trench has exposed the end of a city block between Cardines II and III East and bounded by Decumanus VI North. The buildings of this sector abutted the city fortifications known as the Theodosian Wall. The wall was built in the 5th century in response to the Vandal invasion of North Africa.(23) Several other trenches of varying size have been opened during the campaign. A general plan of the site appears in Figure 3.3.

The pottery which provides the basis for this investigation was brought to Canada for study by Dr. L. Neuru in 1981. She originally had full responsibility for processing and publishing the ceramics from the site. This analytical project was to be focused on pottery fabrics assigned by Dr. Neuru to a typology developed around the ceramics from the entire site. Circumstances intervened which prevented the completion of a typological framework before the selection of samples for chemical analysis. Dr. J. Freed has since taken over the enormous task of preparing the pottery for publication. Her work is nearing completion, but results have not been integrated with the stratigraphical reports and the dating information furnished by the coins. This situation has influenced this study in several ways.

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23. Wells et al. (1986); Wells and Wightman (1980).

Dates established for the strata from which the pottery derives may require revision, but they are not likely to be changed sufficiently to affect the general conclusions reached in the present investigation of their chemical characteristics. It was also necessary to proceed by using criteria which may not match precisely the ones developed by Dr. Freed for separating and defining individual fabrics. Correspondences will need to be determined after her work is terminated. Because the completion of the ceramic inventory has been delayed, it is not possible to determine accurately what proportion of the pottery from individual layers and the site as a whole is represented by the fabrics chosen for laboratory examination. It is clear; however, that these groups are the most common in the material available for sampling. By inference their importance should extend to the site as a whole. Sherds from a number of other strata, among the materials transported from Carthage, were examined in the preliminary selection stages. There were several hundred examples of the main fabric types (Fabrics Types III and IV) in these deposits. Although frequencies of occurrence are unavailable, the fabrics selected for analysis were prominent in the assemblage from the site as a whole.

Other criteria which influenced the selection process were adopted to insure accurate results. Fragments with calcium concretions were avoided, because the formation of such deposits could have altered the original compositions of these sherds. Care was taken to insure the samples represented single vessels. Diagnostic sherds were chosen, rims for the most part, which did not match other pieces in the sample population. This task was greatly facilitated by the large number of sherds from the deposits. The fabrics display irregularities which are described in the following section of the

report. Pieces which deviated from the norm were avoided, except in those instances when anomalous characteristics warranted investigation. These cases are noted in the text and tables.

Three deposits furnished the ARS for chemical analysis. Their chronology is based, in part, on the pottery itself. The pottery which these deposits contained was divided into two major classes, Fabric Types III and IV. These Fabric Types were subdivided by deposit following the system described below (pp. 11ff.). Table 1.1 presents a summary of the fabric classification, and gives proveniences and dates for each of the subdivisions.

3RD CENTURY DEPOSIT: LOCI 2F 32 - 36.

The earliest deposit consisted of a series of contemporary, interwoven strata. These are loci 2F 32-36. They were laid down within a large rectangular structure refered to as Building A in the site reports. The building was situated North of the Decumanus VI within the main excavation area. (See Figure 1.2).(24) The building was destroyed early in the 3rd century, according to the dates furnished by the pottery. The pottery from the stratum includes Fabrics F I, F II, F III and F IX.

5TH CENTURY DEPOSIT: LOCUS 1M 7.

The second deposit, stratum 1M 7, accumulated on the surface of Decumanus VI after construction of the city wall in ca. 425 AD. The street was blocked at this point by the fortifications. The cul-de-sac made a convenient repository for refuse, within the city, against the southern face of Theodosian Wall. The residents of an adjacent house took full advantage of this space for disposing of their garbage.(25) The "chronological consistency" of this 5th

24. Wells (1985) 7-11.
25. Wells and Wightman (1980) 47-49.

century deposit makes it an excellent choice for analysis.(26) A portion of this material has been presented with illustrations in a recent article.(27) The Fabrics from this stratum are M III and M IV.

5TH-6TH CENTURY DEPOSIT: LOCUS 1N 17.

The third deposit was excavated on the northern side of the Theodosian Wall. This portion of the Canadian site has not been published in detail. The pottery had accumulated above the base of a cistern, destroyed when the city's fortifications were constructed. The assemblage of pottery appears to include both 5th and 6th century material.(28) The pottery from this stratum includes Fabrics N III, N IV and N VII.

The sampling procedure began by assigning catalogue numbers to approximately 500 pottery fragments. After an initial sorting, the remaining samples were color coded and examined individually with 20X magnification. They were placed in groups on the basis of their gross physical properties. The African Red Slip Ware was divided into two main categories which were labeled Fabric III Type and Fabric Type IV. They share many attributes. The principal distinction was based on the color of their pastes. The fabrics were then subdivided according to their stratigraphical context. Fabric Type III was represented by samples from all three deposits. Its subdivisions were labeled F III, M III and N III. Fabric Type IV comprised samples from the 5th and 6th century strata, 1M7 and 1N17. There are some sherds from strata 2F 32-36 which did not belong to this Fabric; however, the limit placed on the sample population did not permit their inclusion in the analytical program. The

26. Wells and Wightman (1980) 49.
27. Neuru (1980).
28. The preliminary dates for the stratum 1N 17 are based on documents in the excavation archives prepared by L. Neuru who examined the pottery.

samples of Fabric Type IV from stratum 1M7 were designated as Fabric M IV, those from 1N17 as Fabric N IV. Other minor fabrics were also distinguished. These are described elsewhere.

These subdivisions provided the groups which were subjected to discriminant analysis. The purpose of dividing the sample in this manner was to determine whether or not one could distinguish between the two main varieties as well as between pieces of the same basic Fabric Type made at the different times. The assortment of pottery from the Canadian site offered an excellent opportunity to investigate the possibility of making such distinctions. The three deposits were clearly defined stratigraphically. The preliminary dating for each locus indicated that the ceramics belonged to well-defined, finite chronological periods. The large volume of pottery provided a suitable sample size which included multiple examples of several common ARS shapes.

The main Fabric Types share many characteristics. Both have thin moderately glossy slips although many pieces have a matte finish. The slip is often finely mottled. It is smooth to the touch but small bumps are prevalent giving it the "pimply appearance" noted by others.(29) All of the vessels analyzed have completely slipped interiors. Only one group, the pottery of Fabric F III, is characterized by a coating covering most of the exterior as well. The other fabrics are not completely slipped. Their coating usually continues from the interior, over the lip and down the sides creating a band one to three centimeters wide. Trails of slip commonly extend below this region. On some vessels these are smeared as though the potter tried to wipe them away. It is believed this results from an application procedure whereby the clay

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29. LRP 292.

slurry was simply poured into the vessels and swirled rather than dipping the pottery into a container of slip.(30) The slip gradually becomes thinner as it approaches the lower edge of the exterior band. There is a simultaneous decrease in luster until the slip becomes entirely matte. This indicates that the reflective quality of the coating largely depends on its thickness. Burnishing may enhance the sheen on the vessel interiors.(31) Smoothing or burnishing marks can be detected on vessels from all of the fabrics. This operation may have been conducted before the slip was applied. It is difficult to be certain of this because the slip is generally so thin. If the pottery was not polished after the coating had been applied it might account for the matte finish on certain fabrics.

The surface is "hard" according to the scale used to evaluate pottery from the British excavations at Carthage. That is to say, the surface can be scratched with metal, but not with the finger nail.(32) The slip adheres very well to all of the pieces representing Fabrics III and IV. The smooth surface, as noted above, is interrupted by many small bumps. This occurs where mineral grains protrude from the underlying paste. Spalling also occurs quite often. The calcite fragments causing these blemishes are generally only a fraction of a millimeter in diameter, but one piece nearly 2 millimeters across was observed.

All of the attributes previously described can be detected easily with the naked eye. In order to scrutinize the samples more closely, all sherds were examined with a 20X hand lens. With the aid of magnification the effect of these protruding inclusions is more easily observed. Their presence is related

30. LRP 294-295. Vessels were apparently dipped to coat their exterior walls.
31. LRP 291.
32. ECBM I, 2. p.7.

to another visual characteristic of these ARS fabrics. Tiny flecks of luster appear in raking light. These can be seen on slipped portions and in places where no coating exists. They create the effect associated with inclusions of mica. Through the lens it appears these bright spots are in fact quartz grains. The inclusions occur as translucent rhomboids, not as platelets. At close range their luster is glassy, and not of the metallic or pearly quality commonly associated with muscovite and other micas.(33)

The identity of these lustrous mineral grains needs to be verified by petrological assay, but it seems they cannot be categorized as mica. Their presence in ARS fabrics is significant for two reasons. Firstly, one description of an early ARS variety refers to "occasional specks" of mica.(34) The material from this study shows that such identifications need verification under higher magnification by subsequent laboratory examination. None of the sherds examined in this study contained inclusions which could be positively identified as mica, muscovite or biotite. Mica is not mentioned in the reported results of a petrological study conducted on ARS from Carthage.(35) This description is unfortunately extremely brief. Consequently it cannot be considered definitive. Mica has been identified in one variety of black-burnished ceramic found at Carthage, but probably made elsewhere.(36)

The glassy quartz inclusions may have been altered by heat. Rapid cooling can cause quartz to shatter. Freshly created facets could yield a

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33. I wish to thank Mr. Phillip Wright, Regional Archaeologist, Ontario Ministry of Citizenship and Culture for allowing me to compare micaceous prehistoric pottery with samples of ARS.
34. LRP 290.
35. ECBM I, 2. p.14-15.
36. ECBM I,2. 8-11.

highly reflective surface.(37) Preliminary tests suggest the pottery was fired to a temperature of 1000 degrees Celsius or slightly less.(38) Quartz will not melt until a temperature of 1713 degrees Celsius is reached unless a flux is present. If the glassy luster of the quartz grains results as an effect of the firing, a glassy layer may have formed on the inclusions through a reaction with the alkaline impurities in the clay. The uncertainties surrounding the origin of the lustrous mineral inclusions make it clear that a petrological study of ARS needs to be published. One could learn much about manufacture by examining thin sections under a microscope. It is unfortunate that more details about the material from Carthage which has already been examined have not been reported. Hopefully, this information will appear at a later time.

The use of a hand lens was adopted for this investigation as an aid to fabric separation and not as a replacement for the petrological microscope. In a sense, the magnifier represents a compromise between the naked eye and more sophisticated equipment. Portability and cost often limit what can be accomplished in the field. It seemed desirable to report what could be discerned with the hand lens since this could prove useful to ceramologists working without the benefits of a suitably equipped laboratory. Examining sherds with a magnifier of 20X is more informative than the common practice of using a less powerful lens or no magnification at all. It can help to define problems which require closer scrutiny and to select specific sherds for laboratory analysis.

As previously noted, smoothing or burnishing marks are clearly visible on the surface of the pottery analyzed in this study. There are numerous small

37. Shephard (1957) 28-29.
38. LRP 295.

pits left by mineral grains pulled out during these operations. There are also grooves formed by inclusions pulled through the leather-hard clay. This has been cited as evidence for the use of molds to manufacture some ARS forms.(39) This may explain some of the grooves, but others are found in longitudinal facets on the exterior of numerous vessels. These flat bands suggest the undersides were trimmed or scraped to procure the desired contour of various vessels represented in the sample population. This could mean that some vessels were free thrown or only partially moulded.

When broken, vessels of Fabric III and IV present a sharp, but irregular fracture. The breaks usually occur in relatively straight lines. They expose a laminated macro-structure. Short gaps as wide as one millimeter occur between layers. There are also many examples of large air pockets running longitudinally through the thicker part of rims. Smaller voids occur randomly in the paste.

The layered core may result from the clay being pressed against a mold. One would expect a more homogeneous structure if the clay had been raised with pressure applied evenly to both sides while turning. In any case, the lamellae suggest the vessels were turned or pressed into a mold for a relatively short time. A longer application of pressure while the clay was plastic would probably have eradicated this structure.

Quartz grains constitute the principal non-plastic material in the paste. They vary in size and may be as large as a millimeter across. Both angular and rounded grains occur. The latter are generally larger. It is not certain whether these were added intentionally.(40) A similar variety can be

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39. LRP 294.
40. ECB1 I,1. 15. LRP 290.

observed in the natural clays of the region. The dispersal of the quartz is not always uniform in the same sherd. Clusters of grains can occur which give the impression that there is no clay present when viewed through the lens. Particles of white calcite are interspersed with the quartz. Some of these may be calcium oxide particles created by thermal alteration of limestone inclusions. They vary in size, but usually are less than half a millimeter wide. Occasionally, as already noted, they are four times as large. This identification of the white inclusions is based on petrological examinations reported elsewhere and on the spalling often associated with them.(41)

Another variety of inclusion can also be detected in the paste. Angular grains of a very dark brown or blackish mineral occur sporadically in the clay body. Usually they are less than .5 millimeters across, but some as large as 1 millimeter were observed. These are not always obvious without magnification. Often, they are present in small numbers and may not be observed along every break in a sherd. Like the other impurities they are sometimes clustered together. Reference has been made to a petrological study of an extensive assortment of African Red Slip excavated by the British Archaeological Mission at Carthage. The material derives from primarily 5th and 6th century deposits. The dating, the catalogue of forms and the physical description of these finds indicate that Fabric Types III and IV are represented in these finds. An assessment of the results from thin sectioning concludes "the petrological method has been taken to its limits" in an effort to distinguish fabrics.(42)

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41. ECBM I,2. 14-15.
42. ECBM I, 12. 14.

The "extreme uniformity" of the geological region which includes Carthage is reflected in both ancient and modern ceramics examined in conjunction with the British investigation. The only mineral species mentioned in connection with ARS are rounded quartz and cryptocrystalline limestone.(43) Other minerals were identified in several varieties of coarse ware whose distribution suggests they were made in the vicinity of Carthage.(44) The rudimentary information available at present does not permit speculation about the identity of the black grains found in Fabrics III and IV. A more detailed petrological report on the British material and an examination of thin sections from the sherds analyzed in this study will be needed to identify the black mineral inclusions and determine their frequency of occurrence in ARS.

The clay matrix of Fabrics III and IV is fairly porous. Numerous small voids can be detected with magnification in addition to the larger cavities visible by eye. The texture of the clay through the lens is quite dense and its surface along the breaks is surprisingly smooth when contrasted with its unmagnified appearance. The size and frequency of quartz inclusions creates an impression of coarseness which is altered by a closer viewing. A darker color zone, independent of the lamellae described above, can be detected in the center of many of the ARS sherds. The contrast is often slight, but some cases exhibit a pronounced difference. The occurrence of this darker core led to the creation of two additional fabric groups for this investigation. Its presence provides evidence for the techniques used for firing ARS. This aspect of the production method is discussed at greater length in Chapter II of this report. (See below: Section 2.1)

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43. ECBM I,2. 15.
44. ECBM I,2. 8-13.

The physical attributes of Fabric Types III and IV suggest they belong to the broader categories known as terra sigillata chiara A and D. Several subgroups have been identified some of which share characteristics with the material from the Canadian Site.(45) More precisely, they seem to match the variants 2.1 a and b of the classification used to catalogue ARS from the British excavations.(46) The Fabric Types and their subdivisions are listed in Table 1.12 on page 54. This table also provides a summary of provenience and chronological distribution. The designations used in this study should be considered as temporary expedients, required to facilitate statistical analysis. A typological study of the pottery from the Canadian site is finally nearing completion. It will be necessary to integrate the results of the chemical analysis with the system devised for the typological analysis.

The Fabrics

Material from the 3rd century deposit (loci 2F32-36) was divided into four fabrics: FI, FII, F III and FIX. Fabrics FI and II were distinguished by a dark band of color in the center of the clay body. This band is most prominent in Fabric F I. The group has only three members. As can be seen from Table 1.5, it was represented by open bowls of the Form 8 and 9 varieties.(47) The exterior finish is relatively thick and lustrous. The Munsell color is red, (2.5YR 5/8). The outer portion of the core is light red (2.5YR 6/8). Sandwiched between these light red layers is a very dark grey to black zone (2.5YR N/4-N/3). In other respects these sherds are similar to those of the F II and F III Groups. Fabric F II includes vessels with a less intense, but

45. LRP 287-292.
46. ECMB I, 2.48.
47. All form disignations refer to the typology elaborated in LRP unless otherwise indicated.

clearly distinct zone of darker coloration. The entire clay body displays colors of the 2.5YR hue. The outer zones have a value of 2.5YR 6/8-5/8 which match the slipped vessel exterior. The darker core is reddish brown, 2.5YR 4/4. Six sherds, three of them the flaring Form 8 bowls, were assigned to this category. The resemblance between the examples of these two groups and the material assigned to the F III group suggests these are variants of the more common category. Fabric F III is represented by common ARS forms with the exception of a small rounded lid (Sample 163). The slip color is red, 2.5YR 5/8, although patches of more reddish color, 10YR 5/8-6/8, often occur. The core displays this range of color; however, its value is more commonly lower, closer to a Munsell reading of 2.5YR 4/8. When compared with the subgroups which compose Fabric IV, the F III sherds usually have fewer white inclusions. This is the most common fabric in the sample available from the 3rd century loci. It could reasonably be equated with the terra sigillata chiara A group of fabrics on the basis of the general characteristics already described, particularly because of the more complete slip covering.(48)

One further group of vessels from the 3rd century deposit was singled out. This is comprised of four Form 23 bowls and two Form 26 casseroles. These seem to have a slightly coarser texture than the F III fabric, but their principal distinction is the presence of a dark brown band on the exterior. Although their attributes in other respects would have placed them in the F III category, they were given a separate label (F IX) in order to test the significance of this difference in manufacturing technique.

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48. LRP 288-290. I wish to thank Dr. J. Freed for assisting me by identifying a few reference sherds for comparison with my fabric groups.

Two groups of pottery were separated from the material in locus 1M7, the 5th century deposit (See Table 1.6). These do not represent all of the varieties found in the deposit, but they comprise most of the material available for analysis.(49) The predominant slip color is 2.5YR5/8 although patches occur where the color strays in value. Both the slip and the paste have colors which match those of Fabric F III. The slip is rather less glossy than what one encounters in the 3rd century pottery. The most obvious distinction between this material and the F III group is the lack of slip on the lower exterior portions of the M III vessels.

One example of cooking ware, sample 183, was included with the other vessels in this category. It is a trefoil lipped jug which represents the LRCW I variety of pottery.(50) Although the slip was reduced, the core resembled closely that of the M III fabric. Including this sample would permit a comparison with the composition of red gloss pottery.

Fabric M IV shares the essential physical attributes and surface colors of Fabric M III. It is distinguished from the latter group principally by the color of its paste and by a somewhat greater number of white inclusions. The core of the M IV vessels corresponds to a 2.5YR 5/8 color designation, although some pieces fall between the 6 and 8 values.

The two principal fabrics analyzed from locus 1N17 were distinguished by the same criteria as those used to separate the material from locus 1M7. Fabric N III is basically equivalent to Fabric M III; N IV matches M IV. The basis for the distinction is stratigraphical (see Table 1.7). As noted above,

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49. A portion of the pottery from this deposit is presented with illustrations in a recent article. Neuru (1980).
50. The identification is provided along with a description and an illustration by L. Neuru. Neuru (1980), No. 30.

this material from 1N17 probably includes 6th century pottery as well as vessels made during the 5th century. Two unique pieces were assigned a separate fabric number, N VII. They are two thick-bodied lids with conical profiles and high plain handles. A steam hole pierces the lid at the base of the handle. The exterior surface of the lids has a color of 2.5YR 5/6 which contrasts with the color on the underside (5YR 7/3). If this results from an application of slip it is exceedingly thin. The roughness of the surface suggests that the appearance of a slip results from smoothing or wiping the objects when wet. The core of the lids near the base has a color of 5YR 7/6. When holes were drilled to remove a portion for analysis, they revealed a much darker core in the handle of Sample 379. The clay in this portion was reduced producing a color of 2.5YR 5/2 (dark dusky red). In most other respects the fabric resembles the red-gloss pottery. The fracture, though, is rather more ragged. Although they constitute a very small group, they were analyzed for comparative purposes.

Essentially the fabric groups of Fabric Type III, F III, M III and N III, correspond to the variant 2.1a distinguished by the British research team. They do not correspond exactly because a color code of 2.5YR 6/6 is assigned to the core of the British category. This difference might arise from alternative interpretations of the Munsell Chart, but one would need to compare sherds to be certain of this. Fabrics M IV and N IV which constitute Fabric Type IV apparently represent the combined fabrics 2.1b and d of the British classification. The core colors match in both classifications as does the apparent increased frequency of limestone inclusions. The British system distinguishes between matte and lustrous slip for variants b and d.(51) This

51. ECBM I, 2.48.

distinction did not seem applicable to the pottery analyzed from the Canadian site. Given the variable quality of slip on individual pieces and the observable effect of thickness on the luster of the slip coatings, this separation seemed unwarranted. It must be recognized that the inconsistencies in surface color can arise quite easily in material fired at the same time, but resting in different parts of the kiln. For these reasons greater emphasis was placed on the coloration of vessel cores for assigning fabric identification.

None of the red-gloss from the Canadian site can be linked to a specific manufacturing site on the basis of provenience. Material from a known production center, located southwest of Carthage, was also analysed. The manufactory was situated on the slope of Djebel Mahrine a few kilometers from the modern town of El Fahs, near one of the main Roman transportation routes along the Miliane drainage basin. Its location would have provided equally easy access to the Medjerda corridor which leads northward to Utica. Consequently, the site was well suited for the distribution of its production. The location and topography of the site are described in Chapter III. Sherds were collected during a visit to the site in 1980. Samples of clay were also obtained at that time. The pottery was obtained from a dump consisting entirely of red-gloss sherds which cover the modern ground surface over an extensive area. The deposit rests at the base of a slope near a sunken stream bed. (See Figure 3.15) This unnamed watercourse contained only shallow pools of stagnant water in July, but proper management of this resource might have ensured a supply for the pottery during the summer months. Alternatively, potting could have been organized seasonally. It seems there was a fairly permanent settlement at the

site. Wall foundations cover the adjacent hillside for a distance of 50 to 100 meters. These have been disturbed by the planting of trees.

Virtually nothing is known about the history of the site. The results from a study of pottery collected during a more recent ground survey have been published. This has shown that a variety of plates and bowls were produced at Mahrine. A significant number of these were embellished with stamped decoration. Lamps also were made by the potters who worked there.(52) Comparison of the forms and decorative motifs with parallels from other sites indicates the production began during the first half of the 5th century. A second phase, of relatively brief duration, lasted until 460 or perhaps 480 A.D.(53)

The pottery produced at Mahrine has been categorized as t.s.c. Type D.(54) It does share most of the physical attributes of the fabrics M III and N III, and M IV and N IV. The quality of the slip and paste and the fracture of the Mahrine fabric are essentially the same. Mackensen reports the color of the paste and slip at 2.5YR 5-6/8. This matches most of the samples examined in this study, but the slip is by no means uniform on every piece. Mottled surfaces appear quite frequently as they do on the Carthage material. The color range is the same. Non-plastic material in the clay body appears identical to that observed in pottery from Carthage. The white calcium carbonate crystals appear somewhat less frequently than they do in the Carthage material but their distribution is not uniform. The black inclusions, on the other hand, are relatively more common in several of the sherds from Mahrine. They also tend to

52. Mackensen (1985) 29.
53. Mackensen (1985) 30-32.
54. Mackensen (1985) 32.

be somewhat larger, often a millimeter long. They are not always evenly dispersed. Other pieces with fewer black particles resemble the material from Carthage quite closely. The quartz grains in these samples seem to be generally smaller than those seen in the Type IV fabrics from the Canadian site. Their facets are highly reflective. This, once again, produces the effect of mica.

About forty sherds were collected from the pottery dump. Over half were rejected for analysis because they were thickly coated with a white concretion which could have biased the results. The original form could not be reconstructed for many of the decorated sherds because of their size (see Table 1.8). Considering the range of forms identified and illustrated from the site (55) it seems probable that most of the unidentifiable samples derive from the plates of form 61 and bowls of form 67. Although the sherds are quite small, comparing the motifs with examples illustrated elsewhere suggests the decorated pieces may span the full chronological range of the Mahrine production.(56) On the other hand, none of the sherds can be positively identified as belonging to the flaring plates of form 104A which were produced during the second phase of operation which coincided with the second half of the 5th century.(57)

Two of the pottery fragments, Samples 234 and 235, appear to be overfired wasters. Their coloration is much darker, they are extremely hard and their tone when struck a sharp blow suggests they have vitrified. In addition to the pottery sherds, two small ARS lamp fragments were analyzed. The one fragment large enough to identify with certainty consists of a plain vertical

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55. Mackensen (1985) 30, 34-36.
56. The motifs and their arrangement belong to styles A ii and A iii elaborated by J. Hayes, LRP 218-219, Pls XII and XIV, although positive identification is not possible in some of the smallest sherds. All of the motifs on these samples are illustrated by Mackensen (1985) 37-39.
57. Mackensen (1985) 30.

tab or "stump" handle and the beginning of a rim decorated with relief design too fragmentary to reconstruct. This is a lamp of the Hayes Type II.(58) The other fragment preserves a filling hole and what appears to be a relief rosette. Lamps of at least two types were manufactured at Mahrine.(59)

The final Sample (number 249) is not a pottery vessel. It is a fragmentary ceramic disc which is illustrated in Figure 1.3. The object is unslipped, but otherwise the clay body seems identical to that of the pottery and lamp fragments. One surface has concentric shallow grooves, which are identical to the smoothing marks found on ARS pottery except that these are more pronounced. The other side is smooth. Part of a slightly raised ridge survives in the center of the grooved face around the edge of what seems to have been a hole transversing the disc at its center. The function of this object is obscure and no parallels have been found as yet. If it was used for pottery manufacture, its small size and profile indicate it cannot have been a mould for the forms known to have been made at Mahrine. If fitted with a handle it could have been used as a pestle, but it would not have been very durable. Alternatively, it might have been suitable for pressing clay into a mould or for burnishing vessels as they turned on the wheel. It would have been sufficiently hard for either of these functions.

Three other groups of ceramics were submitted to chemical analysis for comparison with the red-gloss pottery. The first of these included ARS lamps. Only a small selection of these objects was available for sampling. They were found in occupational debris in House 2 on the Canadian site. Their

58. LRP 311. See below for further discussion of this type.
59. Mackensen (1985) 29.

stratigraphic context appears to be datable to the 5th and 6th Centuries.(60) More precise dates are not available at present. The lamps, designated as Fabric LI, were uniform in appearance with two exceptions. The fabric of this group closely resembles that of Fabric Type IV. The lamps have a thin matte finish. Trails of slip usually occur on the interior of the reservoir wall. The slip color, 2.5YR 6/6, is quite consistent. The cores have the same color as fabrics M IV and N IV (2.5YR 5/6). Flecks of luster from mineral inclusions are common and rather more noticeable than they are in the pottery. These are not mica platelets. Calcite crystals are abundant and often larger than one millimeter.

Several different shapes are represented in the sample. They are summarized in Table 1.9. The Hayes Type I category are most numerous. These correspond to the Form 2 category of the British classification which has been adopted for the catalogue of this material.(61) They have pinched handles with a central grove and a raised rim which bears a herringbone motif. Two of these, (nos. 489 and 490) have parallel oblique lines in place of the herringbone.(62)

Two samples (nos. 471 and 472) were obtained from Form 1 (Hayes Type II) lamps. Although these sherds are quite small, enough remains to identify them. They have a plain handle and a flat rim delineated by ridges.(63) Aside from their form, their physical attributes match those of the other lamps. This is of interest because it has been reported that there are "chemical differences

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60. Wells (1985) 12-14.
61. Hayes LRP 310-312. ECMB I, 2.237-239 and Pls 3,18-19. The lamps are the equivalent of Type VIII C in Pavolinils typology. Pavolini (1982).
62. This variant does not appear in the British classification, but there are parallels from Carthage, LRP 311.
63. ECBM I, 2.233 and Pls 1-3; LRP 310-311. These are Pavolini's Form X Pavolini (1982) 146-148.

between Forms 1 and 2 implying the use of chemically contrasting clays".(64) It is unfortunate that more specimens of these two forms were not available for comparison in this study.

Two Form 3 lamps (nos. 482 and 485) were also assigned to fabric L I. These are distinguished by a large relief rosette which fills the entire discus. The sample of this fabric was completed by two Form 5 lamps. These have a rectangular depression in the discus.(65) One fragment (no. 476) preserves only a small portion of the rim, which has an egg and tongue relief moulding.(66) The other (no.487) is a complete lamp with a square discus. It has a relatively thick slip with moderate luster which tends to flake away from the clay body. This unique piece was included in the analysis to gauge the compositional range one would expect to encounter in red-gloss lamps.

A selection of earlier lamps was also analyzed. The samples derive from the 3rd century deposit which furnished ARS Fabrics F I - III. The lamps, listed in Table 1.10, with one exception, are representatives of Type VII in the classification of Deneauve.(67) Three fabric groups were defined on the basis of their physical properties. The lamps appear to include both locally made and imported pieces. The forms can be traced to imported lamps from Italy which supplied Carthage until African workshops began production in the 2nd century.(68) Numerous factories identified their wares with stamped

64. ECBM, I 2.230. Apparently 20 samples of each variety were analyzed. Anselmino (1982) 165.
65. ECBM I,2.240 and Pls 1-2.
66. ECBM I,2.240 and Pl 5,3.
67. Deneauve (1969).
68. Hayes (1980) 63 and following note.

trademarks.(69) One of the fragments analyzed preserves this feature, but so little remains that it is impossible to identify the name.

The lamps of Form VII A and C are thought to be imports.(70) Seven of these were analyzed. The other lamps represent form VII B which has been associated with North African workshops. They were assigned to different fabrics on the basis of physical properties rather than form. This seemed more appropriate considering the obvious differences in their appearance. It also seems reasonable to suspect that moulds could be transferred between workshops. Furthermore, lamp designs could be copied easily by taking casts. Consequently, I included imported and "local" forms in all of the fabric categories.

Lamps of this variety were definitely manufactured in Africa Proconsularis. A shop containing moulds and finished pieces was discovered nearly a century ago at Carthage. Lamps of the VII B category may have been made on or near the estate belonging to the Pullaeni family.(71) Although the sample was limited in size, it was decided to analyze these lamps to estimate variability within the fabrics. This would indicate the feasibility of separating imports from local fabrics by chemical analysis.

Fabric LMP I is characterized by a thin dark slip which does not adhere evenly to the clay body. The surface coloration is mottled with highly lustrous patches which in places have a metallic sheen. The duller areas have a Munsell color of 2.5YR 5/6, the lustrous regions vary in color from 10R 4/8 to 10R 3/2. Trails of slip can be seen on the interior walls of the reservoir. The clay body is hard and produces a sharp fracture. The texture is finer than

69. Deneauve (1969) 82-84, Anselmino (1982) 159.
70. Deneauve (1969) 82-84.
71. Haywood (1959) 56 and 61.

what one observes in the ARS. Nevertheless, quartz inclusions are numerous. These are evenly dispersed in the paste. Fine calcite grains are common. The paste color is not always uniform but a coloration of 2.5YR 5/8 dominates. Decorative motifs can be identified on some of the larger sherds (see Table 1.10).

Fabric LMP II is represented by only four sherds. They were distinguished from the other lamps principally by their moderate luster and color. The paste of these lamps has a distinct central zone (color 7.5YR 5/6) surrounded by layers of a lighter color and more reddish hue (color 5YR 7/6). The moderately lustrous, thin slip is mottled with patches ranging from 5YR 4/3 to 5YR 4/6.

The third group of early lamps, Fabric LMP III, have several distinct attributes. The paste is similar to Fabric LMP II, but the color is more uniform (7.5YR 6/4-5/4) and lime deposits are more common. A thin, relatively uniform colored slip (7.5YR 3/0-4/0) was applied to the surface. These sherds are more lustrous than the second group, but not as lustrous as the first.

The groups are probably too small to provide a complete chemical profile. Collectively, however, they can provide an assessment of the range of compositional values one might expect from these lamps. Also, by comparing their compositions with red-gloss lamps, one could at least detect gross differences which might imply the use of alternate raw materials in manufacture. The obvious color differences between the earlier lamps and their ARS successors could be interpreted as the result of different clay composition. This seems to be the basic assumption of various authors although it is not always stated in

precise terms.(72) This question could be resolved by analysis of these lamps.

Material from a 7th century kiln excavated on the Canadian site provides the one class of pottery analyzed in this study which was definitely manufactured at Carthage. The kiln occupied the southwestern corner of a small room in a series of constructions bordering the northern side of the Decumanus VI. This area corresponds to Trench 9 which is shown in Figure 3.3.(73) The kiln was built with clay bricks and was only about 1.5 meters wide at its base. It appears to be an example of the common variety where pottery was fired on a raised grate or platform directly above the combustion chambers and with openings between the two parts. A reconstruction drawing has been published.(74) A small pile of discarded pottery was found in the southeastern corner of the kiln room. A few other rejects were found in the kiln itself.(75) Preliminary examination of associated materials has dated the use of this workshop to the 7th century A.D.(76) The full report of the excavation has not been published.

The kiln was used for firing a variety of coarse pottery. The vessels include juglets, cups and bowls (see Figures 1.4-1.6). The pottery should probably be classed as a type of Late Roman "buff ware".(77) It may correspond to the new category, LRCW 7, proposed by L. Neuru in a recent article.(78) A

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72. For example, Anselmino (1982) 158-160.
73. Excavation was carried out by Simon Ellis who kindly permitted analysis of the pottery.
74. Ellis (1985) Figure 1.
75. Personal communication from Dr. Ellis. The material in the kiln is from locus 9G027. The rest is from the adjacent stratum, locus 9G015.
76. Ellis (1985) 21.
77. Hayes (1976) 100-102.
78. Neuru (1980).

full description of these finds and their relationship to the other coarse wares retrieved during the excavations in the northern sector of Carthage is not possible at this time. A study of the pottery from these excavations has not been completed. Furthermore, this coarse ware is part material from a separate excavation conducted by the late Dr. Edith Wightman. Publishing this pottery without the collaboration of those who have inherited her responsibilities would be inappropriate.

The surface of the pottery generally has a mottled appearance. It was probably to have been coated with a very thin slip, but some of the sherds appear self-slipped. The vessels show signs of polishing or smoothing. This probably occurred before the coating was applied since ridges and pull marks are masked by the slip. Surface colors vary. The most common exterior hues are reddish yellow, 7.5YR 7/6-6/6 and 5YR 7/6. The interior surface is often much redder (10R 5/8-6/8). One or two other tones occur in places on the same vessel. Sharp, relatively straight fractures reveal numerous medium sized quartz inclusions in a dense clay matrix. The paste color is variable but tends to match the vessel surface. These characteristics are shared by other Roman "buff wares".(79) The paste and color range suggest the workshop was making a later version of the coarse ware, Fabric 2.4 or 2.5, catalogued from the Avenue Bourguiba Site.(80)

The three identifiable forms from the kiln material, as illustrated in Figure 1.4-6, have parallels in these fabrics. The trefoil juglet (Sample 402) is well attested at Carthage.(81) Complete samples, as yet unpublished, were

79. Hayes (1976) 100-102.
80. ECBM I, 2 11-12.
81. Fulford in ECBM I, 2. 204-206, Form 10, Fabric 2.15.

found by the author in situ during the excavation of the 6th century occupation strata of House 2 on the Canadian site. The small cup (Sample 403) occurs in a late 6th century context.(82) The bowl, Sample 426, with a horizontal projection below the rim is recognizable as a debased version of the flanged bowls which have a long history in the North African pottery tradition.(83) It should be mentioned that two of the smaller sherds, Samples 422 and 430, are definitely wasters. Both are bloated and the latter is certainly a fragment of a vessel which exploded during firing.

A small, undiagnostic body sherd from an unfired vessel was included in the analysis (sample 433). Slip removed from the small cup (Sample 402) was analyzed separately as sample 404. One fragmentary piece of kiln furniture was recovered during excavation (Figure 1.7). The exact function of the object is obscure. It was analyzed for comparison with the other ceramics.

The sample population represents approximately 50 percent of the material collected from loci 9G015 and 9G027 respectively: sherds from the small dump and those found within the kiln. The thickness and shape of the pieces chosen for analysis make it highly probable that each one represents an individual vessel. Collectively they constitute Fabric CW I. This is the only coarse ware group examined.

82. Fulford in ECBM I,2. 184-185. Form 23, Fabric 2.5.
83. A similar coarse ware vessels was recovered by British excavators. See ECBM I,2. 200-201, Form 11.

SECTION 1.3

SAMPLE PREPARATION

After the sample population had been selected, sherds were sampled by removing a 1 to 5 gram fragment with a commercial tile cutter. The surface of each sample was stripped with a tungsten carbide drill bit. The sherds were held in one hand. Rubber gloves were worn at all times. The bit and finger of the gloves were rinsed with reagent grade ethanol between strippings. The samples were then rinsed and allowed to soak for 24 hours in distilled water and dried at room temperature in covered containers. The samples were then given a preliminary crushing wrapped in a quadruple polyethylene envelope made by folding storage bags. Each sample was then transferred to an agate mortar and ground by hand. The mortar was washed in deionized water and rinsed with ethanol after each sample was ground. The mortar was cleaned by grinding quartz after each five samples had been processed. Samples were dried at 100 degrees Celsius for 12 to 14 hours, placed in sealed, labeled, plastic drug containers and stored in desiccators charged with indicator silica gel.

Preparation of the samples for spectrographic analysis was accomplished by fusion with lithium metaborate.(84) An aliquot of 0.1000 grams of dried, powdered sample and 1.00 grams of $LiBO_2$ were mixed in a weighing dish and transferred to a graphite crucible. These were heated for 20 minutes at 1000 degrees Celsius in an electric furnace. The crucibles were swirled after 10 minutes to promote fusion. The molten mixture was poured directly into a Pyrex beaker containing about 40 milliliters of 5% HCl. The glass was dissolved

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84. Feigenson and Carr (1985); Michels (1982) 115-116.

by agitation for 15 to 20 minutes. A few drops of HF were added during the final minute. The solution was poured into volumetric flasks and diluted to 50.0 ml. It was transferred immediately to polyethylene storage bottles. This particular method was selected because it permits the direct determination of silica. The other method of sample preparation employs acid digestion with a mixture containing HF. Silicon is lost through volatilization.(85) Analysis of Roman British pottery employed this latter procedure.(86) A duplicate fusion was made with one sample from each batch of ten samples.

Lithium borate fusion creates a lithium concentration of about 3000 ppm in the sample solution. This element enhances emission from most other elements by a factor of 2. At the same time, it suppresses the enhancements of Na and K which interfere with other determinations. The lithium borate solution was used without any further treatment for measuring chromium abundance. The major elemental concentrations were measured using a 10 fold dilution of the dissolved sample in dilute HCl containing 5000 ppm Sr. Strontium increases ionization potential which decreases the resistance to flow between the liquid sample phase and the spectrometer flame and promotes a uniform temperature in the flame itself.(87)

The sample preparation technique makes it impossible to compare pottery and raw clay samples directly. Pottery can reabsorb volatile material when buried, increasing its weight. The most common source of this increase results from the hydrolization of calcium oxide. Reheating the pottery in the laboratory will release both the water absorbed by this process, and CO_2.

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85. MacLaren et al. (1981) 1802-1803.
86. Hart and Adams (1983) 179-180.
87. Feigensen and Carr (1985).

There also may be other substances which did not volatilize during the original firing, but which would be removed by the fusion procedure. The effect of these processes on sample weight is highly variable and it can introduce significant distortions in the values obtained from determinations of chemical compositon. Therefore, abundances were normalized. First, I determined loss on ignition for all pottery and clay samples following the standard procedure.(88) One to two grams of dried sample were weighed and placed in porcelain crucibles. After heating them to 1000 degrees Celsius in an electric furnace, samples were cooled in a desiccator and weighed. The difference in weight is reported in Appendices VI and VIII, expressed as a percent of the original sample weight. These values were used to normalize the weights of the sample portions fused for DCP analysis by subtracting the decimal equivalent of weight lost by ignition from the pre-fusion sample weights. Calculations of chemical abundance were made using the corrected sample weights. Most of the ARS lost less than 1% of its weight. The coarse ware and clays contained significant amounts of volatile material.(89)

88. Maxwell (1968) 487-488. See also Widemann et al. (1975) 50.
89. It would have been preferable to use these refired portions of the samples for determination of elemental abundances. Because of the size of the sample population the laboratory schedule necessitated two separate operations.

SECTION 1.4

DIRECT CURRENT PLASMA EMISSION

Elemental abundances were determined by direct current plasma emission spectrometry, DCP, a relatively new analytical tool.(90) It has rapidly proven to be a reliable and efficient method for analyzing a variety of materials. Appropriate instrumentation can accomplish simultaneous determination of as many as 24 elements which has made it attractive to geochemists and environmental scientists.(91) The method has begun to attract the interests of the archaeological community(92), but other types of spectrometry are still more common. Plasma emission is distinguished from other emission methods by the plasma flame used to excite the atoms in the sample. The flame is produced by an electrically energized stream of argon which reaches a temperature of 6000 K. The dissolved sample is then introduced into the argon stream as an aerosol. The component atoms emit a spectrum of light. The intensity of emitted light is proportional to the concentration of the element in the dissolved sample. This light is passed through a diffraction grating to a photomultiplier which converts the light to electronic impulses. These in turn are electronically recorded and transformed into numerical values. The instrument is calibrated by measuring standard solutions of known concentration.(93) The high temperature of the plasma flame and its stability afford low detection limits and a high

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90. The instrumentation was made available by the Department of Geology, University of Ottawa. I am indebted to John Loop of the Geochemistry Laboratory for his instruction in the operation of this equipment and for his advice and encouragement.
91. MacLaren et al. (1981).
92. Hart and Adams (1983).
93. Feigenson and Carr (1985).

afford low detection limits and a high degree of precision. Results often show less variability than those obtained with atomic absorption spectroscopy and x-ray fluorescence.

The standard solutions for calibrating the spectrometer were made from 1000 ppm Fisher Atomic Absorption Standards. These were diluted with solutions containing 5000 ppm Sr and 3000 ppm Li in dilute HCl. Reagent grade HCl (Fisher) and deionized water were used in all procedures. Blank lithium borate fusions were processed with every 40 to 50 pottery samples in addition to batches of several liters (representing 10 fusions per liter). The blanks, analyzed by insertion at intervals between the unknowns, showed no contamination.

Nine elements were analyzed at the wavelengths listed in Appendix X, Table X.2. Scans with high and low standards and several samples were performed above and below each wavelength to detect background emission. The only element requiring a correction was chromium. A slight increase in background emission was observed .05 mm above the wavelength. The possibility of interelement interference from overlapping emission spectra was tested at each wavelength with a series of dilutions made from stock solutions. Chromium and manganese were the only elements affected. Iron produced slight enhancements. A correction was applied to all Cr and Mn determinations using the formula:

$$Ca = CorrFactor \times CI,$$

where Ca is the analyte concentration, CI the concentration of the interference element and CorrFactor is the correction factor. The iron increased chromium values by .75 ppm for every 1 ppm Fe in the sample. Mn abundances were increased by 1.3 ppm/ppm Fe.

An additional correction was made to the chromium abundances for all pottery samples to account for drill bit contamination. There are conflicting reports about contamination from tungsten carbide bits affecting chromium concentrations. One research group detected significant amounts while another reported none.(94) Faced with conflicting evidence, it was decided to test for any contamination which could bias the results from the analysis of ARS. Five ARS sherds were sampled where no slip was present. The unslipped portions were ground and analyzed along with drill-stripped portions of the same samples. After analysis it could be seen that chromium deposited from the bit raised the total concentration by an average 24 ppm. This could enhance abundances considerably. Spectrometer readings for all samples were corrected by subtracting the correction factor from the total concentration. No other elements were affected significantly by drill bit contamination.

Three emission measurements were made for each elemental determination. Their mean value corresponds to the concentration for the sample reported in Appendix I-III. The results from replicate fusions of individual samples were also averaged. Samples were analyzed in batches of 30. These were placed in the sample tray in groups of 10 with high and low standards between them to measure any voltage drop and to recalibrate the instrument. Minor voltage fluctuations were occasionally observed. Values were adjusted in these instances using the equation:

$$Ccor = Cm + Cm \times CF,$$

where Ccor is the corrected concentration, Cm equals the measured concentration and CF is the correction factor. The correction factor is calculated from the

94. Attas et al. (1984) and Carriveau (1980).

measured ratio of the change in voltage to the original voltage. When variations above 5% were observed the results were discarded. After changing electrodes and recalibrating the instrument, the samples were retested.

Samples of three different United States Geological Survey rock standards were dried overnight, fused and analyzed to verify the accuracy of the determinations and to measure precision. Five solutions were prepared from each standard. The fusions were interspersed with those of the other samples. It was decided to use three different rock standards to insure that the lithium fusion method would provide accurate results with different minerals.The results presented in Appendix X indicate good agreement with values furnished by the U.S.G.S. for these standards.

Because the number of assays carried out for each rock standard was small, the standard error calculated using the differences from the mean in the usual manner would not provide an adequate estimate of precision for the entire sample population. Consequently, an alternative procedure was utilized to measure error. This method is commonly applied to data derived from analyses of geological samples; (95) therefore, it is appropriate for providing a more realistic evaluation of the precision associated with the results obtained from the pottery and clay from Carthage.

This estimate of standard deviation uses the equation:

$$\underline{s}^2 = \Sigma(x - x)^2 / 2N;$$

where $\underline{s}$ is the standard deviation and the values for x are the abundances derived from each pair of replicate analyses performed on a single sample. N is

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95. Kretz (1984).

the total number of duplicate analyses. The samples should have similar compositions.

Results from 54 pairs of pottery determinations representing 37 separate samples and the values derived from the 30 pairs of replicate analyses of the three rock standards were combined to form the total population of similar sample pairs. The appropriate data is presented in Appendix XI. The pottery samples were all ARS, containing less than 5% calcium.(96) Their compositions are quite similar to those of the standards. The range of concentrations for the major constituents is essentially the same in both the pottery samples and the standards. The variation in concentration for each of these elements ranges from 1 to 8%. The trace element manganese is 4 to 10 times more abundant in the rock standards and chromium concentrations are approximately equivalent in both the standards and the pottery.

The estimates of standard deviation, summarized in Appendix XI, vary from 3.5 % to 8.8% of the average abundance for the major constituents. The precision of the manganese determinations is 9.0%. These standard deviations in general are comparable to those reported in other provenience studies.(97) Values of 10 to 15 %, for example, were assigned to data from the neutron activation analysis of black-gloss pottery from Carthage.(98) The calculation yielded a value for s of 23.4% for the chromium assays. Although considerably higher than the other deviations, this value is consistent with the precision for chromium analyses reported in the literature.(99) Essentially, the

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96. Paired determinations of pottery samples made with calcareous clays were not utilized in this calculation because they contained ten fold greater quantities of calcium, a major constituent, than the rest of the samples.
97. Tite et al. (1982) and Hatcher et al. (1980) provide comparative data.
98. Pike and Fulford (1983) 82.
99. Values of s of 17-20% are reported for chromium. Hatcher et al. (1980) 137.

calculation of standard deviation revealed an acceptable degree of precision for the laboratory techniques employed to analyse the pottery from Carthage. It should be noted that the detection limit of the DCP spectrometer was sufficient to provide chemical abundances in four significant figures for several of the constituents assayed for this study. However, confidence limits of 95%, based on the estimated standard deviations, do not permit reporting the results with such a high degree of accuracy. The concentrations of chemical constituents, presented in the appendices, reflect the limits imposed on the data by the evaluation of precision.

TABLE 1.1

POTTERY FABRIC DESIGNATIONS AND CHRONOLOGIES

POTTERY TYPE	ARS * FABRIC TYPE	FABRIC GROUP	DISCRIMINANT CODE ++ A	B	PROVENIENCE [CANADIAN SITE LOCUS NUMBERS]	APPROXIMATE CHRONOLOGY (Century AD)
AFRICAN RED SLIP	III	F I	41		2F 32-36	3rd
	III	F II	42		2F 32-36	3rd
	III	F III	43	3	2F 32-36	3rd
	***	F IX	49		2F 32-36	3rd
	III	M III	53		1M 7	5th
	IV	M IV	54		1M 7	5th
	III	N III	63		1N 17	5th - 6th
	IV	N IV	64		1N 17	5th - 6th
	***	N VII	67		1N 17	5th - 6th
	***	MA IA	30	5	MAHRINE	5th
	***	MA IB		13	MAHRINE	5th
ARS LAMPS	***	L I	70	7	HOUSE 2 CANADIAN SITE	6th - 7th
BUFF COARSE WARE	***	CW I	80 #		9G 015 & 027	7th
	***	CW II	81 #		9G 015 & 027	7th
"ITALIC" LAMPS	***	LMP I	91 #		2F 32-36	3rd
	***	LMP II	92 #		2F 32-36	3rd
	***	LMP III	93 #		2F 32-36	3rd

* The main "Fabric Types" are described on pages 11 to 22.

*** Not assigned to one of the the main ARS "Fabric Types".

++ Numerical codes used to identify fabrics for discriminant analysis
A = code for analyses 1 and 2 (Appendices I & II)
B = code for analyses 3 and 4 (Appendices III & IV)

\# Single discriminant analysis: Appendix V

TABLE 1.5

CATALOGUE OF FORMS

SAMPLES FROM LOCI 2F32-36

SAMPLE NUMBER	FABRIC ORIGINAL	FINAL+	FORM++
126	F III	#	10/Rim
127	F III	**	10/Rim
128	F III	#	10/Rim
129	F III	**	10/Rim
130	F III	#	10/Rim
132	F III	#	10/Rim
133	F III	#	11/Rim
134	F III	#	34/Rim
135	F III	#	34/Rim
136	F III	#	9/Rim
138	F I	**	9/Rim
139	F III	#	9/Rim
140	F III	#	9/Rim
141	F III	#	8/Rim
142	SLIP (141)		
143	F I	**	8/Rim
144	F II	F III	8/Rim
145	F I	F IX	8/Rim
146	F III	#	10/Rim
147	SLIP (146)		

+ Assigned by 2nd Discriminant Analysis. # Unchanged. **Unassigned.
++ All form designations are from LRP unless marked F = Fulford in ECBM I,2.

TABLE 1.5 cont.

SAMPLES FROM LOCI 2F 32-36

SAMPLE NUMBER	FABRIC ORIGINAL	FINAL+	FORM++
148	F II	**	8/Rim
150	F II	#	8/Rim
151	F II	#	3C/Rim
152	F II	#	3C/Rim
153	F III	**	6A/Rim
155	F III	**	Closed?
157	F III	#	22/Rim
158	F I	#	Closed (F-22?)
159	F III	#	Closed
160	SLIP (159)		
161	F III	#	Body
162	F III	**	Body
163	F III	#	Lid
164	F II	**	?
167	F IX	**	23/Rim
168	F IX	F III	23/Rim
169	F IX	F III	23/Rim
170	F IX	**	23/Rim
171	F IX	#	27/Rim
172	F IX	F III	27/Rim
175	F III	**	3C/Rim
176	F III	#	3C/Rim

+ Assigned by 2nd Discriminant Analysis. # Unchanged. **Unassigned.
++ All form designations are from LRP unless marked F = Fulford in ECBM I,2.

TABLE 1.6

CATALOGUE OF FORMS++

SAMPLES FROM LOCUS 1M7

SAMPLE NUMBER	FABRIC ORIGINAL	FABRIC FINAL+	FORM ++
179	M III	**	93
181	M III	**	91(N-17)
182	M IV	**	80(N-3)
183	M IV	**	Jug(N-30) (LRCW I)
184	SLIP (183)		
185	M III	#	99
186	SLIP (185)		(Oudna?)
187	M IV	**	67
188	M IV	N IV	165?
189	M IV	**	91
191	M III	N III	91
193	M III	N III	61++
194	M IV	#	91
195	SLIP (194)		
196	M III	#	91

+ Assigned by 2nd Discriminant Analysis. # Unchanged. **Unassigned.
++ All form designations are from LRP unless marked F = Fulford in ECBM I,2.

TABLE 1.6 cont.

SAMPLES FROM LOCUS 1M7

SAMPLE NUMBER	FABRIC ORIGINAL	FINAL+	FORM++
197	M IV	M III	F-39
198	M III	M IV	91
199	M III	**	67
200	M III	**	61/87++
201	M IV	N III	61/87++
202	M IV	**	? (Stamped Grille Motif)
203	M IV	#	80
204	M III	**	80
207	M III	N III	75
210	M III	N IV	70var(N-13)
211	M III	**	61/87
212	SLIP (211)		
213	M IV	**	80(N-1)
215	M III	#	12/102
216	M IV	N IV	12/102(N-9)

+ Assigned by 2nd Discriminant Analysis. # Unchanged. **Unassigned.
++ All form designations are from LRP unless marked F = Fulford in ECBM I,2.

TABLE 1.7

CATALOGUE OF FORMS
SAMPLES FROM LOCUS 1N17

SAMPLE NUMBER	FABRIC ORIGINAL	FABRIC FINAL+	FORM++ & DECORATION
250	N IV	#	F 111/112
251	N III	**	73?
252	N IV	N III	107?
253	N III	#	76
255	N III	#	61B
356	SLIP (357)		
357	N IV	N III	61B
358	N IV	**	61B
359	N III	N III	61 ?/ Grille, Fringed Circles
362	N III	#	61 ?/Concentric Circles Palmettes
363	N III	**	F 111/112 ?
364	N III	#	76
365	N IV	**	F 111/112
366	N III	#	62A
367	N IV	#	80A
368	N III	#	80A
370	N IV	#	81B
371	N III	#	80B
372	N III	#	76 var
373	N III	#	59

+ Assigned by 2nd Discriminant Analysis. # Unchanged. **Unassigned.
++ All form designations are from LRP unless marked F = Fulford in ECBM I,2.

TABLE 1.7 cont.

SAMPLES FROM LOCUS 1N 17

SAMPLE NUMBER	FABRIC ORIGINAL	FABRIC FINAL+	FORM++ & DECORATION
374	N III	**	61 ?/Clover leaf
375	N III	N IV	Juglet (Handle)
376	N III	**	81B
377	N IV	#	63
378	N VII	#	Bell Lid
379	N VII	#	Bell Lid
380	N IV	#	91A/Feathering
381	SLIP (380)		
382	N III	**	91A/Feathering
383	N III	**	91A/Feathering
385	SLIP (386)		
386	N III	#	91A/Feathering
387	N IV	#	91A/Feathering
388	N III	#	91A/Feathering
389	SLIP (388)		
390	N III	**	91A/Feathering
391	N III	#	67
392	N III	**	67
393	N IV	#	91 var
394	N IV	#	70 var
395	N IV	#	80B
396	N III	#	81
398	N III	#	59
399	N IV	#	62A

+ Assigned by 2nd Discriminant Analysis. # Unchanged. **Unassigned.
++ All form designations are from LRP unless marked F = Fulford in ECBM I,2.

TABLE 1.8

CATALOGUE OF FORMS

SAMPLES FROM MAHRINE

SAMPLE NUMBER	FABRIC ORIGINAL	FABRIC FINAL+	FORM++ (AFTER LRP)	DECORATION
226	MA I	**	59/Rim+Body (waster)	Vertical Grooves
227	MA I	**	59/Rim	Vertical Grooves
228	MA I	**	61/A	?
229	MA I	**	59/Rim	?
230	MA I	**	67/Rim	?
231	MA I	#	Tab Handle Lamp/Type III	?
232	MA I	#	67 ? Floor	Grille
233	MA I	**	67 ? Floor	Palmette Concentric Circles
234	MA I	**	67/Rim	?
235	MA I	**	59/Rim	?
236	MA I	**	91/Rim Body	Feathering Black Exterior
237	MA I	**	91/Rim & Body	Feathering Black Exterior
238	MA I	**	59/?	Grille
239	MA I	**	67 ?/Body	Palmette & Concentric Circles
240	MA I	#	59/Body	Clover Leafs & Concentric Circles

+ Assigned by 2nd Discriminant Analysis. # Unchanged. **Unassigned.
++ All form designations are from LRP unless marked F = Fulford in ECBM I,2.

TABLE 1.8 cont.

SAMPLES FROM MAHRINE

SAMPLE NUMBER	FABRIC ORIGINAL	FABRIC FINAL+	FORM++ (AFTER LRP)	DECORATION
241	MA I	#	67 ?/Body	Rouletting
242	MA I	#	67/Body	Palmettes & Clover Leaf
243	MA I	#	?/Body	Palmette
244	MA I	#	?/Body	Palmette & Concentric Circles Black Body
245	MA I	#	?/Body	Concentric Circles
246	MA I	#	?/Body	Concentric Circles
247	MA I	#	Medallion	Heart. (MacKensen 157)
248	MA I	#	Lamp	Relief Rosette
249	MA I	**	Mould?	?

+ Assigned by 2nd Discriminant Analysis. # Unchanged. **Unassigned.
++ All form designations are from LRP unless marked F = Fulford in ECBM I,2.

TABLE 1.9

CATALOGUE OF ARS LAMPS (FABRIC L I)

SAMPLE NUMBER	FABRIC ORIGINAL	FINAL+	FORM++	DECORATION
471	L I	#	1	Rim, Rosette Triangle
472	L I	N III	1	Rim, ? Discus, Chi Rho (Reversed)
475	L I	#	2	Rim, Herringbone
476	L I	#	5	Rim, Egg and Tongue
477	L I	**	2	Rim, Herringbone Discus, Chi Rho (Reversed)
478	L I	**	2	Rim, Herringbone Discus, Chi Rho
479	L I	**	2	Rim, Herringbone
482	L I	#	3 ?	Rim, Oblique Ridges Discus, Rosette
485	L I	#	3	Discus, Rosette
487	L I	M III	5	Square Discus
488	L I	**	2	Herringbone
489	L I	#	2	Oblique Ridges
492	L I	N III	2	Oblique Ridges

++ Form = ECMB I, 2.1
Form 1 = Plain Handle
Form 2 = Grooved Handle

+ Assigned by 2nd Discriminant Analysis. # Unchanged. **Unassigned.

TABLE 1.10

CATALOGUE OF LAMPS

SAMPLES FROM LOCI 2F32-36

SAMPLE NUMBER	FABRIC ORIGINAL	FABRIC FINAL+	DENEAUVE TYPE	DISCUS & RIM DECORATION
434	LMP I	#	VII A/C ?	
438	LMP II	#	X C	
439	LMP I	#	VII B	
440	LMP III	#	VII B	
445	LMP II	#	VII A	
446	LMP II	#	VII A	
449	LMP I	#	VII A	
451	LMP III	LMP II	VII B	
452	LMP III	#	VII B	
453	LMP I	#	VII D	Grape Leaves - Rim
454	LMP I	LMP II	VII A	
455	LMP I	#	VII A	
458	LMP III	**	VII A	Palmettes & Wreaths - Discus (Deneauve no. 792)
461	LMP III	LMP II	VII A	Bust of Helios - Discus (Deneauve no. 705)
457	LMP I	#	VII A	Bust of Helios ? Discus
463	LMP II	LMP III	VII B	
467	LMP III	#	VII A	Palmettes & Wreaths - Discus (Deneauve no. 792)

+ Assigned by Discriminant Analysis. # Unchanged. **Unassigned.

TABLE 1.11

CATALOGUE OF COARSE WARE (KILN GROUP)

SAMPLE NUMBER/ FINAL FABRIC+	SHERD TYPE	LOCUS
402 / CW IB	Juglet/Rim and Handle	P9G015
403/ CW IA	Cup	"
404 / CW IA	SLIP (403)	
405 / CW IB	Juglet/Rim	"
406 / CW IA	Juglet?/Rim & Handle	"
407 / CW IB	Cup?	"
408 / CW IB	Handle	"
409 / CW IB	Handle	"
410 / CW IB	Handle	"
411 / CW IB	Handle	"
412 / CW IB	Handle	"
413 / CW IA	Body Sherd	"
414 / CW IA	Juglet/Rim	"
415 / CW IA	Bowl?/Body	"
416 / CW IA	Juglet/Upper Body	"
417 / CW IA	Body Sherd	"
418 / CW IA	Juglet	"
419 / CW IB	Bowl/Base	"
420 / CW IB	Juglet	"

+ Assigned by Discriminant Analysis.

TABLE 1.11 cont.

COARSE WARE (KILN GROUP)

SAMPLE NUMBER/ FINAL FABRIC+	SHERD TYPE	LOCUS
421 / CW IB	Body Fragment	9G027
422 / CW IB	Body Sherd (Bloated Waster)	"
423 / CW IB	Bowl/Plate?/Base	"
424 / CW IA	Kiln Furniture Fragment	"
426 / CW IA	Flanged Bowl	"
427 / CW IA	Straight Handle	"
428 / CW IA	Body Sherd	9G015
429 / CW IA	Juglet/Base	9G027
430 / CW IA	Body Sherd/Exploded Waster	"
431 / CW IA	Jug?/Body Sherd	"
433 / CW IA	Body Sherd (unfired	

+ Assigned by Discriminant Analysis.

FIGURE 1.1

LOCATION OF CARTHAGE

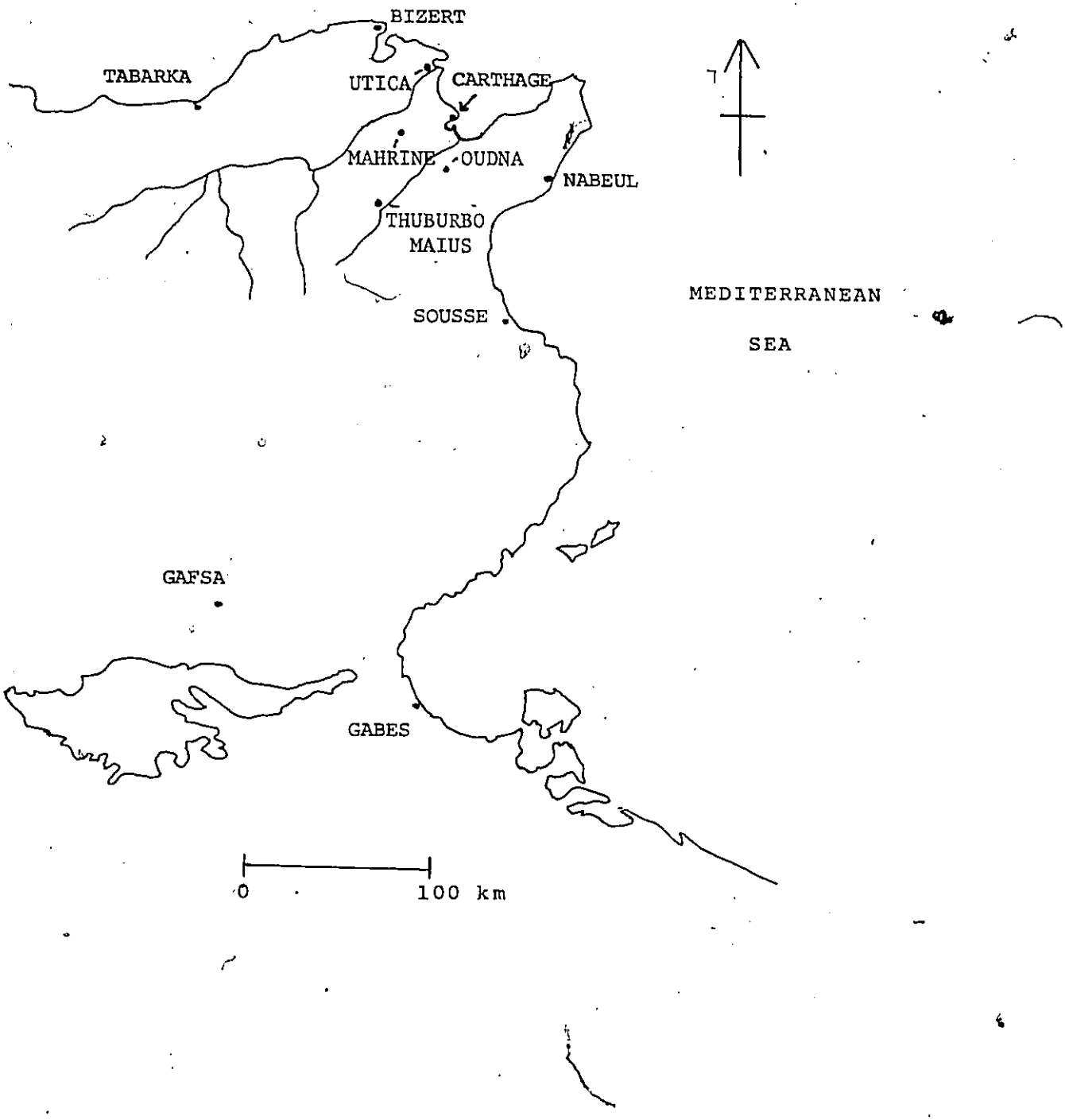


FIGURE 1.2

Main Excavation Trench.

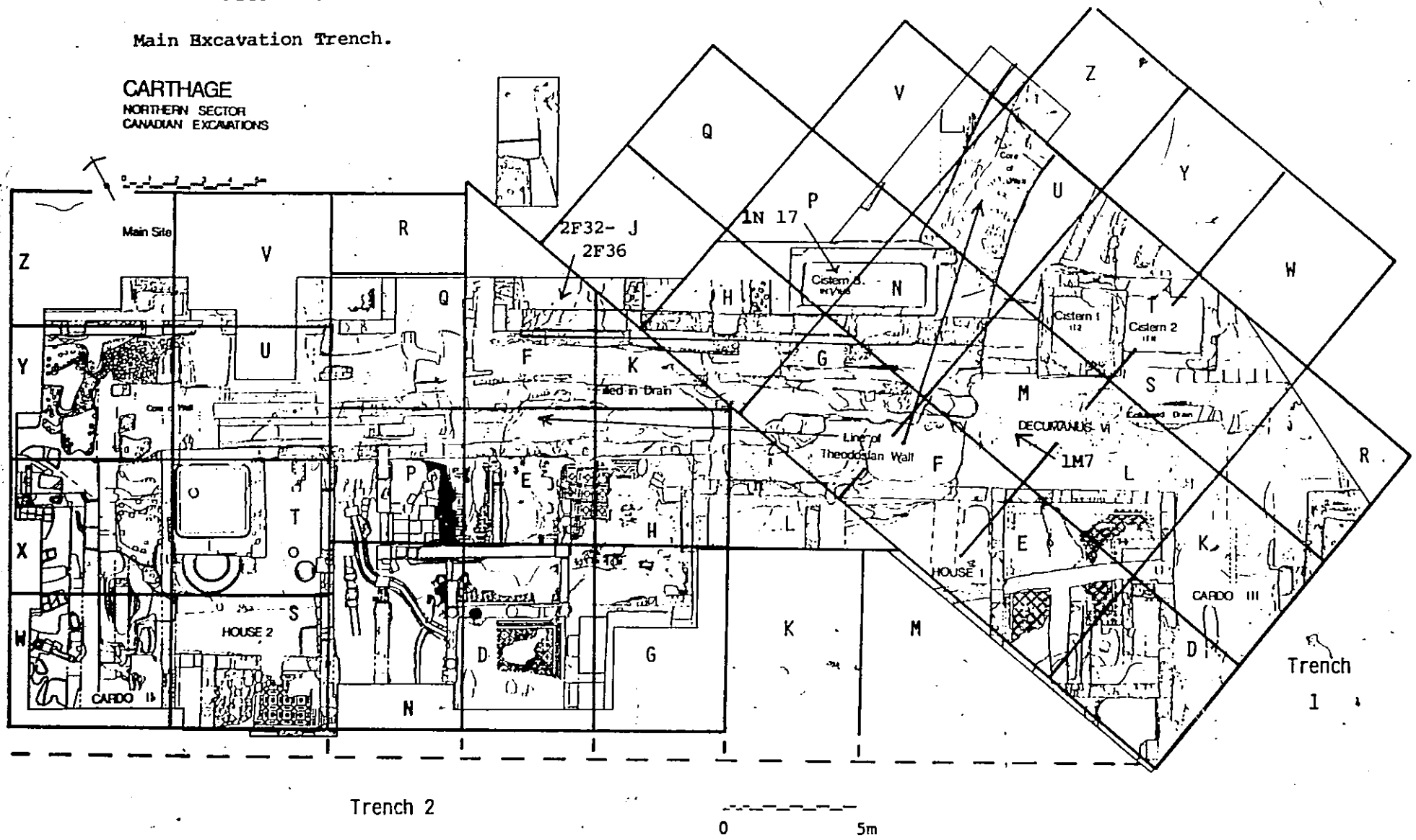


FIGURE 1.3

MAHRINE MOULD ?
FRAGMENT

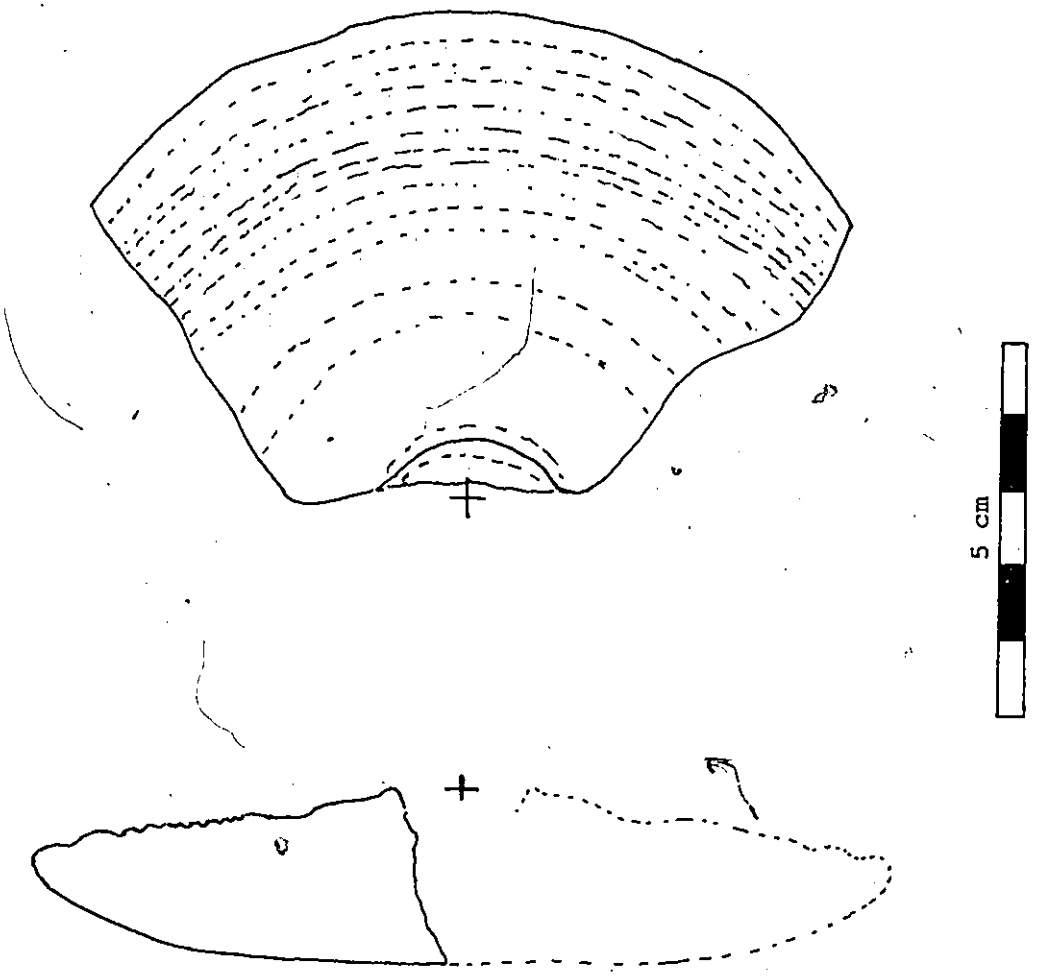


FIGURE 1.4

COARSE WARE
JUGLET
(SAMPLE 402)

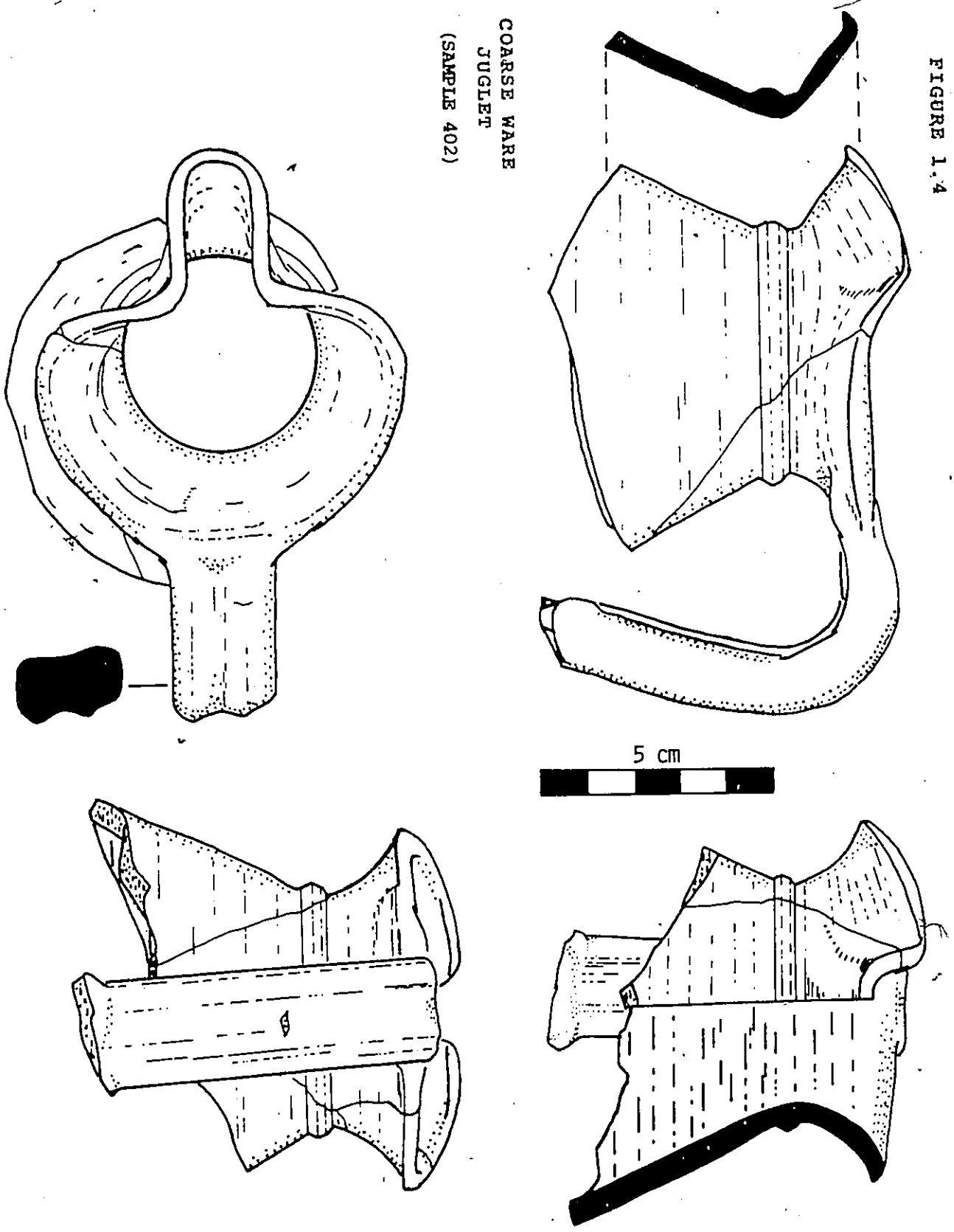


FIGURE 1.5

COARSE WARE CUP
(SAMPLE 403)

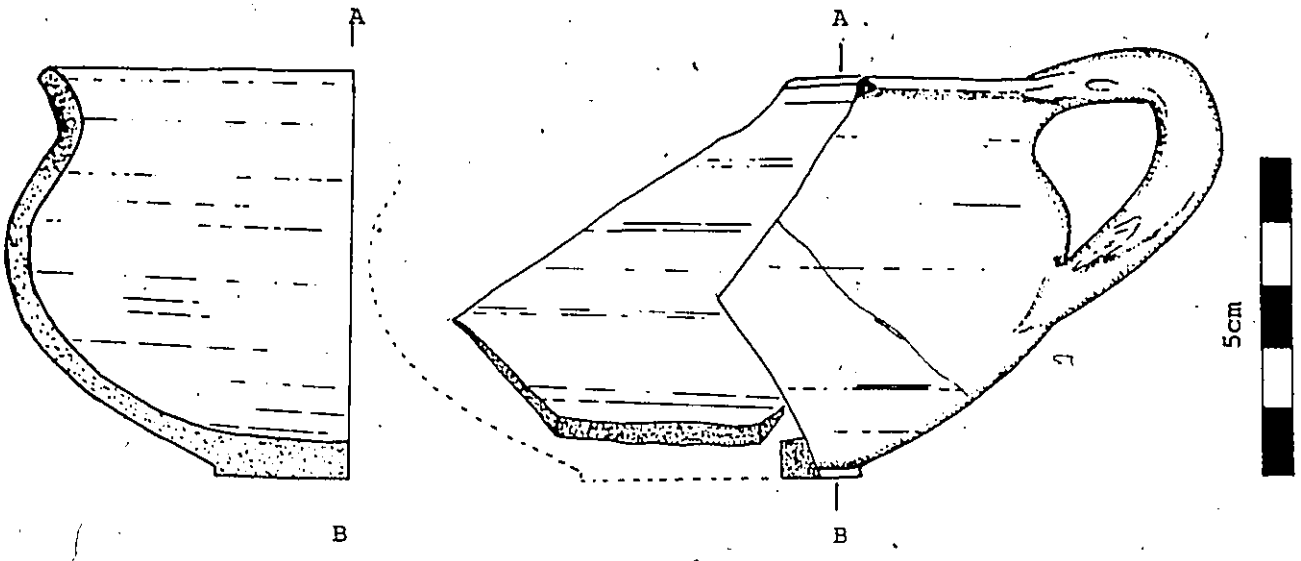
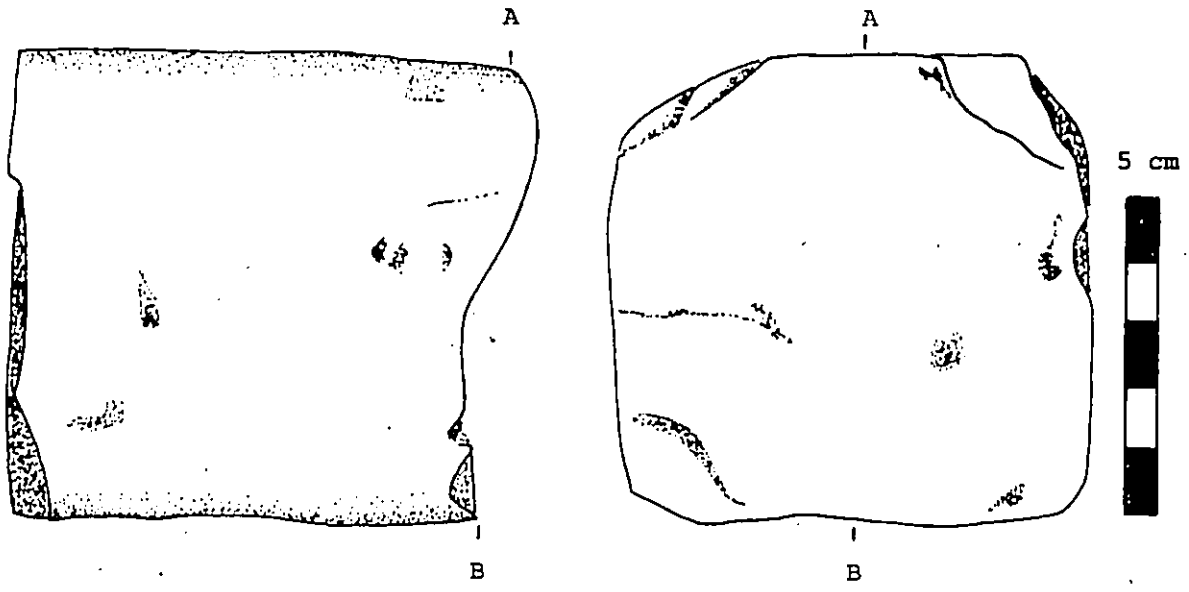


FIGURE 1.7

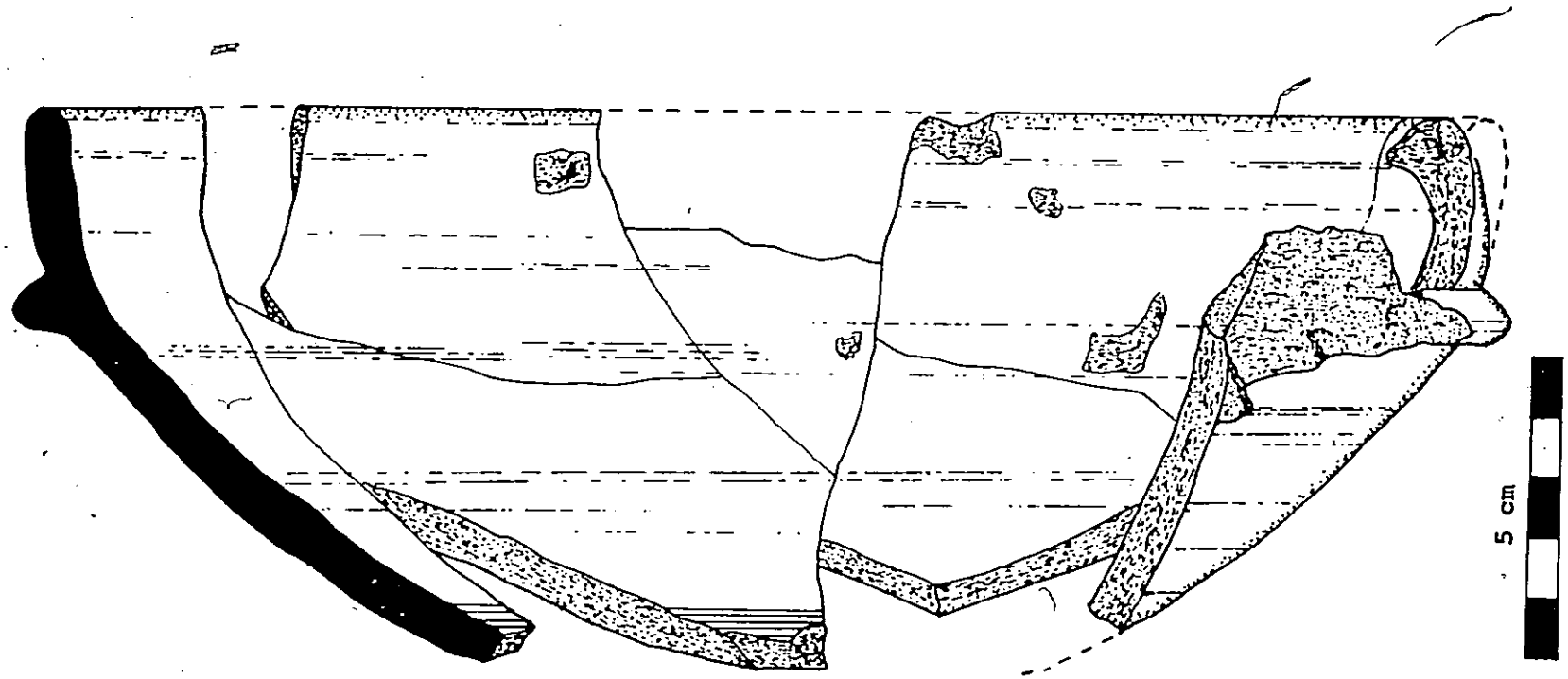
KILN FURNITURE
FRAGMENT (SAMPLE 424)



FIGURE

1.6

COARSE WARE BOWL (SAMPLE 426)



SECTION 2.1

CHEMICAL COMPOSITION AND ARS MANUFACTURE

Results from the chemical analyses of ARS are presented in Appendices VI and VII. Generally, the abundance of chemical constituents is comparable to that observed in other varieties of pottery made in the Mediterranean region during the classical period.(100) The ARS does contain more silica than the Roman red-gloss pottery made at the major workshops in southern Gaul. At La Graufesenque, for example, the mean silica concentration was 52.7%. (101) The various fabrics analyzed in this study had about 10% more silica. Presumably this results from the relatively larger amounts of non-plastic material in the pottery from North Africa which is immediately obvious when viewing sherds originating on either side of the Mediterranean.(102) Adding temper to the paste could augment silica levels, but we do not know how the potters prepared their clay. The abundant mineral inclusions in ARS might reflect incomplete purification of the raw materials they used. This is an attractive explanation since the local clays generally contain much quartz sand in addition to other mineral impurities. (See Chapter III.)

Possibly the ARS manufacturing technique demanded a well-tempered paste. Unlike the Samian from Gaul, the African red-gloss vessels are not heavily decorated in relief moulding. It has been pointed out that several

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100. Banterla et al. (1973), Hatcher et al. (1980) and Pragg et al. (1974).

101. Picon et al. (1975) 194. Similar values are reported in the other articles published by the Lyon CNRS personnel. See other articles by Picon.

102. I wish to thank Colin Wells and Dr. D. Brearley of the University of Ottawa who provided examples of Samian ware for examination.

African forms must have been produced by using moulds.(103) There are also reports that moulds have been found at manufacturing sites such as Oudna. A fragment of a mould was also recovered from the Canadian Theodosian Wall site, but it has not been published.(104) The fact remains that with a few exceptions the decoration of ARS is more rudimentary. Some of the ARS vessels from Carthage deposits show signs of being free thrown. If moulds were not used as extensively to form ARS vessels as they were in the Samian workshops, it might have been necessary to use a stiffer clay for raising vessels on the wheel. Until more is known about North African production methods, these possibilities cannot be evaluated effectively.

One other chemical component needs to be considered for what it can tell us about production techniques. The low calcium oxide concentration (1-2%) of the ARS is of particular interest when comparing the North African pottery with the Roman red-gloss fabrics of Italy and Gaul. The elemental abundances of calcium indicate the ARS was made from siliceous clays. In contrast, the Samian produced by the major workshops in Italy and by their offspring in the European provinces was made with calcareous clays. Such clays contain at least 10% CaO and often much more.(105) It has been observed that some local producers in Europe attempted to "imitate" Samian ware with clays containing relatively little calcium. The reliance on calcareous clays, therefore, is not coincidental in the manufacture of the principal Samian fabrics.(106) Why they preferred pastes of this composition is not clear,(107) Potters deliberately

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103. LRP 295.
104. A personal communication from L. Neuru.
105. Picon et al. (1971): and other articles by Picon.
106. Picon et al. (1975).
107. Widemann et al. (1975) and Tite et al. (1982) 119-120.

chose to use raw materials with elevated calcium levels. How they made their selection is discussed elsewhere. For the moment we need only consider the disparity between the composition of ARS from Carthage and the red-gloss pottery made in other parts of the Roman world.

In contrast to the African red-gloss pottery, the 3rd century lamps analysed in this study display a definite link with the calcareous paste tradition. Imported lamps of the same basic design supplied the market at Carthage for most of the first two centuries after the foundation of the Roman city. Then local manufacturers captured the market.(108) The chemical abundances from the present study show that the producers of African buff-colored lamps adopted their preference of clays along with the basic forms and decoration used in the imports. They also kept the practice of identifying their wares with stamped trade marks. These lamps were supplanted by the red-gloss variety.

Local production of the "Italic" type with calcareous pastes apparently exercised little influence on the production of African Red Slip lamps. However, CaO abundances as high as 6% were detected (sample 482) in the ARS lamps from the Canadian site.(109) This is well below the 10-33% range commonly found in Samian ware, but there may have been potters at Carthage, originally trained in the Italic lamp tradition, who used calcareous clays to make red-gloss lamps in Africa, in response to the increased popularity of ARS. Further research is warranted to determine when the ARS lamps with elevated

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108. Deneauve (1969) 82-84.
109. The sample population of ARS lamps did not include all of the fabrics recovered from the Canadian excavations. Some of these may be made from even more calcareous pastes.

calcium concentrations first appear and what proportion of the production they represent.

Red-gloss pottery was made in vast quantities during Late Hellenistic and Roman times at various locations in the Eastern Mediterranean. These fabrics have yet to be investigated as thoroughly as the Samian ware of the western provinces. What has been identified as "eastern sigillata" was recovered at Bengazi (ancient Berenice) on the Libyan coast. It has been analyzed by atomic absorption spectrometry. The results indicate a calcareous clay was utilized which yielded concentrations of CaO from 3 to 10% in the ceramic.(110) Examination of any red-gloss pottery produced there during the Roman era is needed to elucidate the role of calcareous clays in the local pottery technology.

Black-gloss pottery was produced both from calcareous and from non-calcareous clays in various parts of the Mediterranean.(111) The frequency with which certain varieties occur at Carthage suggests they were made there or produced elsewhere in Africa Proconsularis before the Roman conquest.(112) It would be necessary to examine carefully Punic pottery from the region to establish how long the reliance on siliceous clays prevailed in North Africa. Black-gloss from Carthage has been analyzed, unfortunately only trace element abundances were determined. This provides no means for comparison with the ARS investigated in this study;(113) and the results do not help to determine if calcareous or siliceous clays were employed for producing black-gloss at Carthage.

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110. Hatcher (1980) 150.
111. Picon et al. (1971).
112. Morel (1986) describes two fabrics which are probably made locally.
113. Pike and Fulford (1983).

East of Carthage, black-gloss workshops at ancient Berenice apparently relied on calcareous raw material. Black-gloss pottery from excavations at Bengazi consists of several different groups identified by principal component analysis. The most common variety on the site contained an average of 13% CaO. The minimum observed in the 10 fabrics was 6%.(114) If any of these represents local production, the use of calcareous clays for table ware manufacture in Tripolitania is confirmed. Until more complete analysis of black-gloss from Carthage is available it is impossible to know whether the same pattern of high CaO abundance prevailed further west. There are, of course, other varieties of Punic ceramic objects which might have been made with noncalcareous clays, but until Punic material from Carthage has received further study, the role of calcareous clays in the pre-Roman pottery tradition of North Africa cannot be evaluated fully.(115)

One exception to the choice of calcareous clays for red-gloss manufacture is found in the first Century A.D. "imitation Samian" produced at Lezoux, east of Lyons. The Samian from this period contained a range of .95 to 2.8% CaO, and the local coarse pottery contained equivalent amounts.(116). Analyses have detected a significant difference between the initial output and the materials utilized for the later products from this center. By the 3rd century A.D., clays yielding concentrations of 4 to 16% CaO in the finished

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114. Hatcher et al. (1980).
115. It is interesting to observe that the concentration range of CaO in the black-gloss is similar to the amounts of this constituent occurring in the red-gloss pottery from Bengazi. Perhaps this is merely a coincidence, but it would be interesting to explore the relationship between locally made pottery from this site and the imported fabrics to determine whether or not immigrant craftsmen were active in the production of red-gloss pottery in this part of North Africa. Roman coarse ware from Bengazi has been analyzed but CaO abundances were not determined. Krywonos (1980).
116. Picon et al. (1971).

ceramic replaced the siliceous clays which had been utilized during the initial period of activity at this site. Conversely, the coarser varieties of pottery continued to be made with relatively non-calcareous clays. Manufactories at several locations in Eastern Gaul also made Samian ware from siliceous clays after the 1st century.(117)

It would be unwarranted to assume any direct connection between the preference for siliceous clays at these production centers and the choice of clays by the potters of Africa Proconsularis. It is, of course, quite possible that some artisans made their way to Carthage from Gaul. If this had occurred, one might reasonably expect to find similarities between the shapes and decorative techniques used at Lezoux, Lyons and elsewhere and the material from Carthage. The forms adopted by the producers of ARS evolve independently after the 2nd century. The typology of ARS does not suggest the African workshops were transplanted from elsewhere.(118)

Clearly, the use of siliceous clays for ARS manufacture implies the African industry was not instituted by potters familiar with the techniques used for making Samian wares. At least the artisans making ARS seem to have been unaware that tradition and experience dictated the choice of calcareous clays for Samian production. European Samian made with such clay displays lustre and hardness of superior quality when compared with most ARS. It is hard to imagine that anyone familiar with the clays needed to achieve this quality would not exploit calcareous clays if they were available. The potters at Carthage and at other sites in northern Tunisia did have a choice in the varieties of clay

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117. Widemann et al. (1975) 195-197.
118. LRP 15.

available to them. The clays analyzed in the course of this study leave no doubt about this fact. Calcareous clays were readily available for making ARS.

Nevertheless, one could argue that the initiators of red-gloss manufacture in North Africa were aware of the potentially better results obtainable with calcareous clays, but other circumstances such as land use may have prevented access to appropriate clay beds. Such factors might have forced potters to use a less desirable clay for their red-gloss vessels. This argument carries little weight. The analysis of coarse ware and lamps from Carthage discussed in this study has established that calcareous clays were exploited by local potters. It is perfectly reasonable to assume that such resources could have been utilized for ARS production if the potters had wanted to use them.

Examination of some of the sherds from Carthage which were analyzed in this study suggests still other differences between the techniques utilized for the Samian industry in Europe and methods associated with the red-gloss tradition of North Africa. This supports the contention that the availability of resources was not the determinant factor in the selection of siliceous clays for ARS manufacture.

The ARS sherds of Fabric Types I and II which displayed partially reduced cores are particularly informative. The cores contrast sharply with the well-oxidized exteriors. Because iron is the colorant in ARS, this combination presumably results from a two stage firing. Reducing conditions would have been maintained during the initial stage, oxidizing conditions would have been required during the final stage to produce the red surface coloration. Numerous studies have investigated the behavior of iron compounds in fired clay.

A brown or black color is produced from ferrous iron compounds, while ferric oxide produces the bright red coloration of the surface.(119) The dark zones found in the cores of the Type I and Type II ARS sherds indicate that the final oxidizing phase of firing was not always maintained long enough for complete conversion of the iron in the clay body to its red oxide. In some cases the interior might have been shielded from complete oxidation by the slip, but this needs further investigation.

The Samian manufactories in Gaul took advantage of an advanced pyrotechnology to obtain the desired coloration of their products. Several kilns in which Samian was fired have been excavated at different locations. These installations consisted of two superimposed chambers. The raw pottery was stacked in the upper compartment. The fuel was burned in the lower one. A system of vertical flues which passed through the kiln chamber vented the fire box. Heat rising through these chimneys heated the pottery by convection. The principle is precisely the one applied in Roman bath buildings. The kiln design promoted even heating of the pottery. Furthermore, because smoke and soot were discharged from the fire box through the vents, they did not come in contact with the pottery. These combustion products create the conditions which turn iron oxide black. By isolating the pottery from such reducing agents, this ingenious arrangement insured the pottery would derive a uniform red color from the firing.(120)

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119. This alteration in the kiln atmosphere between reducing and oxidizing enabled Greek potters to achieve the polychrome effect on black-figure and red-figure pottery. Farnsworth (1963) and (1970); Bimson (1956); Bestwick and Smith (1974); Picon (1973).

120. Vernhet and Balsan (1975) 24-27; Hull (1963); Peacock (1982) 72. An excellent series of photographs and drawings of Samian kilns is provided by Reutti (1984). Vernhet loc.cit. noted that sherds with partially reduced cores, similar to ARS Fabric Types I and II, are reported from Samian

There is no evidence that kilns of this type existed at Carthage. Several kilns are known within the area, but they all belong to the common Mediterranean variety. These had raised firing chambers with perforated floors which exposed the pottery to gases and fly ash from the combustion of fuel placed in the compartment below.(121) There are several undocumented kilns of this type in the heart of the city which I was able to inspect. In addition to the 7th century coarse ware kiln on the Canadian site, a very large installation of approximately the same date was located near the coast within the city limits.(122) A very well preserved furnace of 5th century date has been published in detail. Its precise function remains unknown.(123) It should be mentioned that a visit to the site of Tiddis permitted me to examine kilns used to produce ARS.(124). None of them resemble Samian kilns known from sites in Gaul and Britain. Although some doubt remains, the evidence favors the conclusion that ARS was made in the simpler type of kiln. The generally consistent results, achieved without the more advanced technology possessed by their European counterparts, inspires admiration for the skills of the African potters.

The number of Type I sherds identified in this study represents a small fraction of the total sample population. Consequently, it is possible that more than one technique was used in ARS manufacture at Carthage. Once

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manufacturing sites in Europe. They were produced by workshops making "imitation" Samian with siliceous clays.

121. Cook (1961).
122. The author has inspected the kiln which is adjacent to the Dermech Basilica.
123. Senay and Beauregard (1980) 90-93 and Plans xvi, xviii and xxxi.
124. The kilns have not been published in detail. Bertier (1972). The trip to Tiddis was made possible by the generosity and perserverance of Dr. Colin Wells. I am deeply gratified that he was willing to endure the difficulties and discomforts of this voyage.

again, the answer to this question will require locating workshops and analyzing their products. Until material from known manufacturing sites elsewhere in North Africa is examined in the laboratory it cannot be assumed that all ARS was produced in a different manner from the Samian made in the European provinces.

The presence of black bands of slip on the exterior of some Form 23 and Form 26 vessels (See Figure 2.1) deserves special consideration. The black bands indicate that reduction conditions were employed in the manufacture of ARS and they suggest at least two different firing cycles were used. Form 23 plates have slipped red interior surfaces. Most of the exterior is also oxidized. The reduced areas show a gradation in color. The tone is darkest at the rim near the top of the vessel wall. Below this is a thin matte band which must have been produced by the lip of another vessel, stacked below the first, where it rested against the surface during firing.(125) The matte black ring is followed by a lighter zone of color which ends with an indistinct edge. There seems to be no slip where the dark band appears, but it would be desirable to confirm this observation with a microscopic examination.

The presence of black bands is probably not the result of carelessness.(126) It is more reasonable to suspect that for whatever reason the potters wished to produce these forms with a polychrome surface. The color scheme was probably obtained deliberately from a two stage firing or perhaps a

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125. Mackensen (1985) 34; Fig. 4. Wasters from kilns excavated in various parts of the Roman world prove that this method of stacking pottery was very common. Illustrations of such material from the Samian manufactory at La Graufesenque are provided by Vernhet and Balsan (1975) 27. See also Labrousse (1975) 61. Samian kilns at Rheinzabern were charged in this fashion; Reutti (1984) 23;Abb.18.

126. This is the suggested explanation for the phenomenon. LRP 47. Form 181 which is related directly to form 23, (or may be a coarser version of the same form), also has the black bands on the exterior which have been attributed to "irregular firing conditions in [the] kiln." LRP 200.

second firing altogether. The cores of the Form 23 and Form 26 vessels examined for this study are well oxidized. This indicates that reduction took place during the final phase. The red color of the interior slips on these vessel forms also supports the assertion that the polychrome effect did not result from an initial reduction firing followed by an oxidizing phase; the combination which was used to produce Greek polychrome pottery.

The success of the Greek method depended on producing a reduced, partially vitrified slip during the penultimate firing phase. The iron rich slip turned black under reducing conditions. The temperature was sufficient to sinter the surface of this coating. When the kiln atmosphere was altered by admitting oxygen during the final firing phase, the slip was protected from oxidation by its sintered surface and remained black. In contrast, the unslipped portion of the vessel turned red as the iron in the body was oxidized.(127)

The reverse process must have been used to make Form 23 and Form 26 plates. In fact, several common unslipped cooking ware forms have such partially reduced surfaces. If a reducing atmosphere had preceded oxidation, as in the Greek method, the slip on the interior of the ARS vessels would have turned black. As noted, this would probably have been irreversible if the slip vitrified.(128) It appears these ARS plates were initially heated under oxidizing conditions which produced the red color of their interior slips and cores.

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127. See above: note 118.

128. A microscopic examination is required to confirm the supposition that ARS slips have sintered. It is likely they did because slips made from siliceous clays sinter easily within the temperature range which ARS firings would have achieved. The behavior of siliceous slips has been examined recently by Tite et al. (1982) 118-119.

If the final phase of firing was carried out under reducing conditions a further difficulty would have to be surmounted. The remaining unslipped portion of the exterior vessel wall was also red. This would not be the case if the pottery was completely reduced. The solution to these conflicting demands may have depended upon the method of stacking the plates in the kiln. When these vessels were placed one inside of the other only the rims of each plate would have been directly exposed to the kiln atmosphere. This exposed area would correspond to the area of black coloration. If the pottery was thoroughly oxidized during the initial firing phase, a red clay body and slip would result. If reducing conditions were then created, unslipped portions would turn black. The portion of the vessel exterior covered by the vessels stacked below and within it, could have been sufficiently shielded to remain oxidized during a brief reduction phase. The protruding portion of the vessel, exposed to reducing gases, would have changed color producing a black band. Success would have depended on careful control of the kiln atmosphere at all times.

This proposed reconstruction may not correspond in full detail to the method which the potters adopted. But it does conform to the behavior one would expect from the various components if these basic procedures were followed. Experimental confirmation would be required to verify the results. What is indisputable from considering the manufacture of the plates, is that reduction firings were used by the potters at Carthage who made ARS.

The firing cycle proposed for the manufacture of Form 26 plates is precisely the opposite of the one apparently used to produce the most common, monochrome red, ARS. The evidence suggests the workshops used both. The proportion of ARS with black rims is relatively quite small. It seems strange

the potters would bother to adopt a different technique for firing a few plates which certainly earned no more on the market than the plain ARS. By firing other pottery with the Form 23 plates their production would have required little extra effort. The various cooking wares used in Carthage and elsewhere (LRCW I, II etc.) also had grey or black surfaces. The ARS Form 23 and 26 plates could have been fired simultaneously with the cooking ware. Admittedly the evidence is not conclusive.

Even if ARS and other fabrics were not normally fired simultaneously, individual workshops could have produced both cooking ware and red-gloss pottery. It is generally believed communal firings were practiced for Samian manufacture at La Graufesenque.(129) Batteries of kilns occur on many sites and legionary potteries produced different types of ceramics, occasionally red-gloss pottery.(130) There could have been similar installations near Carthage where small, independent workshops shared facilities and expertise. An arrangement of this sort could explain how polychrome ARS was manufactured. Without some knowledge of the physical attributes of the African workshops, further discussion of these topics cannot resolve the outstanding questions. The scenarios sketched here concerning mutual production of different fabrics are proposed as suggestions worthy of serious consideration. Only archaeological investigation of North African workshops can provide the data required for a meaningful evaluation of these tentative hypotheses.

One further speculation should be considered in this context. If manufactories produced both coarse pottery and ARS, it could account in part for another phenomenon which has puzzled scholars. Roman cook ware from Carthage

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129. Peacock (1982) 128.
130. Peacock (1982) 145-148.

was exported.(131) This seems strange considering its worth. The production of both fabrics within the same workshop or manufacturing complex would have made it easier for an artisan or middle man to "sweeten the deal" with a crate or two of cooking ware.

Reliance on an alternative, more primitive pyrotechnology than what was used in Europe for Samian manufacture may have encouraged the use of siliceous clays for making ARS. If, as the evidence suggests, a reduction stage was normally part of the firing cycle, calcareous clays could have been difficult to manage without the advanced kilns available in Europe. As little as 5% CaO in the paste promotes the formation of calcium-aluminosilicates.(132) These inhibit the formulation of large ferric iron particles which are essential for producing an intense red color.(133) If reducing conditions are maintained in the kiln, calcareous clays produce a "buff" or beige coloration. The color is exceedingly difficult to alter by reoxidation.(134) Furthermore, for reasons which are not understood completely, a high gloss surface can be produced at relatively lower temperatures with a siliceous clay slip.(135) The difficulties of manipulating calcareous clays in reduction firings may have lead the ARS manufacturers to avoid them.

If the models presented here are accurate reconstructions of the ARS firing techniques, the use of siliceous clays can be seen as the successful adaptation of raw materials and available technology to produce ARS. However, using these clays would have presented the potters with other difficulties. By

131. Fulford in ECBM I,2. 256-257.
132. Picon and Vichy (1974) 43; Shepard (1954) 23.
133. Maniatis et al. (1982) 101-102.
134. Tite et al. (1982) 117-118.
135. Tite et al. (1982) 118-119.

exposing the slip to reducing conditions, they risked turning it permanently black. Burnished, siliceous slips sinter, forming a glassy layer which protects them from reoxidation.(136) This was the key factor in producing the polychrome effect on Greek black-figure and red-figure pottery.(137) The mono-chromatic black-gloss pottery popular during the Hellenistic period and the Samian wares produced in Italy and Gaul, also have vitrified slips.(138) Ferro-ferrous compounds of alumina are characteristic of these surface coatings, but the role which these chemical species play in the process is only partially understood.(139) Incipient vitrification occurs in siliceous and calcareous clays at temperatures above 800 degrees Celsius.(140) ARS was fired in this temperature range.(141)

Once sintered, a reduced slip can be reoxidized, but this is "exceedingly difficult". How the producers of ARS compensated for this cannot be determined without a program of trial firings and laboratory examination. By maintaining kiln temperatures below the sintering threshold of the slip during the reduction phase they could have diminished the risk. Possibly, they deliberately used a thin, unfloculated slip.(142) Experimental recreation of the Samian ware surface coating has demonstrated that the clay particles of the slip must be of colloidal size. Otherwise the results are not comparable to the

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136. Tite et al. (1982) 114-116.
137. Farnsworth and Wisely (1958) 169-170; Bimson (1956).
138. Picon and Vichy (1971); Maniatis et al. (1982).
139. Tite et al. (1982) 118.
140. Tite et al. (1982) 110-113.
141. LRP 295. Tite sees no point in being more precise than identifying one of three basic temperature ranges: below 800 degrees - bonfire; 850 - 1000 degrees kiln; above 1000 degrees. Tite et al. (1982) 113.
142. Illitic clays work best for producing the Samian finish. Bimson (1956). The occurrence of these clays in the vicinity of Carthage has not been investigated.

red-gloss produced in the European provinces.(143) An unsintered slip, combined with incomplete oxidation, may explain the matte finish of ARS, but a definitive answer will require additional research.

Several samples of slip were analyzed to determine whether or not they were significantly different from the clay body. Different clays were used for the paste and slip of both Samian Ware and Greek Black Figure Pottery.(144) This does not appear to be the case with ARS. Elemental abundances show slight variation (Table 2.1). With the exception of silica, they are within the range which could be expected if the clay used for the vessel walls was purified to make the slip.(145) The slightly higher values of silica are not what one would expect. Results from analyses of other Roman fabrics and of Greek pottery show a decrease in the silica content of the slips. Those who performed the research believed this reflects greater amounts of temper in the pastes which they analysed.(146) Their measurements were made by electron microprobe analysis of thin-sections which permitted selective sampling of the clay phases. The ARS slips, removed by a comparatively crude procedure, were probably contaminated with material from the clay body. It is reasonable to suppose that quartz grains, pulled loose by the drill bit, raised the silica abundances abnormally. In retrospect it would have been preferable to separate these from the rest of the slip. However, the falsely elevated silica values do not alter the general conclusion that a similar clay was used for both the body and the slip of ARS.

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143. Bestwick and Smith (1974) present a complete review of the experiments which have been completed since the 19th century.
144. Tite et al. (1980) 115ff. Probaby, Siliceous clays were adopted because they produce a more intense coloration.
145. Tite et al. (1980) 115ff.
146. Tite et al. (1980) 112-115.

Several important aspects of the ARS manufacturing techniques will remain obscure until additional evidence can be acquired from more comprehensive analytical investigations. It is certain that the ARS was produced from non-calcareous clays. The physical properties of several pieces suggest that at least some of the ARS was fired in a manner quite distinct from the one utilized by the factories which made the major Samian fabrics. These features of ARS production confirm the independence of the ARS industry in the Carthage region from its European counterpart. It seems enterprising artisans who wished to capitalize on the popularity of red-gloss pottery developed a means for imitating the products of European manufacture. Despite the uncertainty surrounding the firing methods employed by African workshops, the evidence at hand clearly suggests that the ARS made in the vicinity of Carthage evolved without any direct participation from craftsmen trained in the Samian tradition. The North African potters were able to find materials compatible with their own pyrotechnology. They achieved their success independently.

SECTION 2.2

DISCRIMINANT ANALYSIS

It was hoped that differences in composition between the ARS fabric groups might be detected simply by comparing frequency plots of chemical abundances. The initial results did not provide a clear distinction between the fabrics. This could be seen by comparing the frequency diagrams of the components. If a larger sample of pottery had been analyzed a more normal distribution might have resulted. On the other hand, it seemed possible that some sherds had been improperly assigned during the initial sorting. Generally the overlapping component distributions between fabrics made it impossible to see any significant differences between the ARS fabric groups by a simple comparison of frequency diagrams. The one exception is the two sherds which comprise fabric N VII (See p. 22). Although their color is quite close to what one observes in the other fabrics, they contain a twofold greater amount of calcium than their slipped counterparts. They certainly constitute a fabric whose composition is more closely related to the buff coarse ware and lamps. While some difference might have been expected between the unslipped objects and their red-gloss contemporaries, the use of a completely different clay was not anticipated.

Given the similarity in composition between the other ARS fabric groups, a multivariate statistical technique known as discriminant analysis, was applied to the compositional data to determine if separation was possible. This method has been used most frequently for statistical validation in the

social sciences, particularly in the field of behavioral research.(147) It has proven its utility for differentiating between contemporary issues of ancient coinage(148) and for classifying projectile points.(149) This multivariate technique has yielded excellent results in provenience studies of Samian Ware undertaken by a CNRS research group.(150) The manufacture of moulds and Samian from the same clays at Rheinzabern was confirmed by the discriminant classification procedures.(151)

Discriminant uses raw data to compute a new set of variables which are subsequently compared to distinguish between groups. The groups in this study are the various pottery fabrics. The variables computed for discriminant analysis are mathematical combinations, known as 'discriminant functions' or 'canonical variates'. They have the general form:

D: = diZ1+diZ2+....diZn

where di are weighing coefficients and Z are standardized values for each original variable from 1 to n. The Z scores are the compositions of the various elements. Ideally D for all members of one group (e.g. pottery fabric) will be the same. Each coefficient is calculated from two covariant matrices. One uses mean and standard deviations for between groups sums of squares and cross products. The other matrix contains the within-groups sums of squares and cross products. These calculations make the use of computer mandatory.(152)

The number of functions derived for a particular discriminant analysis varies. It will be equal to one less than the number of groups or equal to the

147. Klecka (1975).
148. Carter and Frurip (1985).
149. Watson (1986).
150. Widemann et al. (1975); Picon et al. (1975); Wilson (1978) 232-233.
151. Heimann (1980) 213-215.
152. Klecka (1975) 434-435; Picon et al. (1975) 19.

number of variables whichever is less. One function will be computed for each original variable in the latter instance. The functions are arranged in decreasing order of "discriminating power". One may judge their contribution to the separation process by values of Chi squared reported by the SPSS-X program used in this study. Values for D are calculated for each case (pottery sample) by substituting the experimental results in all of the functions derived for each group. If there are four functions, there will be four values of D for each case. Each function may be considered as defining one dimension of multi-dimensional space. Because the functions are ordered by their power of discrimination, distances between the means of the first function are more significant than distances observed when comparing means of, say, the fifth function.

The location of a particular group in this space is defined by its "centroid". Averaging the values of D for each function provides a group mean for that function. When the means of all functions derived for a group are added together, the sum gives the location of the centroid. This is where all the functions defining a group intersect. The distance between the centroids of the various groups constitutes the criterion for separating them.(153)

The coefficients by which each raw score is multiplied are derived so that the combined score for any single function will have a mean of zero and a standard deviation of one. Consequently, a single case score on that function represents the number of standard deviations between that case and the mean.

The procedure used for classifying the pottery data incorporated a stepwise method for creating the discriminant functions. The order in which the

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153. Klecka (1975) 442-443.

variables were inserted in the discriminant functions was based on their discriminating power. This was measured by computing the maximum F ratios between pairs of fabric groups. The F ratio = variance of means over pooled variance. Higher F values indicate variance is less likely to be a result of chance.(154) Each variables was evaluated individually to determine which one would yield the best discrimination. This variable was then paired with the other variables to select the second variable. The remaining variables were then combined to form triplets with the first two to select the third. This process continues until all possible combinations have been evaluated. This method produces an optimal set of discriminating variables when groups are not widely separated.(155)

Once the positions which particular groups occupy in discriminant space are established, the probability of group membership for each case can be determined. This is accomplished by a separate classification procedure. A classification function is derived for each group. If there are three groups (pottery fabrics) there will be three classification functions. The classification function is used to calculate a classification score. The basic equation is:

Ci = ci1V1+ci2V2+....cinVn+K

Ci = the classification score for group

ci = the classification coefficients for each variable

K = a constant

V = the raw data score for each variable.

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154. Moroney (1965) 233-236; Wonnacott and Wonnacott (1984) 293-297.
155. Klecka (1975) 447. The procedure maximized Mahalanobis distance. See Wilson (1978) 232.

The coefficients are computed from the centroids determined in the initial phase of analysis and from covalence matrices which pool the values displayed for each variable by all members of the group. The scores in each group classification function are then calculated for each case under consideration. If three groups are being compared, each case (pottery sample) will have three separate scores.(156)

The case is assigned to the group whose function produces the highest score when the raw data set for that case is substituted in the equation. The raw data here consists of the nine values for chemical composition. In effect, the classification score is a measure of the probability of group membership. The higher the score a case receives when its variable values are substituted in a group classification equation, the greater the probability that it belongs to that group. The classification probabilities in this study were weighted to account for unequal group size.(157)

By classifying cases it is possible to measure the validity of the criteria used to differentiate between groups. The classification step can also detect cases which are anomalous and possibly improperly assigned. Finally, unassigned cases can be placed in groups with which they have the greatest affinity. Four separate discriminant analyses were conducted with the data for African Red Slip. The results are shown in Appendices I - IV.

The groups compared in the first analysis included all of the separate sets of pottery fabrics classified by visual comparison. Nine discriminant functions were derived. The Chi squared values for the first four varied from

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156. Klecka (1975) 445.
157. Picon et al. (1975) 195-196; Klecka (1975) 445-447.

645 to 123 with 99 and 48 degrees of freedom respectively. These give significance levels of 0 indicating the discriminating variables derived from them contain significant amounts of discriminating information.

CaO occupied the first position in the variables ordered by increasing discriminating power. It was followed by NaO and AlO. Silica ranked 9th. The group territorial map (Figure 2.2) shows that although statistically distinct groups could be separated, the centroids are very close together. Consequently, scatter plots of values for the first two discriminant functions show overlap between the groups. Since the third and fourth functions also contribute a considerable degree of the separation, the two-dimensional representation exaggerates to some degree the proximity of the centroids. Even so, the groups are not widely separated. When the individual samples were classified in the final step of the first discriminant analysis, group proximity is apparent once again. The results are summarized in Appendix I.

The tables in this appendix give several parameters for each sample. The original group is followed by a listing of the highest probability group to which the case belongs based on the discriminant analysis. The value for within-group probability P(P/G) reports the probability that a sample would lie at the calculated distance from the group centroid. The probability (D/G) is the probability that the case belongs to the selected specified group (i.e. the between-groups probability). When a case does not fit the group to which it was originally assigned, it is marked with an asterisk.

Considering the performance of the fabric categories in numerical order it is immediately apparent that Fabrics F I and F II (41 and 42 in the classification table) cannot be separated from other contemporary fabrics.

Admittedly the total sample population of these fabrics is small so the full concentration ranges may not be represented. Possibly a broader range of chemical constituents would have to be measured to yield discrimination, although research has demonstrated that such an approach will not always work.(158)

The fact that six out of these ten cases have been reassigned to fabric 43 (fabric group F III) may have a special significance. The darker cores of these samples which led to their initial separation from Fabric F III supports the contention that they are misfired variants of the more common fabric. The unslipped cook ware vessels which comprised fabric groups F IX (Discriminant group 49) are also more compatible statistically with group 43. Only one of these 6 samples retains its original identity. Four are closer to group 43 and one is closer to fabrics N IV and M III. It seems reasonable to conclude that the cook ware was made from the same clays as the other ARS fabrics. This strengthens the hypothesis that this fabric could have been made by the same workshops which produced monochromatic ARS, although an alternate firing procedure was probably required.(159)

The largest original fabric group, F III, (discriminant group 43) retained its integrity during the classification phase. Only two of its twenty-three cases were reassigned: one to Fabric M III, one to Fabric N III. The within-group probabilities are generally in the 90th percentile. The between-group probabilities are relatively low. They vary from about .3 to .8 with many values below .75. This reflects the proximity of other centroids. The

158. Lemoine et al. (1982) 58-60.
159. See above: pp. 73-74.

probabilities are also decreased because samples assigned to fabrics F I, F II and F III properly belong to the F III compositional group.

The material from locus 1M 7, comprising two main fabrics, shows considerable discrepancy between the original assignments for its cases and the statistical categories. Only four of the original fourteen cases fit the discriminant group for M III. Fabric M IV fares only slightly better. Evaluating the individual cases it seems that four of the M IV category should have been placed in the N III group. The separation based on the physical properties of vessel cores was particularly inadequate for these fabrics. The fact that several of the samples from this stratum are statistically congruent with groups in other strata may be interpreted in several ways. It is possible that surviving material from the 3rd century was redeposited. This would account for the single vessel assigned statistically to Group F III. Although it can not be ruled out completely, this seems an unlikely explanation since the forms suggest a 5th century and not a 3rd century date. Quite possibly these equivocal classification probabilities arise because the Type III and IV fabrics collectively represent collections of several minor groups. This would also account for the 4 cases from the 3rd century deposit (loci 2F 32-36) which the discriminant analysis would place in groups from the 5th and 6th century strata. Nine of the cases in M III and IV groups were matched by fabric classification of the material from Locus 1N 17. Since these two loci are closer together on the chronological scale and probably overlap in time, the presence of similar material in locus 1M 7 is less surprising.

The segregation of fabrics by comparing paste color in sherds from locus 1N 17 yielded coherent compositional groups. Seven of the original 38

cases had probability values which could eliminate them from their original categories. Four of the 1N 17 specimens would simply be reassigned to the other fabric group from the same stratum. One sample matches the main fabric group, F III, from the 3rd century deposit. Two would be assigned to the group composed of material from Mahrine.

The original group of sherds from Mahrine consisted of twenty pottery samples and two lamp samples. The fragmentary mould or burnisher, no. 249, was left unassigned. The discriminant classification eliminated four of the pottery samples. The score for the mould gave it a high within-group probability, but a relatively low probability of group membership (.91 vs .76). The probability scores for many of the sherds which were attributed to the main group were also below acceptable levels. Once again, in spite of the apparent physical similarities shared by the individual vessels in this sample, divergent compositional groups occur.

The ARS lamp group lost 40% of its numbers during the first discriminant analysis. Three had a greater probability of belonging to the N III ARS fabric, while one had a discriminant score which would place it in the M III fabric group. Sample 471, one of the examples of a Hayes Type II lamp was eliminated.(See p. 26) The other example of the Hayes Type II variety, no.472, remained within the group.

Membership probabilities for the lamps, as well as those of the other groups were generally below the 90% percentile which has been generally accepted as the minimum value for group attribution.(160) Only 63.6% of the cases as originally grouped were properly classified. The number of misassigned cases

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160. Picon et al. (1975). Wilson would like to see higher values but does not suggest a figure. Wilson (1978) 233.

would have affected the position of group centroids. Consequently, this reduces the discriminatory value of the analysis.(161)

A second classification analysis was attempted. Cases which had been improperly classified were reassigned to the highest probability group identified by the first discriminant tabulation. Not all of the cases were reassigned. The rejected cases from the fabrics of loci 2F32-36 which matched groups of the more recent strata were not assigned to a group. It was assumed that they would more reasonably represent a subgroup of the 3rd century since their stratigraphical, and hence chronological context, made it impossible for them to represent fabrics made 100 to 200 years later. Samples of the 5th and 6th centuries with an affinity for the 3rd century group were also left unassigned. The possibility that they were residual material seemed unlikely considering the vessel forms. Cases were reassigned between the fabric groups of strata 1M 7 and 1N 17. Because these two loci overlap chronologically, fabrics of any given type could have been deposited in both of them.

Specimens from Carthage designated by the first discriminant analysis as belonging to the Mahrine fabric and those from Mahrine with discriminant scores which would place them in Carthage fabric groups were left unassigned. This procedure was adopted because it could not be proven that these samples actually were transferred from one site to the other. Although some of the lamp samples could have been reassigned to other fabric groups, it was decided to leave rejected ones unassigned. It could be argued that these cases might have been made in workshops producing red-gloss table ware. Indeed, it seems rather

161. The fact that some of the slips would be classified in other fabric groups is not very significant since their silica abundances are artificially high.

probable when one considers that both lamps and table ware were produced at Mahrine, but this could not be substantiated for the material from Carthage.

The second analysis yielded a much higher percentage of properly classified cases: 95% of the total sample population matched the pre-analysis attributions after revising group membership. Considering the results of the first analysis and the generally low between-groups probabilities, this consistency was unexpected. Furthermore, many of the ungrouped samples could be reassigned to the newly defined groups with high probability ratings. There remained, however, samples in all of the fabric groups which had values below 0.90 for between-groups probability. Their poor fabric affinities excluded them from the newly defined groups.

The results from the second discriminant analysis were used to establish the final group attributions. These attributions appear in the tables of vessel forms provided with Chapter I, Tables 1.1 through Table 1.11. The original and final group attributions are also shown in Appendix VIII which lists the elemental compositions of each sample. Samples with membership probabilities below the .90 limit were not given a "final" fabric designation. Cases with these values were excluded from the final calculations of group means which are presented in Appendix VII.

The results of the discriminant classification show that five compositional groups can be distinguished among the samples of ARS from the three deposits excavated at the Canadian site. The significance of these groups must be considered. Assuming the ceramic was made at or near Carthage, one might suppose the variations in composition may be explained by different workshops producing pottery with basically the same techniques, but with

slightly different procedures. When one examines how closely the distributions of element abundances resemble each other, an equally plausible explanation can be suggested. Production methods, although standardized, in one or more manufactories, yield ceramics of variable quality which tend to have distributions of the chemical components that can be separated statistically. Vessels made in one workshop can have a composition which matches pottery from another workshop. This is likely to be true, especially if the raw materials used by both are the same or relatively similar.(162)

The fabric groups as they were originally defined, fell into two broad categories which were labeled Fabric Type III and Fabric Type IV. Although the divergence of color and relative frequency of calcareous inclusions were not totally reliable, the basic distinction was validated by the statistical analysis of the subgroups.

Two additional discriminant analyses were conducted to determine the homogeneity of these two classes of fabric. The three subgroups of Fabric Type III; Fabrics F III, M III and N III, were placed in a single discriminant group. Fabrics M IV and N IV were combined to form a second group representing Fabric Type IV. The two single samples remaining in Fabrics F II and F IX were left ungrouped as were the two examples of Fabric N VII. All of the samples eliminated from the fabric groups by the second discriminant analysis were assigned to a new group. This was done to determine if there might be a third Fabric Type which resembled the other two so closely that it would not be obvious from a visual examination of the pottery.(163) The sherds from Mahrine

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162. Picon et al. (1975); Lemoine et al. (1982).
163. I wish to thank Mr. Gordon Watson for suggesting this particular aspect of the analysis. He was able to group otherwise anomalous projectile points with a similar procedure.

which remained in the original group constituted a fourth group designated Fabric MA I. The Mahrine sherds eliminated by the previous classification analyses were assigned to another group labeled Fabric MA IB. This was done to see if they might form a coherent subgroup of material. The final group was comprised of lamps retained in Fabric L I by the statistical analysis.

The results of this third classification analysis are presented in Appendix III. It is obvious that the samples which composed the anomalous group of ARS samples from Carthage are poorly matched. Combining them as a separate fabric has the effect of lowering group membership probabilities for all of the categories. The territorial map of discriminant functions show the anomalous samples occupy a central location in discriminant space (see Figure 2.3). If these samples do belong to a separate Fabric Type it simply cannot be separated from the rest of the Carthage material. It appears, however, that these specimens represent several different groups as originally hypothesized. The newly created group of Mahrine samples did produce a fairly cohesive group of five specimens with membership probabilities in the 90th percentile. This is an excellent illustration a phenomenon discussed elsewhere;(164) distinct compositional groups are often observed in a body of material originating from the same manufacturing center.

A final discriminant analysis was conducted for the Fabric Types III and IV from Carthage. Anomalous samples of the ARS from Carthage ejected from these two Fabric Types by the third classification analysis were not assigned to any group. The other groups of Carthage pottery from the previous

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164. See pp. 89 and 94.

classification procedure were kept intact except for the two lids comprising Fabric N VII which were left unassigned. The samples with high probabilities of membership in the principal Mahrine fabric, group MA I, retained this designation. The other ceramics from this site were left unassigned. This left 89 cases with group attribution and 51 unclassified samples.

This fourth multivariate analysis generated three discriminant functions. Sodium, manganese and calcium were the principal contributors to the discriminating power of these classification equations. Figure 2.3, the territorial map for the discriminant groups, shows clear separation, although some cases along the boundary cannot be assigned absolutely to one group. The distribution of discriminant scores for the cases of each group are shown in Figure 2.4. The individual groups are reasonably homogeneous, but the cluster boundaries converge. Cases whose discriminant scores place them near the shared boundaries receive low between-group probabilities. Consequently, their fabric identities are uncertain. The results of the classification analysis appear in Appendix IV.

The final classification procedure indicated that 98% of the group attributions were valid once each of the Fabric Type III and IV samples were reassigned to the Fabric Type for which it had the greatest affinity based on the scores received in the third discriminant analysis. When the new scores were computed for the cases left ungrouped by the third analysis, 29 of these previously anomalous samples displayed between-group probabilities above .9 of membership in the main Fabric Types (Types III and IV). Out of the entire sample population, 21 had probability values below this limit and therefore could not be assigned with certainty.

Essentially, the two principal Fabric Types can be distinguished by their different patterns of elemental abundance. There are abnormal samples within each of these groups whose membership remains in doubt. These represent approximately 15% of the sample population. Ten of the anomalous Mahrine samples were assigned by the classification procedure to Carthage Fabric Types. Seven of the cases received probability scores above .9 for membership in the Carthage groups. (See Appendix IV.) This underscores the similarities in composition between one group of ceramics made at Mahrine and the material from Carthage, particularly Fabric Type III.

The significance of the patterning which distinguishes between the two major Fabric Types from Carthage is by no means clear. It could reflect independent sources of manufacture at separate production complexes. Alternatively, the distinction could derive from inconsistent execution of the fabrication technique within a single manufactory. A choice between these two possibilities cannot be made with the information currently at our disposal.

The population of each main Fabric Type can be separated into subdivisions chronologically. This is most dramatically observed in Fabric Type III. The clusters formed when discriminant scores are plotted (see Figure 2.4) indicate the elemental abundances of the fabrics are quite similar. This can be appreciated from the concentrations of the various components presented in Appendix VII. This tabulation presents the mean abundances of the constituents for Fabric Types III and IV and for their various subgroups. The means are calculated from those cases which received scores in the 90th percentile from the final discriminant analysis and in the second classification procedure respectively.

A plausible explanation for the chronological dissimilarity would be that alternative supplies of raw materials were used at different times. On the other hand, the relative consistency of composition over a period of three centuries or more does not imply drastic alterations in the techniques of manufacture. The subtle differences do not seem linked to a specific element, but to the overall composition. Changes in elemental abundance of such small magnitude could arise from variations in chemical composition within a single, large clay source. This has been recognized for some time as a potential source of component variability.(165) If ARS workshops at Carthage exploited one extensive deposit during a period of several centuries one could expect the composition of their ceramics would fluctuate accordingly.

165. Stern (1977) 73-75; Widemann et al. (1975) 46-47; Bishop et al. (1982). There remains the possibility that homogeneous geology could mask different origins of manufacture.

SECTION 2.3

DISCUSSION OF THE FINAL CLASSIFICATION RESULTS

A closer examination of sub-groups identified by discriminant analysis reveals several anomalies and similarities which have broader implications. The unity of the original ARS lamp fabric was not preserved. The second classification procedure rejected all but six of the cases. Those remaining samples constituted a group whose discriminant space is well separated from the other group centroids. Comparison with the other ceramic fabrics does not indicate any variations in major components which could be explained by different manufacturing techniques. A different source of raw material may account for elemental abundances which characterize the lamp fabric. This could indicate an origin of manufacture different from that of the other ceramics.

Several of the unassigned ARS lamps have a very high silica content which could be interpreted as a deliberate attempt to increase their resistance to heat. Presumably this would be a desirable characteristic in an oil burning lamp. On the other hand, lamps of the L I category do not share this attribute. This suggests the occurrence of pastes with a greater silica content may be fortuitous. The variation is precisely the sort of effect one could expect from from inconsistent preparation of the raw clay. However, it would be hazardous to suggest a definitive explanation for these elevated silica levels with results from such a small sample population as a basis for discussion.

The ARS lamp specimens rejected from Fabric L I by the statistical classification procedure display discriminant scores with affinities for the ARS

table ware of the Type III fabric class. Three of the lamps have probability scores which make it impossible to separate them from the pottery. The single Form 5 lamp (no. 476) with a slip different from the other samples was assigned to Fabric M III. This similarity certainly implies the pottery and lamps originate from the same workshops. The validity of this supposition is strengthened by the fact that lamps probably were manufactured at Mahrine. Both of the Mahrine lamp sherds (samples 231 and 248) were assigned to the MA I fabric group along with seven pottery samples. The scores for the two lamps, .97 and .92 respectively, confirm their membership in the group. The results of these analyses leaves little doubt that in certain workshops ARS lamps were manufactured in conjunction with table ware.

The L I Fabric Group consisting of specimens securely assigned by statistical analysis, includes at least one of each form category included in the original sample population (see Table 1.9); demonstrating it is not always possible to correlate differences in chemical composition with the production of particular forms by separate workshops. This finding contradicts the reported preliminary results from chemical analyses conducted on a group of Form 1 and Form 2 lamps which were mentioned previously.(166) The two Form 1 lamps from Carthage were statistically assigned to different fabrics, well separated in discriminant space. The number of samples acquired from the Canadian site which were tested in this study is too small to provide absolute conclusions. Nonetheless, it appears that one cannot rely solely on form to distinguish between the production of various ARS lamp factories. Obviously the

166. See above pp. 26-27.

relationship between the ARS lamp fabrics requires more study. However, the results are promising because they demonstrate that the potential clearly exists for using chemical analysis to distinguish different lamp fabrics in material which is visually homogeneous.

The ARS from Mahrine provides an example of materials from a known manufacturing site. Consequently, it is appropriate to consider it before turning attention to the ARS table ware from Carthage. The original sample consisted of 22 ARS sherds including two lamp fragments. The second discriminant analysis rejected 5 cases leaving 17 in the group. Six of the remaining cases must be rejected because of low between-group probabilities. The final population of Fabric MA I is thus reduced to 9 samples. The low membership probabilities of the rejected cases most likely arises from the interplay of two factors. First, the proximity of centroids belonging to the other fabrics makes it impossible to assign some cases to their proper fabric with a high degree of certainty. Because the raw materials used to produce the ARS from Carthage have elemental abundances which are quite similar to the concentrations occurring in the Mahrine pottery, the ceramics from these two localities are not easily separated. Consequently, there is a subgroup of Mahrine pottery which cannot be distinguished from the fabrics defined from the analysis of ceramics from Carthage.

The second source of uncertainty which affects the discriminant classification is the variation in composition within the individual fabric groups. We have also seen that a subgroup of about 5 sherds which can be

distinguished from the other Mahrine pottery.(167) There is always the possibility that pottery produced during a finite chronological period by a specific workshop or within a manufactory complex where several independent craft shops operated, will exhibit two or more compositional groups. Experience shows these subgroups usually have their own, approximately Gaussian distribution of elemental abundances.(168) This seems to be the case with the material from Mahrine. Inconsistent preparation of the clay for potting and variation in composition within the source of raw material could easily account for minor variations in the overall composition of a given pottery fabric.

Several of the Mahrine samples are indistinguishable from some of the ARS found at Carthage. Many of the ungrouped Mahrine sherds were assigned to Fabric Type III with high probability scores by the final discriminant analysis. (See Appendix IV.) It is possible, of course, that some Mahrine pottery made its way to the coast. Members of the subgroup at Mahrine might be present in reference groups of Carthage fabrics. On the other hand, none of the samples from Carthage were assigned to the MA I fabric group with probabilities in the 90% percentile. Two of the abnormal specimens from Locus 1M 7, nos. 179 and 181, were classified by the second discriminant analysis as belonging to the Mahrine fabric, but their probability scores were .792 and .512 respectively. The output of the Mahrine pottery consisted of large quantities of decorated plates and bowls. Only a few such pieces from Carthage were analyzed in this study. Two, nos. 359 and 362, were classified as members of Fabric Group N III with acceptable probability scores. The other sample, no. 202, was attached to

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167. It should be noted that the unslipped disc-shaped object has a composition very similar to the ARS, but its membership score is below the probability limit.
168. Picon et al. (1975) 198-199.

the M III fabric, but with an unacceptable probability score of .712. These results do not prove that ceramics from Mahrine never reached Carthage, but no obvious examples of such pottery were detected in this investigation.

Decorated ARS accounted for a very small proportion of the red-gloss recovered by the British Excavation. It seems relatively rare in the other catalogues, but final statistics are not available. It would be desirable to analyze many more decorated pieces of pottery which have been found at Carthage and to compare the results with pottery from Mahrine. Also, it would also be useful to know how much undecorated pottery was produced at Mahrine. A corollary question would be: where was the pottery from Mahrine distributed? These questions are beyond the scope of this study. Stratigraphic excavation and laboratory investigations will be needed to clarify the role this production center played in the ARS industry.

Several aspects of the discriminant analyses of ARS from Carthage need more detailed discussion. The multivariate classification procedures effectively eliminated fabric groups F I and F II, the monochrome ARS table ware with reduced zones visible in the vessel cores. The fact that these vessels have compositions which are indistinguishable from the pottery with oxidized cores strengthens the supposition that samples assigned to fabrics F I and F II are incompletely fired examples of the other fabric groups. This relationship needs to be stressed because of what it implies about the firing cycle used to manufacture ARS on preceding pages 71 and 72.

Membership in Fabric F IX was reduced from 6 to 2 by the classification process. (See Table 1.5) Fabric F IX was used to designate the polychrome plates and bowls with a black band around their rims, nos. 167-171.

Three other members of this fabric group were reassigned with high probabilities to the F III group composed of monochromatic ARS. Since their compositions often are virtually the same, it seems reasonable to suppose both types of ARS were often made by the same workshops in spite of the fact that different firing procedures might have been required.(169)

The 15 members of fabric groups F I, F II and F IX, with 4 exceptions, have membership probabilities from the second discriminant analysis above .9 which would place them in Fabric F III or N IV. Only three, nos. 143, 158 and 170, received classification scores below the 90% probability level in the fourth classification procedure which separated the major types, Fabric Types III and IV. (See Appendix IV.) One may reasonably infer that these vessels were often made by the manufacturers who produced the major fabric types of ARS table ware. The two samples of the Fabric F IX which form a separate group do not invalidate this conclusion.

Fabric F III, the major fabric analyzed from the 3rd century loci, gained several members. The discriminant scores from the second analysis placed all but 8 of the 42 cases from these strata in the F III fabric. When the samples with between-group probabilities below .9 are removed, the total number of cases for the group is 27. Several samples with affinities closer to Fabric M III, N III, and N IV could be interpreted as early examples of these fabrics. With so few examples it seems more likely that they represent a subgroup whose parameters require further definition. There is always the possibility that in any given chronological period subgroups existed along with a major composition categories. The samples of groups F I and II with dark cores are best explained

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169. See above pp. 71-73.

as the result of incomplete oxidation during firing. They should be considered as belonging to Fabric Type III.

The single sample of Late Roman Cooking Ware, no. 183, (See p.20) was classified by the second statistical analysis as belonging to Fabric M IV. The probability score was low enough to reject the piece. The final analysis attributed the specimen to Fabric Type IV with a between-groups probability of .97. Because only one sample was analyzed, definitive interpretation is not possible, but it implies that the vessel could have been made by the producers of red-gloss pottery. It may be observed that the relationship between so called "annex" products and the material from red-gloss manufactories at the same location is rarely discussed in detail. The extent to which resources and personnel were shared merits investigation. This seems especially true at Carthage considering the composition of the LRCW I juglet from locus 1M 7.

The ARS from this locus yielded the greatest variety of fabric types from the initial two groups.(See Table 1.6) The second statistical analysis placed 7 cases in the M III category, but 3 have probability values below .9. Removing cases with insufficient probability ratings from M IV leaves 4 in that group which initially had 14 members. Also, the table indicates that fabrics defined by sherds from locus 1N 17 have representatives in stratum 1M 7. Selecting only cases with probabilities in the 90th percentile places three in each of the fabric groups N III and N IV. Two 1M 7 cases, nos. 179 and 181, had scores which would place them in the Mahrine group but with probabilities less than 90%. An additional two cases from 1M 7, nos. 187 and 211, were assigned to fabric group F III, but the membership probabilities are again below the .9 limit.(See Appendix II)

The group of 11 sherds assigned to Fabric M IV by their physical characteristics was reduced to 6 by the second classification procedure. None of these met the probability requirements for certain attribution. When grouped with the other Type IV sherds in the final discriminant analysis, they were assigned to Type IV Fabric, along with 5 other sherds from this locus with probability scores generally greater than .95 (see Appendix IV). The poor discrimination between Fabric M IV and the other fabric sub-groups might be improved by using a larger reference sample. Conversely, the elemental abundances may simply have a pattern which corresponds to an intermediate fabric type. It could also arise from the combination of two or more subgroups. The dispersal of the M IV group among unassignable cases with various affinities makes it the most diverse of all the original fabric groups.

The heterogeneity detected in the original groups M III and M IV may reflect in part the relatively small size of the initial reference groups themselves, but the chronological range represented by this material may also be greater than the separate intervals of time during which pottery accumulated in the other two deposits. The reassignment of material from 1M 7 to the fabric groups of stratum 1N 17 is congruent with the chronological overlap between the two loci. There are other explanations for the variability in the material from 1M 7 which must be considered in conjunction with results from statistical analyses of the other fabric groups. A contrasting picture emerges from the multivariate classification of fabric groups from locus 1N 17. A total of 38 cases were distributed between these fabrics in the initial classification. The second discriminant analysis assigned 21 cases to Fabric N III of which 6 can be rejected because of their low probability values (see Appendix II). Fabric N IV

has a smaller population. The discriminant procedure placed 15 cases in this group. Three of these are eliminated by their probability scores. One anomalous sample had a score which would place it with the M III group, but not conclusively. Although anomalous cases exist, the original groups remain intact. There also appears to be no material from the N 17 deposit which should be assigned to fabrics identified in other layers. Comparing the results from the three deposits, the ARS fabrics recovered from locus 1M 7 are noticeably more heterogeneous.

It may be tentatively suggested that the broader cross section of fabrics detected in locus 1M 7 could be explained by circumstances which affected the social and economic climate at Carthage during the first quarter of the 5th century. The evidence gleaned from recent archaeological activity suggests the city was experiencing increased prosperity and population growth on the eve of the Vandal conquest. An influx of immigrants from the European provinces was partly responsible for this phenomenon.(170) Concurrently, overseas trade in some commodities may have been decreasing in the last quarter of the 4th century. This has been inferred from the distribution of North African amphora types.(171) Exportation of red-gloss pottery may have been declining as well.(172)

These trends may not have affected the market for ARS at Carthage, especially if the city's population increased. Furthermore, the decline in the export market might not produce an instantaneous reduction in the variability of local production. In fact, the material from the British site on the southern

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170. Humphrey (1980) 116.
171. Fulford in ECBM I,2. 258.
172. Fulford in ECBM I,2. 112-113.

edge of the city shows "the late 4th to early 5th century is a major period of typological change, and not c.425 to c.475".(173) No further comments are made about the apparent contradiction implied by declining ARS exportation and greater diversity in local production. It is hard to reconcile the diversity at this time, as stressed by Fulford, with his statement concerning production at Carthage a century later: "The greater the range and number of contemporary vessels at any site, the greater the chances are that this was the result of regular and frequent traffic."(174)

Although the status of maritime trade at Carthage at the turn of the 5th century remains unclear, the typological variety in the ceramic assemblage from the British excavations establishes the diversity of ARS production at this time. The absence of uniformity in the chemical configurations of the contemporary ceramics from locus 1M 7 may not be completely fortuitous. It would be reasonable to suppose that the demand for table ware accrued in conjunction with the city's growth. The number of ARS workshops may have multiplied in response to the expanded local market. Alternatively, existing manufactories could have increased production.

Either possibility could easily introduce greater variability in the composition of red-gloss pottery. The augmentation of output and the proliferation of local workshops may explain inconsistent elemental abundances. One could anticipate that more intensive exploitation of the local clay sources would accompany intensified activity by the potters, forced to expose previously untouched portions of existing deposits or to open new quarries. As they expanded exploitation of the local raw material reserves, they would presumably

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173. Fulford in ECBM I,2. 113.
174. Fulford in ECBM I,2. 114.

encounter variations in elemental abundances which occur naturally in clay bodies. In fact, the results from the analyses of clay deposits in the Carthage region presented in Chapter III indicate that such fluctuations can be quite extreme. These variations, of course, would induce changes in the composition of the finished ceramics.

Only a portion of the 5th century deposit, 1M 7, has been analyzed and only a partial sample from the other two deposits provides a basis for comparison. More definite conclusions cannot be drawn until it is determined what proportion of the material in these strata corresponds to Fabrics III and IV. It will be necessary to integrate the results of the chemical analyses with the typological study which is nearing completion. The diversity of compositional groups will also need to be tested against a broader data base, including material from various chronological periods. Furthermore, pottery from other parts of the city must be tested. It cannot be assumed that the deposits from the Canadian site are representative of the patterns observed in other portions of the city. Many factors can influence the content of a particular pottery deposit. We do not know how pottery was distributed within the city. Were there markets nearby? Were the pottery workshops within walking distance of this residential quarter? How many manufactories existed at Carthage and were they all located in the same area? These are questions which may never be answered. A larger data base with which to compare material from 1M 7 and the other deposits could compensate for some of the uncertainties which these questions represent. The data is not available as yet.

The uniformity of Fabrics N III and IV, representing material which accumulated later in locus 1N 17, contrasts sharply with the disparity of the

two similar fabric groups in locus 1M 7. If this does not arise accidentally from the sampling procedure, the material from this more recent deposit may reflect a decrease in the diversity of ARS production at Carthage during the 6th century, brought about by a decline in local prosperity under the Vandal Regime.(175) If some of the pottery in the 5th century deposit (1M 7) was imported from outside the immediate area, the absence of such material from the 6th century deposit could be a reflection of disrupted or altered trading patterns in the wake of the Vandal conquest.

There are indications that the export market for red-gloss from Carthage revived during the final decades of the 5th century. This is accompanied by "the emergence of a whole range of new forms".(176) Under these circumstances one might anticipate variability in composition as output increased from local producers to meet this demand. The two fabrics which belong to this time period exhibit a relatively high uniformity in the distribution of their chemical components. On the other hand, is it possible, that the production methods of local fabrics had become more standardized? Perhaps the number of competing workshops had decreased. Further speculation would be unproductive at present. The various interpretations cannot be evaluated satisfactorily for the reasons already discussed. The limited sample size and the need to consider the fabric populations in the context of the complete inventory from the three deposits allows only hypothetical explanations. Nonetheless, further laboratory investigation of pottery production at Carthage could be directed toward testing the apparent increase in

175. Fulford, ECBM I.2. 114, points out that the export market for ARS declined after the middle of the 6th century.
176. Fulford in ECBM I.2. 114 and LRP 423.

fabric variability during the early 5th century and the possibility of a subsequent increase in fabric homogeneity during the 6th century.

Some of the ambiguities which plague the attempts to interpret results from investigations such as this one could be removed if reference groups could be established with the analysis of material from proven production sites. More material from Mahrine, and from other positively identified manufacturing sites such as Oudna, must be submitted for spectrographic examination. More of the ARS from Carthage must be analyzed as well to elucidate the patterns of composition in the fabrics which occur in quantity at this site. Such investigations of chemical parameters will not resolve all of the uncertainties, but further advances in provenience studies of ARS will be severely hampered until analyses of this sort are undertaken.(177)

177. Rumours circulating of a cooperative laboratory investigation of ARS are an encouraging sign.

SECTION 2.4

DISCRIMINANT ANALYSIS OF COARSE WARE AND THIRD CENTURY LAMPS

Results from the examination of the coarse ware produced in the kiln excavated at the Canadian site in Carthage indicate it was made with calcareous clays. The abundances for CaO in this pottery range from about 10 to 20%. These data are reported in Appendices VI and VII. The slip, sample 404, from one vessel, no. 403, was assayed as well. It contained a concentration of 10.9% calcium oxide, 1.5% less than the clay body. A single sample need not be representative of the entire group of coarse ware,(178) but the observed difference in concentrations could have resulted from the removal of larger calcite particles by whatever process was used to prepare the slip. Although the determination of slip composition was biased by the sampling technique, it indicates that a calcareous clay was employed. Since no comparative data is available from Carthage the significance of this finding cannot be evaluated satisfactorily. The lids belonging to Fabric N VII had CaO abundances of an intermediate range, and the single sherd of LRCW I (sample 183) was made with siliceous clay containing only about one fifth the amount of CaO found in the 7th century coarse ware.

The buff coloration, as we have seen, is what one would expect if a clay containing this much calcium was fired under reducing conditions.(179) The design of the kiln would have suited a firing of this sort. By inference, the

178. A difference of this magnitude could arise from the random error associated with the analytical technique. See above: pp. 40-41 and Appendix XI.
179. See above: p. 75.

earlier Roman buff ware from Carthage should also be made from calcareous clays. Analysis of such material could show whether or not there was a significant difference in composition which could suggest alternate origins of manufacture or other local raw material sources.(180)

A preliminary examination of the coarse ware data detected a very wide range of CaO concentrations with a cluster of values around 18%. This suggested the superimposition of two Gaussian distributions. The cases with elevated calcium abundances included most of the handles and a few body sherds. These were designated as a separate group, CW IB, in a second discriminant analysis. The classification procedure, summarized in Appendix V, distinguished between these two groups, CW IA and IB, although three sherds with intermediate CaO abundances showed lower than acceptable between-groups probabilities. The group means for the two coarse ware composition groups are listed in Appendix VII. The disparity observed between the two mean values for calcium abundance is about 7%. The products of the coarse ware workshop are an extreme example of fabric variability.

The unfired body sherd recovered from the kiln room, sample 433, was assigned to fabric CW IA by the multivariate classification procedure. It received a membership probability score of .99 so there is no doubt about the identity of this sample. A sufficient amount remains for further testing to identify the original clay mineral used for manufacturing the CW IA fabric. Another unique sample from the material excavated with the kiln, the fragment

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180. Elemental abundances for several componants of Roman coarse pottery made at Bengazi have been determined spectrographically, but calcium was not one of them. Krywonos (1980).

of kiln furniture (sample 424), was also classified as a member of the CW I fabric with an acceptable score.

The fact that handles have such a radically different composition from the one used for the vessel bodies suggests that different blends of raw materials were used deliberately to fabricate each component. The bodies of the coarse ware bowls and jugs were thrown on the potter's wheel. The handles were not turned, but pulled or rolled. An alternate paste may have been employed to accommodate the different forming technique. The implications for provenience analyses of pottery in general and of coarse ware in particular are obvious. Samples should be taken consistently from the same part of the vessels which comprise any reference group. This will not eliminate anomalous pieces, but it will be less likely to bias the results.(181)

Calcium abundances are also greater than 10%, except for two cases, in the 3rd century lamps. The relevant data are given in Appendices VI and VII. As noted in Section 1 of this Chapter, such high CaO levels would place these objects firmly in the Italic ceramic tradition. Lamps analyzed from the Roman site of Vindonissa, located near the head waters of the Rhine River, offer a means for comparison. Three of the four fabrics distinguished by compositional variability had calcium concentrations in the same range as the lamps from Carthage.(182) The report on the analysis of the Vindonissa lamps does not discuss the status of the fourth variety in detail, but it was made with siliceous clay. This suggests the possibility that a rival factory, staffed by

181. It would be useful to determine whether or not such variation occurs between different portions of single fine ware vessels. Since the ARS analyzed in this study was sampled almost exclusively from rims, any variability from uneven distribution of components within individual pieces of ceramic was minimized.
182. Schneider et al. (1978) 280-282.

potters of local origin, was producing "imitations" without the benefit of the expertise possessed by potters trained in the Italic manufacturing tradition.

The absence of a similar division in the 3rd century lamps from Carthage may be significant. Assuming the typological distinctions between imported and locally made lamps are valid, the results from the chemical analyses imply the direct participation of craftsmen trained in European factories in the North African lamp industry. The limited sample size and the lack of comparative material from other North African contexts makes it impossible to evaluate this suggestion at present. One important question which further research should address is whether or not the lamps bearing the mark of the Pullaeni factory were made with calcareous clays. Their secure provenience would provide a more meaningful comparison with European prototypes.(183)

The similarity in composition between the coarse ware and the lamps makes it difficult to distinguish between these two kinds of pottery. This poses no archaeological difficulties since they are well separated by other criteria. Nonetheless, a discriminant analysis of the coarse ware and lamps was performed to determine if their compositions would suggest a common source for the raw material used to produce them.(184)

The classification procedure clearly distinguished between the coarse ware and lamps. This is not surprising when one considers the chronological interval of four centuries and the difference in production methods which separate the lamps from the coarse ware. The manufacturing techniques for the

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183. This family possessed an estate at Uchi Maius, about 30 km. southeast of the important Roman town of Dougga. The location of the factory which produced the lamps, identified with a stamped trademark, is not known. Haywood (1959) 56 and 61.

184. The lamps were inserted into the sample population for the discriminant classification procedure which separated Fabrics CW IA and CW IB.

two varieties of ceramic can be assumed to be quite different. The lamps were moulded and the coarse pottery was definitely shaped on the potter's wheel. The distinct requirements of these two processes could induce potters to alter the same raw clay in ways which could disguise the common origin of the finished ceramics. Furthermore, the provenience of the lamps is uncertain. It is likely some are imports from Europe and ultimately all of them may have been brought from other sites located at considerable distances from Carthage.

A more interesting aspect of the initial classification results was the fact that the lamps did form clearly separated groups, although the discriminant scores indicated several of the lamps had been improperly assigned. These cases were allotted according to the group memberships suggested by their discriminant scores. Then the lamp population was inserted in the second discriminant analysis performed with the coarse ware subgroups.

The second classification procedure yielded three coherent clusters whose members, with one exception, displayed membership scores in the 90th percentile. These results appear in Appendix V. The plot of discriminant scores in Figure 2.4c-e shows that the individual groups are quite homogeneous Two of the groups are widely separated in discriminant space.

Comparing the results of this analysis with the original groups, based on predetermined typological categories, indicates that the principal forms occur in all three compositional groups. The successful discrimination, achieved in this investigation with experimentally determined parameters, indicates the typological criteria are not a completely reliable index of provenience for the third century buff lamps commonly encountered at Carthage. The results demonstrate that it is inappropriate to designate individual lamps

as imports by using form alone to separate them from the other members of this diverse class of archaeological material. Conversely, forms regarded as strictly North African may originate elsewhere. In spite of the uncertainties which arise because of the limited sample size, the preliminary results obtained with the finds from the Canadian site are promising. Future investigations with larger sample populations and securely provenienced reference groups should be able to distinguish between imported lamps and the various locally made fabrics which feature a common repertoire of decoration and form.

TABLE 2.1

COMPOSITION OF ARS SLIPS

SAMPLE NUMBER		ORG GRP	FIN GRP	WT. % OF OXIDES Si	Al	Ca	Fe	Mg	Na	Ti	* PPM OF OXIDES * Mn	Cr
141	P	43	43	62.9	19.4	.75	5.14	1.25	.043	1.10	117	176
142	S		43	60.1	20.1	.66	6.89	1.34	.042	1.14	48	179
S - P				-2.8	.7	.09	1.75	.09	-.001	.06	-69	3
146	P	43	43	63.7	20.0	.88	4.4	1.06	.049	1.08	118	195
147	S		43	68.8	21.5	.93	5.5	1.09	.038	1.09	67	154
S - P				5.1	1.5	.05	1.1	.03	-.011	.01	51	41
159	P	43	43	62.6	17.4	.86	4.02	1.030	.067	1.03	216	158
160	S		43	65.1	19.6	1.04	5.15	1.330	.067	1.06	142	253
S - P				2.5	2.2	.18	1.13	.300	0	.03	-74	95
183	P	54	**	60.3	14.4	1.86	5.08	1.54	.426	.987	322	216
184	S			62.0	15.5	1.66	5.78	1.41	.228	.994	266	210
S - P				1.7	1.1	-.20	.70	-.13	-.198	.007	-96	-6
185#	P	53	53	56.1	16.8	1.23	3.61	1.87	.325	1.05	302	277
186	S		**	56.8	18.7	2.62	6.27	1.87	.412	1.33	306	298
S - P				.7	1.9	1.39	2.66	-.00	.087	.28	4	21

ORG GRP = ORIGINAL FABRIC GROUP CLASSIFICATION.
FIN GRP = FINAL GROUP CLASSIFICATION
P = SAMPLE WITH SLIP REMOVED; S = SLIP

43 = F III
53 = M III
54 = M III
63 = N III
64 = N IV

\# = LRCW II
** = UNASSIGNED

TABLE 2.1 (CONT)

COMPOSITION OF ARS SLIPS

SAMPLE NUMBER		ORG GRP	FIN GRP	WT. % OF OXIDES Si	Al	Ca	Fe	Mg	Na	Ti	* PPM OF OXIDES * Mn	Cr
194	S	54	54	61.3	14.9	2.02	5.11	1.44	.262	.898	826	136
195	P		54	67.9	15.2	1.42	5.43	1.53	.258	.902	1051	125
S - P				6.6	.3	-.60	.32	.09	-.004	.004	225	-11
211	P	53	**	61.1	16.6	1.34	5.01	1.09	.252	.10	517	136
212	S			62.4	18.5	1.38	6.09	1.22	.308	1.02	507	131
S - P				1.3	1.9	.04	1.08	.13	.056	.08	-10	-5
357	P	64		63.5	14.1	1.04	4.55	1.14	.336	1.01	126	96
356	S			61.5	15.0	.98	4.26	1.13	.183	.99	176	86
S - P				-2.0	.9	-.06	-.29	-.01	-.153	-.02	50	-10
380	P	64		64.9	15.5	1.34	5.29	1.56	.248	.893	205	122
381	S			61.3	14.6	1.17	5.28	1.47	.258	.885	198	131
S - P				-3.6	-.9	-.17	-.01	-.09	.010	-.008	-7	9
386	P	63		72.1	16.0	.59	4.16	1.15	.238	1.12	112	123
385	S			74.3	17.5	.62	5.07	1.17	.246	1.08	62	67
S - P				2.2	1.5	-.03	.91	.02	.008	-.04	-50	-56
390	P	63		68.8	15.6	1.68	4.75	1.39	.272	.990	261	222
389	S			65.4	15.2	1.07	4.35	1.20	.169	.975	112	346
S - P				-3.4	-.4	-.59	-.40	-.19	-.103	-.015	-149	124
400	P	91		60.3	11.9	3.02	6.22	1.56	.700	.93	1045	155
401	S	91		62.3	15.4	2.16	5.68	1.22	.130	1.17	272	171
S - P				-2.0	-3.6	-.86	-.54	.34	.570	-.24	773	16

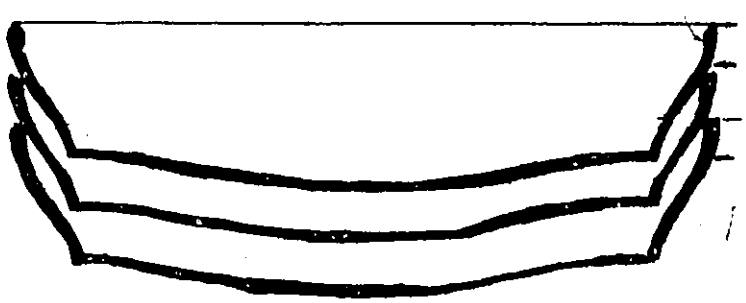
ORG GRP = ORIGINAL FABRIC GROUP CLASSIFICATION.
FIN GRP = FINAL GROUP CLASSIFICATION
P = SAMPLE WITH SLIP REMOVED; S = SLIP

43 = F III
53 = M III
54 = M III
63 = N III
64 = N IV

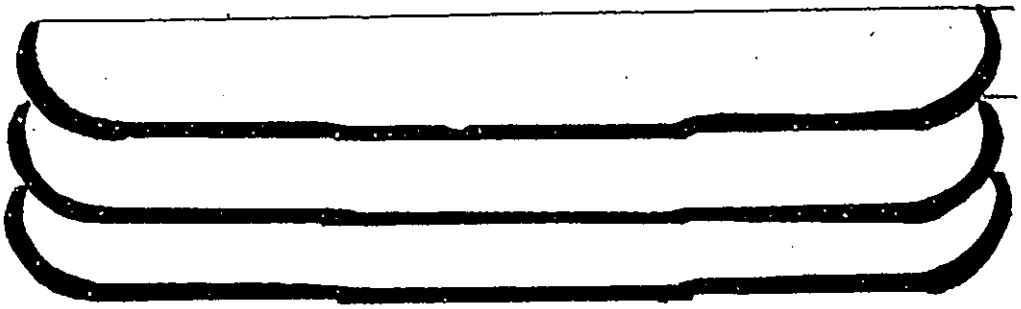
\# = LRCW II
** = UNASSIGNED

FIGURE 2.1

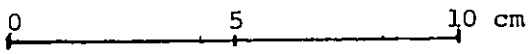
STACKING FORM 26 and FORM 23 VESSELS



FORM 26



FORM 23



APPROXIMATE SCALE

FIGURE 2.2

FIRST DISCRIMINANT ANALYSIS WITH ARS POTTERY. TERRITORIAL MAP FOR DISCRIMINANT GROUPS

(ASSUMING ALL FUNCTIONS BUT THE FIRST TWO ARE ZERO)

CANONICAL DISCRIMINANT FUNCTION 1

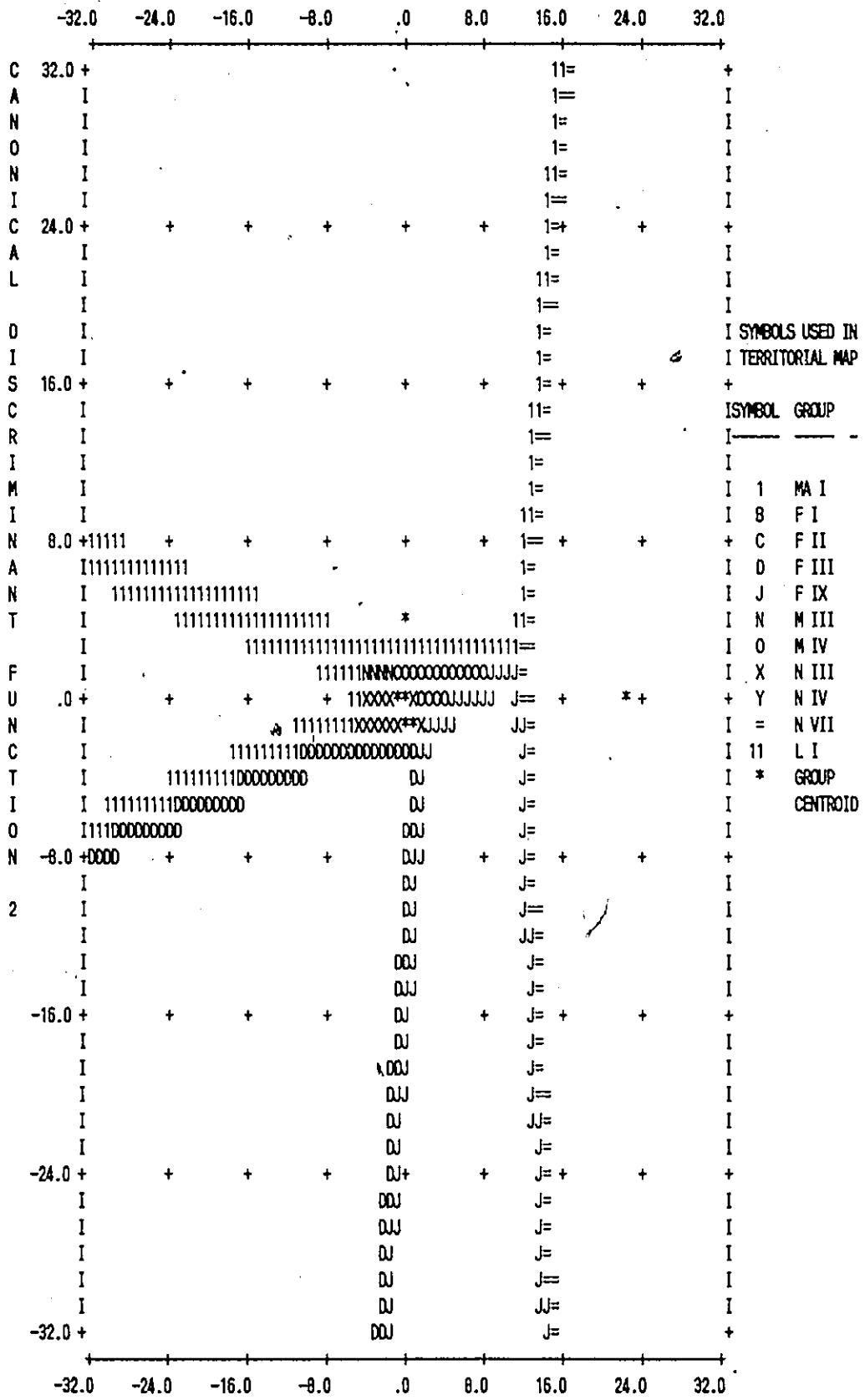


FIGURE 2.3

THIRD DISCRIMINANT ANALYSIS WITH ARS POTTERY FABRICS. TERRITORIAL MAP FOR DISCRIMINANT GROUPS

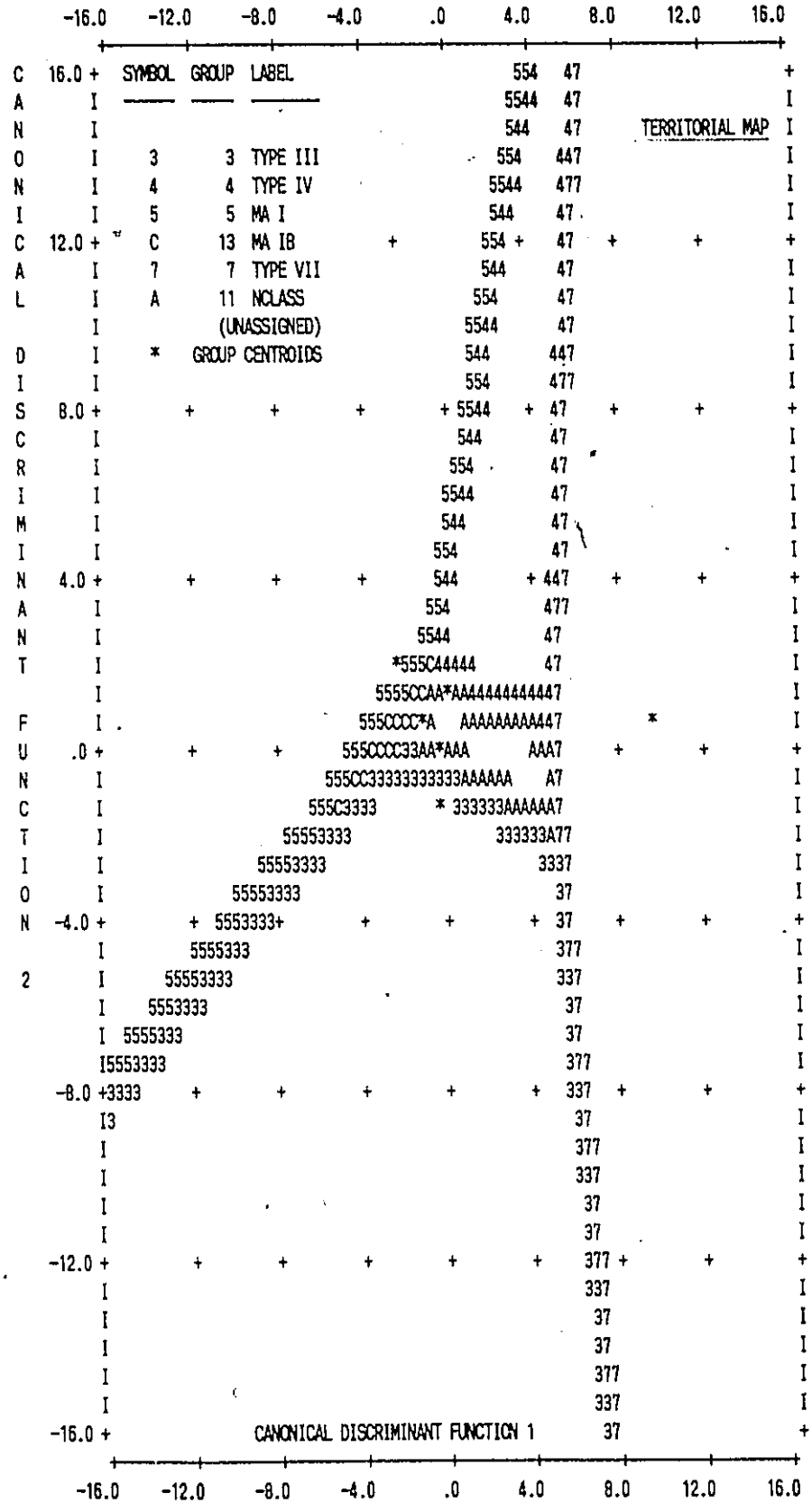
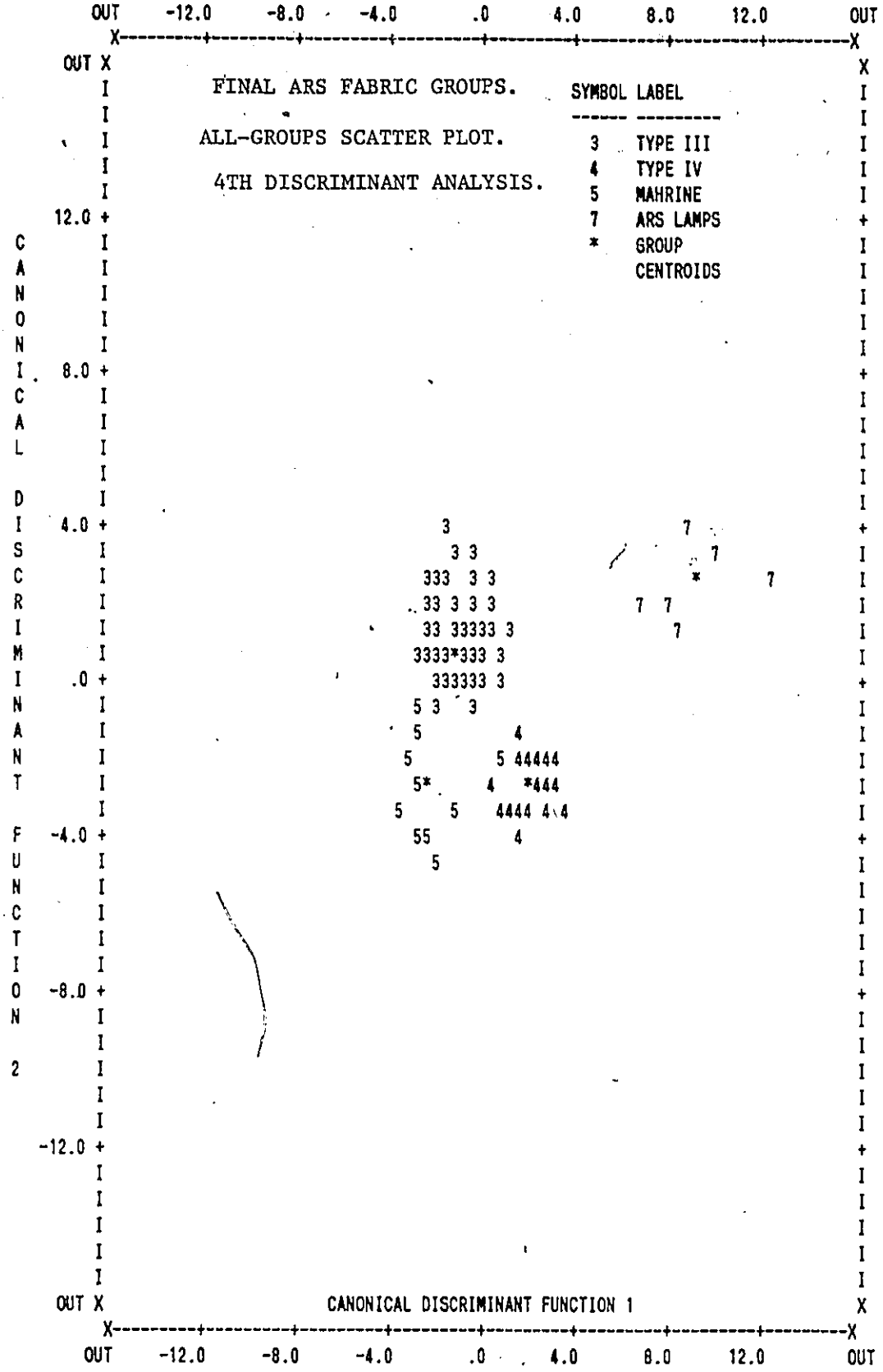


FIGURE 2.4


FINAL ARS FABRIC GROUPS.
ALL-GROUPS SCATTER PLOT.
4TH DISCRIMINANT ANALYSIS.
SYMBOL LABEL
3 TYPE III
4 TYPE IV
5 MAHRINE
7 ARS LAMPS
* GROUP CENTROIDS
CANONICAL DISCRIMINANT FUNCTION 2
CANONICAL DISCRIMINANT FUNCTION 1
OUT -12.0 -8.0 -4.0 .0 4.0 8.0 12.0 OUT
12.0
8.0
4.0
.0
-4.0
-8.0
-12.0

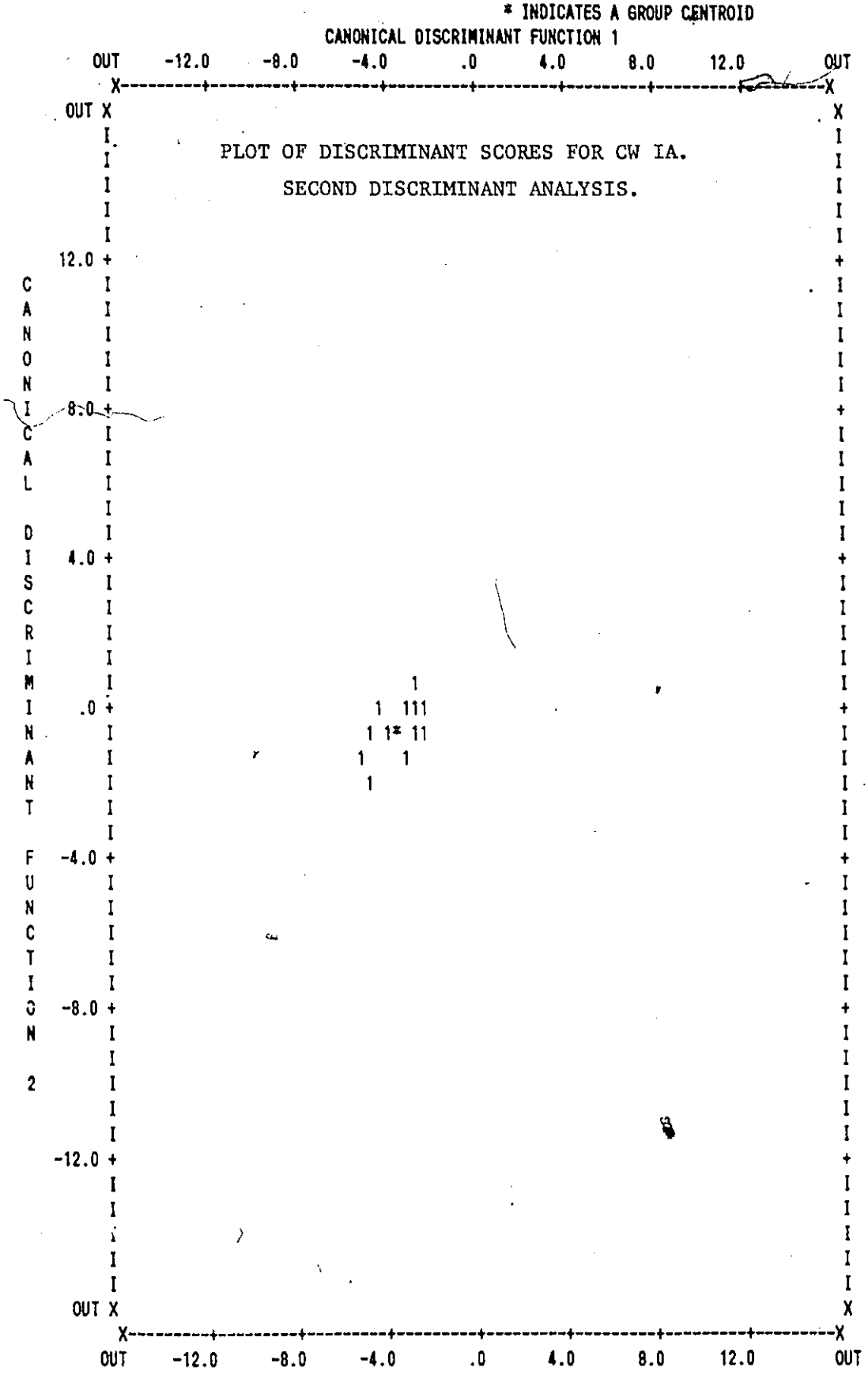

* INDICATES A GROUP CENTROID
CANONICAL DISCRIMINANT FUNCTION 1
OUT -12.0 -8.0 -4.0 .0 4.0 8.0 12.0 OUT
12.0
8.0
4.0
.0
-4.0
-8.0
-12.0
CANONICAL DISCRIMINANT FUNCTION 2
PLOT OF DISCRIMINANT SCORES FOR CW IA.
SECOND DISCRIMINANT ANALYSIS.

FIGURE 2.5a

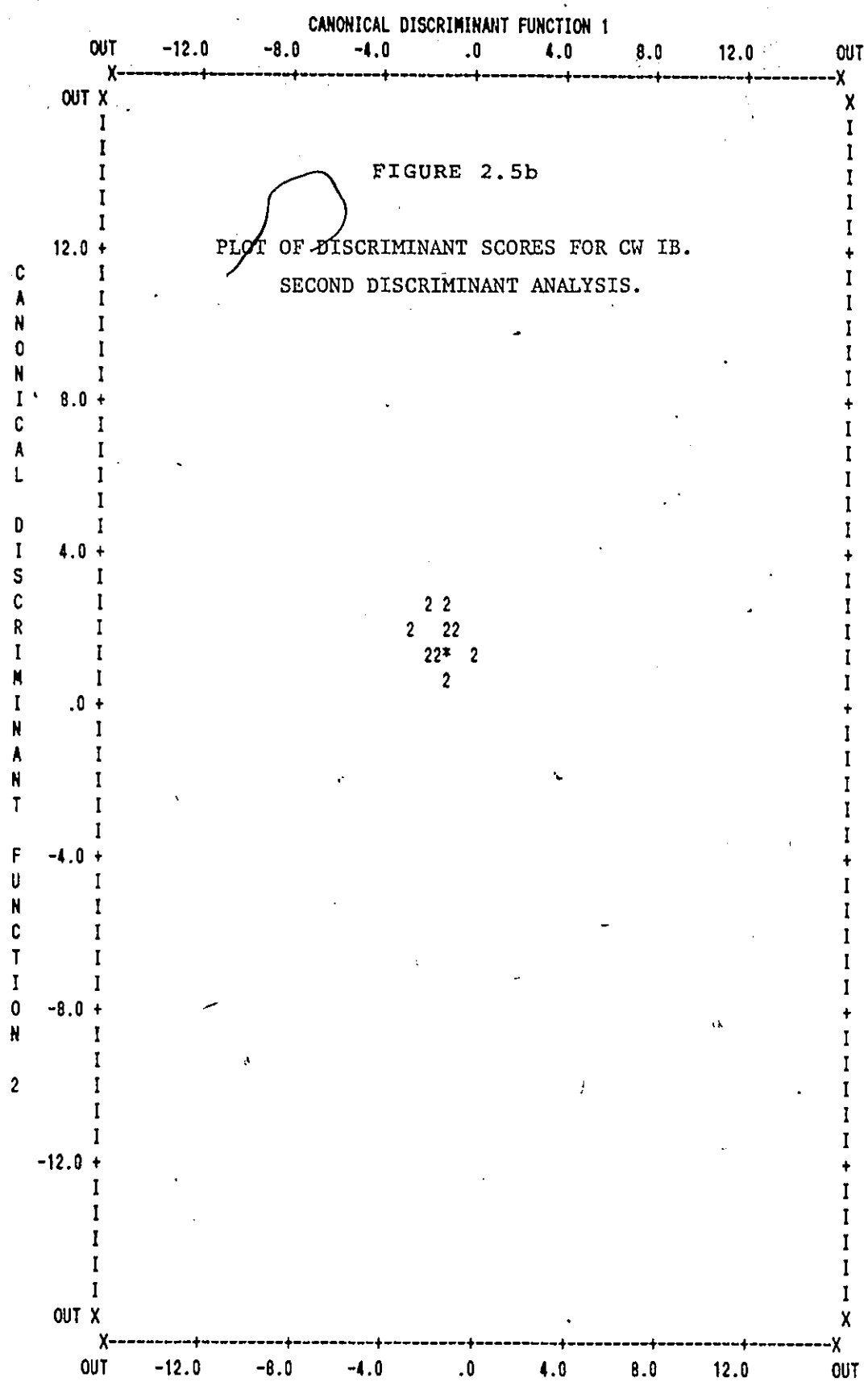


FIGURE 2.5b

PLOT OF DISCRIMINANT SCORES FOR CW IB.
SECOND DISCRIMINANT ANALYSIS.

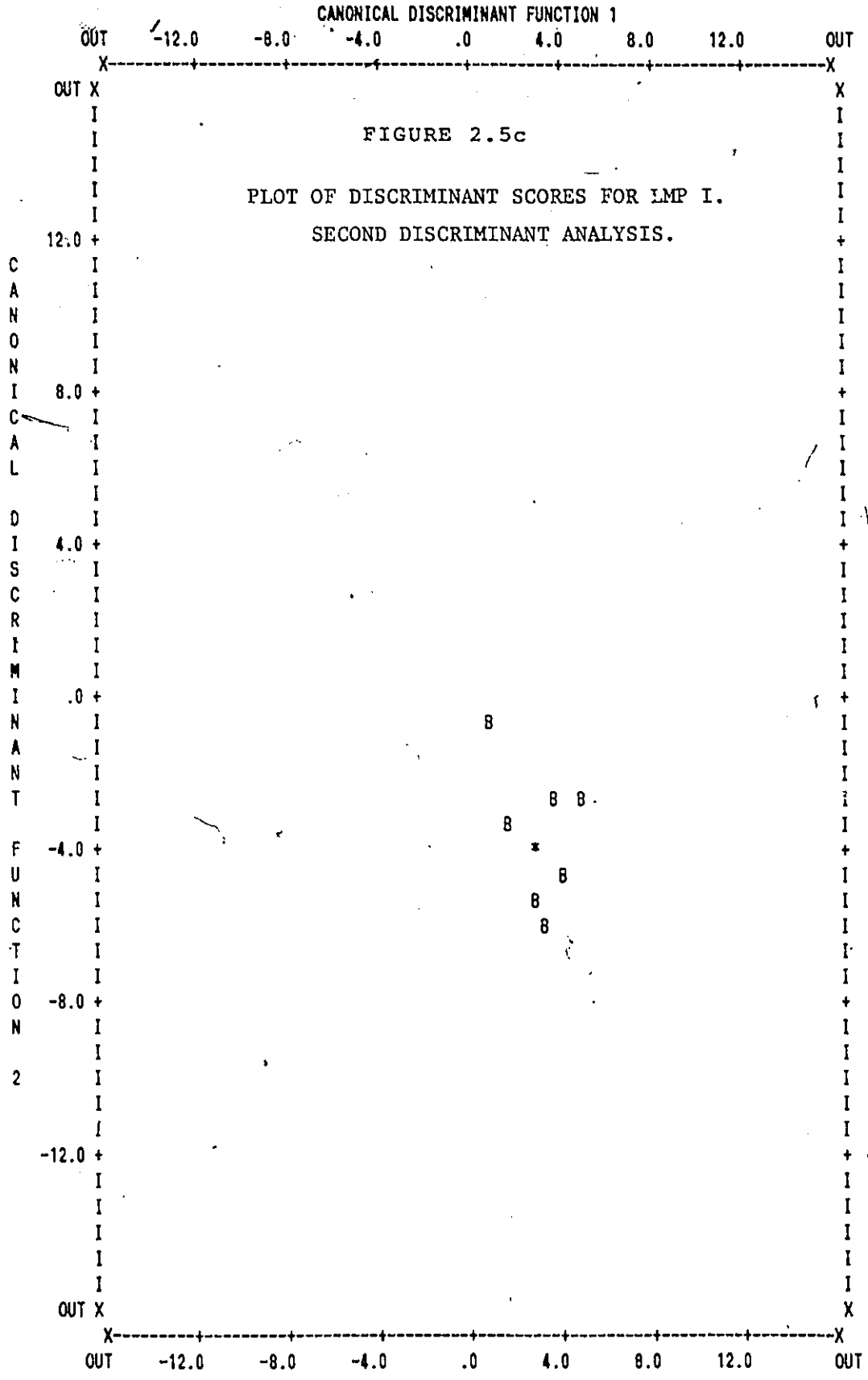


FIGURE 2.5c

PLOT OF DISCRIMINANT SCORES FOR LMP I.
SECOND DISCRIMINANT ANALYSIS.

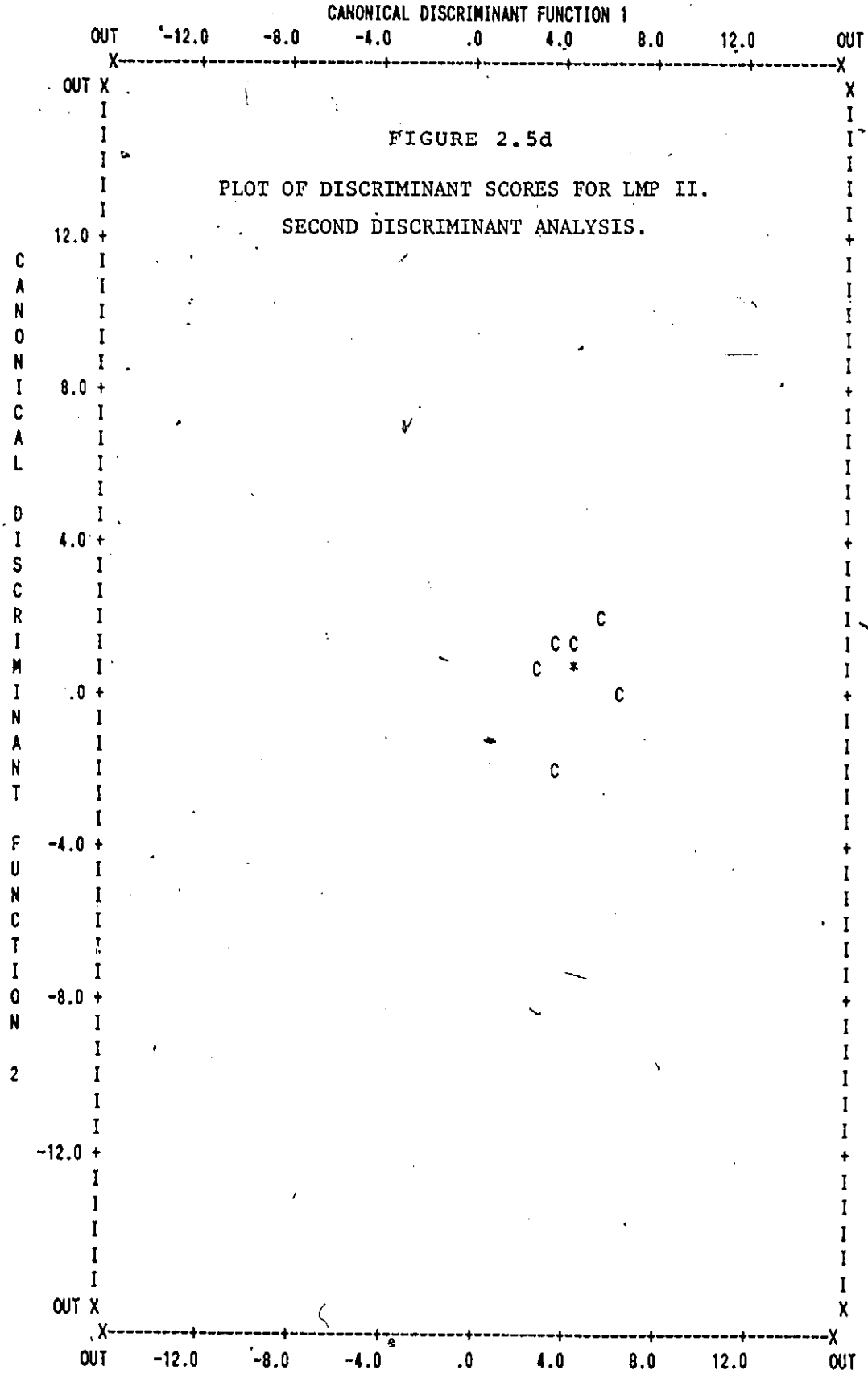


FIGURE 2.5d

PLOT OF DISCRIMINANT SCORES FOR LMP II.

SECOND DISCRIMINANT ANALYSIS.

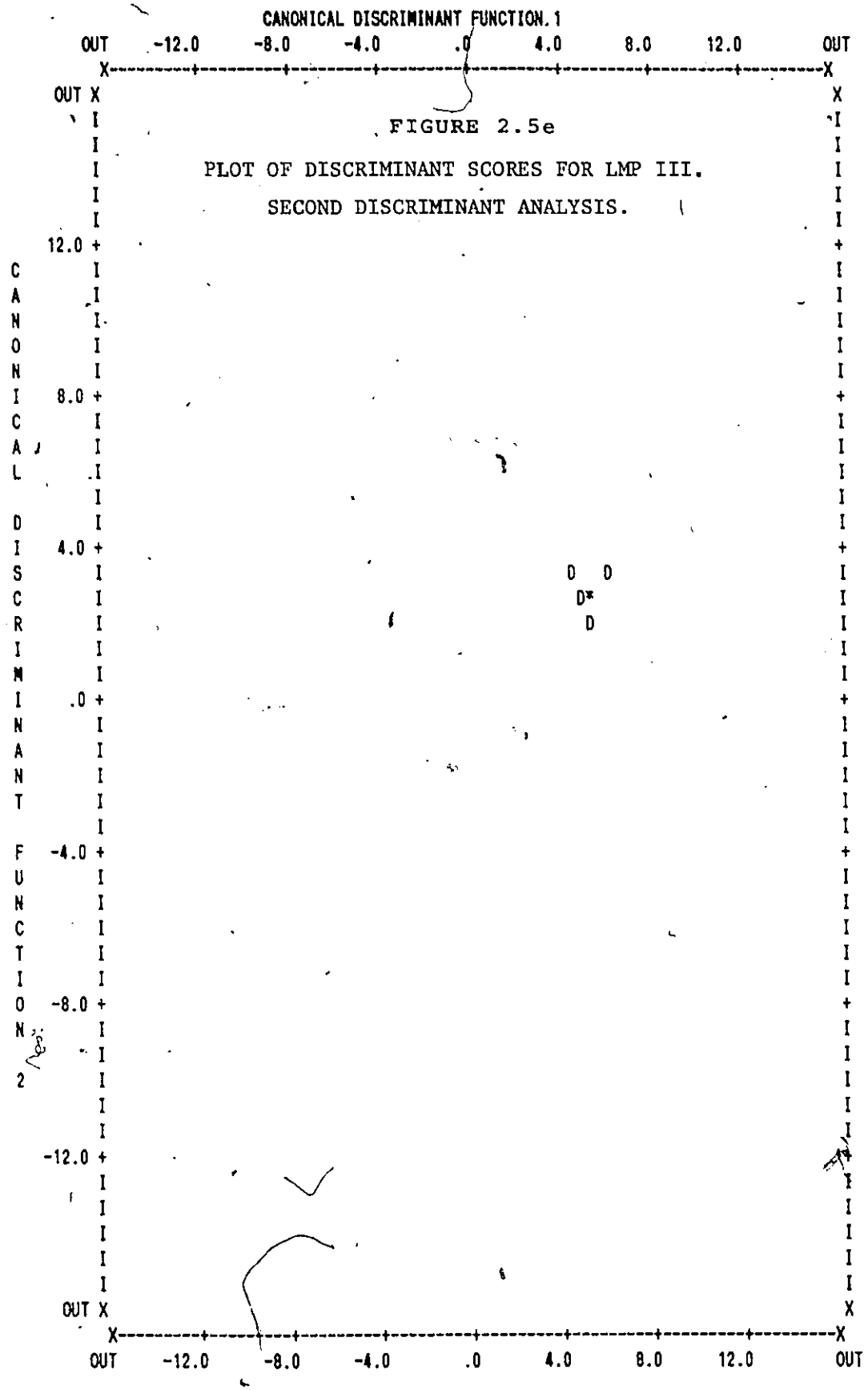


FIGURE 2.5e

PLOT OF DISCRIMINANT SCORES FOR LMP III.

SECOND DISCRIMINANT ANALYSIS.

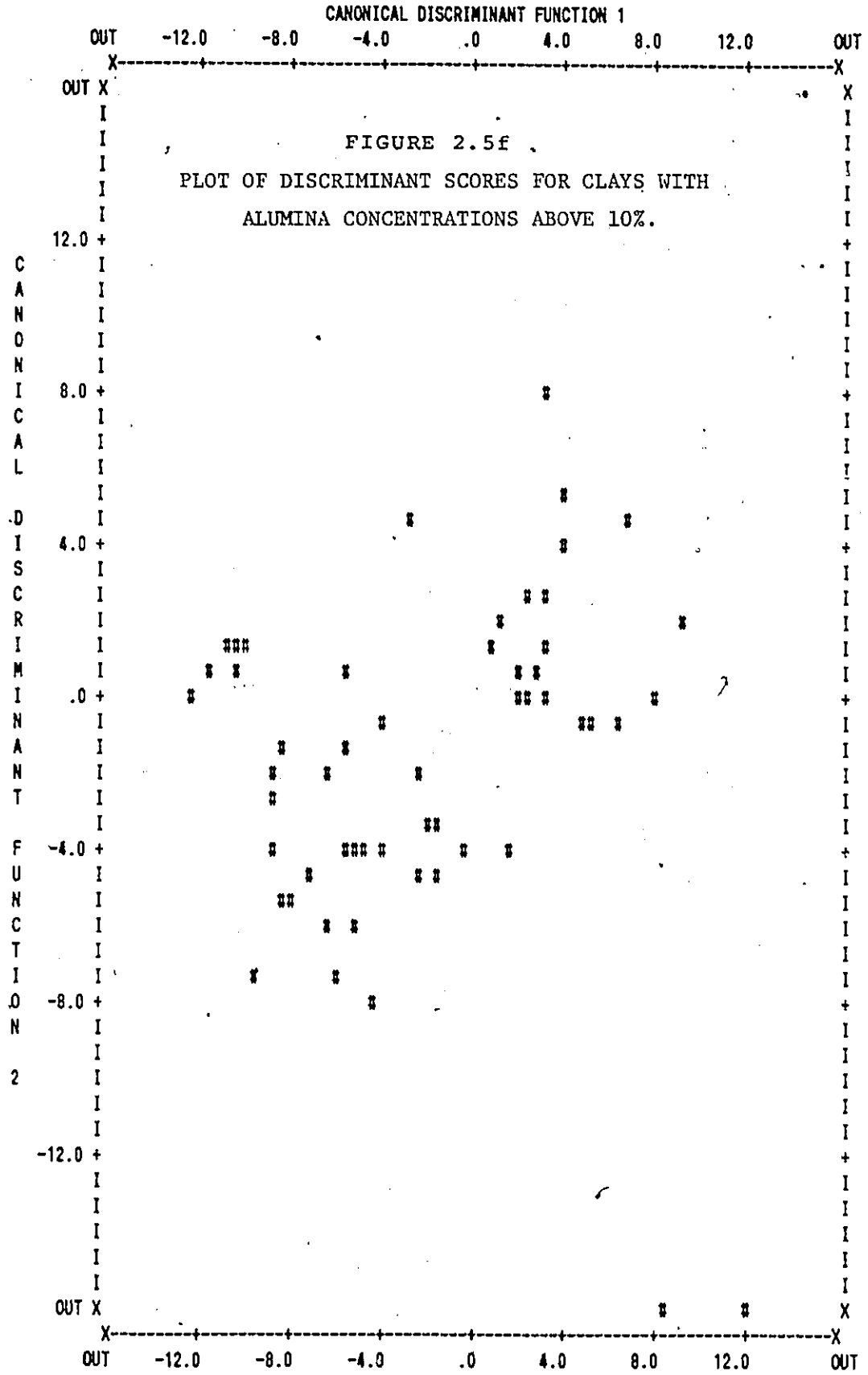


FIGURE 2.5f

PLOT OF DISCRIMINANT SCORES FOR CLAYS WITH ALUMINA CONCENTRATIONS ABOVE 10%.

SECTION 3.1

SAMPLE SITES

The clay sampling program which constituted the second major aspect of the present investigation was essentially designed to obtain a preliminary inventory of the raw materials available for Roman pottery manufacture in the the immediate vicinity of Carthage. This inventory was intended to provide data which could be used as a guide to the proveniences of the ceramics analyzed in the other phase of this research. As we observed at the beginning of this report,(185) it is preferable to evaluate the possibility that a given variety of pottery derived from a particular source by comparing the pottery's scientifically determined physical and chemical characteristics with the analogous attributes of a reference collection of ceramics whose proveniences are securely established by other archaeological criteria. Petrological examination of pottery from Carthage has been used successfully to identify the approximate locations where several varieties of coarse ware and amphorae were originally made. These techniques have not yielded satisfactory results with ARS from Carthage, primarily because the fine ware usually has few diagnostic mineral inclusions.(186) Furthermore, there is general agreement that the most commonly occurring ARS fabrics were indeed manufactured at Carthage because they constitute a very high percentage of the total fine ware assemblage.(187) But

185. See above: pp. 5-6.
186. Peacock in ECBM I,2. 6 ff and 14.
187. See above: p. 5.

this assumption, albeit a reasonable one, must be verified by the identification and subsequent excavation of pottery workshops. Without this archaeological confirmation one can not be sure which ARS fabrics provide reliable guides for tracing the origin of red-gloss pottery found at Carthage.

Consequently, when my research began there was no material available which could have constituted a suitable provenience standard with which to compare the ARS from the Canadian Site. Potentially, the coarse ware, CW I, from the kiln located on the site,itself, might have provided one valuable guide to the origins of the fine ware fabrics. Unfortunately, because the ARS proved to have a composition so radically different from the coarse ware the latter was useless as an index for deciding whether or not any of the red-gloss pottery could have been made by potters plying their trade at Carthage.(188) In any case, the utility of the coarse ware as a point of reference could not be ascertained until all of the ceramics had been analyzed and the results had been scrutinized. Therefore, it still would have been necessary to use an alternate source of comparison on which to base a study of provenience for ARS the pottery from Carthage. The local clays were analyzed to determine if any of them could furnish an appropriate reference standard.

There are limitations to this method. These have already been described, but they should be mentioned again at this point in the present discussion.(189) Uncertainty arises from the fluctuations in composition of natural clays. Such variability is influenced by factors whose affects often cannot be gauged accurately. Any alterations of the raw material by the potters are difficult to quantify because we are usually ignorant of the methods they

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188. See above: Chapter III, pp. 108 ff.
189. See above: pp. 7, 62 and 103.

used for purification or for pretreatment. Despite the difficulties involved with trying to match natural clays with ceramics made from them several research teams have met with success.(190) One of the most convincing investigations compared physical properties and chemical composition of Roman red-gloss pottery produced in Germany with data obtained from clays fired under controlled conditions in the laboratory. The study of the German material combined petrological examinations with spectrometric determinations of elemental abundances to locate the clay beds exploited by the potters.(191)

When the project for analyzing pottery and clays from Carthage was first conceived a similarly comprehensive program was considered for locating potential raw material sources. This proved to be impractical for a number of reasons. Among these, cost and access to the necessary analytical equipment constituted barriers which could not be overcome within the limitations of time under which the present research was conducted.

It was decided that a qualitative assessment of the clay resources at Carthage would be feasible. Furthermore, limited testing would provide data which could serve as a basis for future research and as a guide to other investigators studying pottery in this part of the Roman World. Since there is no published data pertaining to the composition of clay deposits in the Carthage region, the results of a limited study could help define the parameters for more comprehensive investigations.

Having established the objectives described in the foregoing paragraphs, the program proceeded in the following way. First, potential clay

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190. Schneider et al. (1979); Heimann (1982); Birgül et al. (1979).
191. Heimann (1982). Another similar study successfully located the source of clay used for the manufacture of coarse pottery at Cologne. Hancock (1984).

deposits were located by prospection conducted on foot. The plasticity of clays was tested in the field to eliminate unsuitable sources. Then the trial pieces were fired to determine if the clays could be utilized for pottery manufacture. Subsequently, elemental abundances were obtained for nine components by direct current plasma emission measurements. Finally, the compositions of the clays were compared with one another and with the results from the quantitative analysis of the pottery from Carthage. The details of these procedures are elaborated in the following sections of this report.

Raw materials were collected between 1980 and 1982 at Carthage and at several other sites within an approximately 50 kilometer radius of the city. Clays from three other sites where pottery was manufactured during the Roman era were included in the sample population. Budgetary constraints limited sample collection to easily accessible deposits. Clay was collected from strata exposed by erosion and by water courses. Deposits uncovered by the construction of roads and buildings and by archaeological excavations completed the sample.

Consequently, the sample does not represent a complete inventory of the geological formations in the test area. Also, considering the number of potentially exploitable deposits located, a more intensive survey of the Carthage peninsula and other sample sites would probably increase this number considerably. If it had been possible to take core samples, for example, a more complete record could have been produced along with a geological profile of greater depth. On the other hand, it seems reasonable to suppose that potters would have preferred using clays obtainable with as little effort as possible.

There are instances of clay mines(192), but deposits near the surface would be preferred if the clay were of sufficiently good quality.

By restricting sampling to easily reached deposits, the clays obtained for analysis represent resources which would have been more economical to exploit. Also, it is likely that Roman artisans would have detected such deposits. Land use would also have affected the accessibility of clay deposits. Clay beds within the urban sectors of Carthage probably would not have been available to Roman potters. The requirements of space in the densely populated city and regulations prohibiting certain industries which posed fire hazards should have prevented workshops from operating within urban areas. On the other hand, there were pottery kilns in the central part of Carthage during the Byzantine period if not before. At Tiddis in Algeria a substantial potters' quarter with several kilns existed in the centre of the town. Although there may have been some pottery production and quarrying of clay in Carthage at an earlier date, it was decided to concentrate prospection in the areas beyond the known limits of intense habitation.(193)

Sampling soils at or near the modern ground surface was avoided where possible. This precaution would minimize the effect which growth and decay of vegetation, bacterial action and human activity might produce on chemical composition. It has been observed, for example, that elevated phosphorus and sodium concentrations may be encountered within areas where wild animals are abundant.(194) Dense human habitation, presumably, could produce a similar effect. There are cases when this criterion was not applied. Some of the

192. Nicholson and Patterson (1985) 55-56.
193. Peacock (1982) 98-101, observes that kilns were normally located outside populated areas, but adds exceptions to this rule.
194. Hart and Adams (1983) 181.

samples were taken in ancient and modern urban areas. Others were obtained where agricultural is currently being practiced. The application of modern chemical fertilizers could alter soil composition drastically from what it was in antiquity. In several instances the decision was made to sample soils which might have been fertilized or which could have absorbed run off from cultivated land, because more suitably located deposits at a site could not be found during the time and with the equipment available for prospecting. Given the alternative of having no data at all from some sites, the choice of acquiring less than ideal samples seemed preferable for a preliminary survey. Interpretation of the results obtained from such samples would have to allow for the possibility of contamination. The descriptions of the sites whose soil was tested identify clays which could have been affected by post-Roman activity.

The sites where clay samples were taken are described in the following section of this report. Their locations are indicated on the diagrams and plans which accompany this chapter. (See Figures 3.1-3.19) It was not possible to obtain detailed maps of all sample sites. Topographic maps of certain areas were not available from the Tunisian cartographic service either because the supply was depleted or because the appropriate maps were subject to security restrictions. Archaeological publications furnished some of the diagrams. Sketch plans were made in the field during sample collection. The accompanying illustrations derive from these field notes when more accurate maps were unavailable.

Carthage

A total of ten different clay deposits were sampled on the Carthage promontory. During the Punic and Roman era the city was situated on a

peninsula. The so-called Sinus Uticensis to the north has since became filled with silt, moving the shore line a considerable distance northwest. Numerous descriptions of the topography are available from recent excavation reports. The Carthage region is part of a larger geological formation which ranges from Algeria to Egypt. Clays occur in abundant tertiary sediments.(195) The disposition of the sites where samples were collected on the Carthage peninsula is presented in Figure 3.1.

Site 1 - Hamilcar. (Figure 3.2)

Hamilcar is located approximately 100 meters southwest of the modern Hotel Hamilcar. Horizontal strata of argillaceous soil are exposed on the eroded slope of an escarpment which rises abruptly from the Mediterranean shore to an elevation of approximately 56.5 meters. A fortuitous excavation by mechanical earth-moving equipment in June of 1980 cut a section through the clay bearing strata. Seven strata of varying thicknesses could be distinguished on the face of the four to five meter high section, but only six could be reached for sampling: the uppermost layer and the lowest five. The approximate configuration of the strata is shown in Figure 3.2b along with the approximate locations from where the samples were taken. Samples 1-7 were obtained from this deposit. Samples 8 and 9 are fractions prepared by washing a portion of sample 7.

This clay bed would have been quite accessible during the Roman period. There are no indications of any ancient habitation on the top of the escarpment adjacent to the clay deposit. There is a large Roman cistern about 700 meters to the north across the paved road leading to the Hotel Hamilcar.

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195. Bullard (1978); Peacock in ECBM I,2. 14.

Further north along the escarpment, red sandstone was quarried for use in Roman and Punic times. It seems likely that the quarry operators would have known about the nearby clay deposit. Whether or not they chose to exploit it must remain conjectural, but mining the clay would have been consistent with the activity carried out a short distance away.

Canadian Excavation Sites. (Figure 3.3)

The excavations conducted by the Ottawa-McMaster Team along the northern limit of the Roman City detected argilliferous strata in several spots. Clays from three sites were tested. These sites are located in excavation units. The sample locations are shown in Figure 3.3. Because this area was intensely occupied from the 3rd century until the capture of the city at the close of the 7th century, the clay beds could not have been used by potters. The site is; however, located on the edge of the city and the ground level appears to have sloped downward toward the north, beyond the city limits. It is quite possible these clay strata could have been accessible beyond the city wall.

Site 2 (Trenches 1 & 2)

Two samples were taken from clay-bearing strata in the main excavation trench. Sample 10 consists of material excavated from layer 2CC1M42. This soil appears to belong to a natural stratum cut by foundations of a building occupied during the 3rd Century A.D. Samples 11 and 12 were prepared from sample 10. Sample 13 was taken from layer 2F44, a stratum cut by Roman building activity. Although these strata are over two meters below modern ground level, they were not as inaccessible in Roman times at least until 3rd century accumulation in this area.

Site 3 (Trench 6)

Other samples, (nos. 14-18) were taken from excavation trench 6. The argillaceous strata were approximately 1 to 2 meters below the 5th century road surface. When samples were taken in 1980 these layers were considered not to have been redeposited by building activity. Access to any recent interpretations from those in charge of publication of this part of the site has not been possible.

Site 4 (Trench 8)

The remaining samples from the Canadian site, nos. 19-23, were obtained from trench 8. The strata, exposed at 1 to 2 meters below Decumanus VI, appeared to be in situ, but no further information is available as yet.

Site 5 - La Malga A. (Figure 3.4)

A clay bed, approximately 850 meters northwest of the Canadian site, was located with the help of Mohammed Ben Amar, a local resident who had acted as foreman and site supervisor with the Canadian Team. When he heard of attempts to locate clay sources he suggested a visit to this site where local artisans obtain clay for making imitations of ancient lamps which are sold to tourists. The site is situated on level ground in an open field some 50 meters from a small dwelling (see Figure 3.4). There was short grass growing here when samples were taken. The land has been used for cereal cultivation in recent years. There are no visible vestiges of Roman or Punic activity in the vicinity. This site, like the one at Hamilcar, could have been exploited quite easily during the life of the Roman Carthage since its location would not have

interfered with activities in the urban area. Access would have been subject to the discretion of the landowner

Samples were obtained from what seemed to be a single stratum of clay exposed by three shallow pits about one meter deep and two to three meters apart. It seems these were excavated by the local manufacturers of ceramic souvenirs. Samples 25 and 26 were taken 1 meter below ground surface, one meter apart, in the bottom of the first pit. Sample 27 was taken from a pit about 4 meters to the north at the same depth. Sample 28 was taken from a third pit some 2 meters west of sample 27 at a depth of 25 cm.

Site 6 - La Malga B. (Figure 3.4)

The major water storage facility for the Roman City was located about 500 meters south of the previous site. Two samples, nos. 29 & 30, were taken there from the present ground surface, 30 meters east of the aqueduct channel which forms the eastern boundary of the cistern complex. Vegetation was sparse in this area where the argillaceous soil offered very poor drainage. According to Mohammed Ben Amar, this was in the centre of a deposit whose clay was preferred for making souvenirs, but residents had been prohibited from excavating here since the area became part of the Parc Archéologique de Carthage. Presumably Roman potters were also prohibited from quarrying in the area adjacent to the city's water supply, although there are no traces of any buildings which would have encumbered the site. While this would not have been an ideal quarry, the soil was sampled to obtain comparative data (see Figure 3.4).

Site 7 - Colline de Junon. (Figure 3.5)

Along one of the modern roads leading eastwards from the La Malga Cisterns at the base of the Colline de Junon, a ditch varying about .50 to 1 meter below ground level, cut through a thick stratum of clay. (See Figure 3.5) The deposit extended some 50 meters along the road west of a monument known as l'Edifice des colonnes. A single sample, no. 31, was taken at a point 40 meters above sea level and approximately 75 meters from the monument. This is the only visible indication of Roman building activity near this clay bed. However, there has been little exploration of this portion of the city. Following the ditch failed to yield any sign of occupation for a distance of about 100 meters west of the building. Further examination of the area was prevented by thick vegetation. No artifacts from any period were observed in the material removed during excavation of this part of the ditch. Roofing tiles and pottery were observed east of the bath building. Unfortunately the ditch was refilled before additional samples could be obtained. Since the area in question was located within the enclosure of the 5th Century city wall the resource was probably not available for use. On the other hand, there were apparently no buildings which would have prevented removal of material.

Site 8 - Byrsa. (Figures 3.5-3.6)

Excavations by French archaeologists on the Byrsa Hill in the centre of the Roman city revealed a stratified clay deposit where samples 32 to 44 were obtained. The deposit is located 50 meters above sea level. A 1.5 meter trench had been cut through the deposit revealing 10 superimposed layers of argillaceous soil. The quality of this clay had also attracted local artisans

who had asked the excavation director for permission to take some of it.(196) The Byrsa clay would have been sealed beneath the forum of the Roman city. Although Roman potters could not have exploited this raw material, the deposit offered an excellent opportunity to examine the composition of a stratified clay bed. One stratum was sampled twice to measure variability within the layer. Figure 3.5 shows the location of the sample site. The position of the strata and samples taken from them are illustrated in Figure 3.6.

Site 9 - Gamart A. (Figure 3.1)

Prospecting in the northern part of the peninsula located argillaceous soils near the village of Gamart (see Figure 3.1). Samples were taken where the modern road cuts through the deposit. This area is now an orchard. It is not known how the land was used in Roman times, but there is no evidence of building in the immediate area. Sample 45 was taken 50 cm below the ground surface where a single stratum of clay was visible. Samples 46 and 47 were taken at the same depth 50 meters and 65 meters respectively west of the first sample.

Site 10 - Gamart B. (Figure 3.1)

A short distance southwest of the orchard at the base of the Djebel Khaoui erosion of the slope had exposed a stratum of clay approximately 1.5 meters thick. Pits had been cut into this layer apparently to obtain the clay. Sample 48 was taken from a pit 50 cm below ground surface. Fractions of this clay were numbered as samples 49 and 50. Further up the slope, erosion had revealed another stratum of material of distinctly different quality which was also tested (Sample 51) This is unencumbered land. It seems unlikely that human activity has altered the composition of these strata.

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196. Personal communication Prof. S. Lancel. See Lancel (1982).

Site 11 - Nabeul A. (Figure 3.7 and 3.9)

The modern village of Nabeul is renowned for its ceramic production. Extensive clay pits are located immediately west of the village.(197) Samples were taken in two areas where modern quarrying was in progress. (See Figures 3.9-3.11) The first area was adjacent to the northern side of the modern road at distance marker "25 Grombalia" of Route C 27. This location is approximately 0.5 km from Nabeul. Quarrying had exposed several distinct layers of clay whose configurations are illustrated in Figure 3.9. Samples 52 through 58 were obtained at this site.

Site 12 - Nabeul B. (Figures 3.10 and 3.11)

A deep cutting 500 meters east of the Sample A site revealed a sequence of clay strata approximately 7 meters deep. The strata within reach were sampled. The sample locations are indicated in Figure 3.11. The scale of this drawing, made at the time of sampling, is approximate.

Site 13 - Oudna A. (Figures 3.7 and 3.12-13.)

The Roman Town of Uthina, modern Oudna, is a site where ARS manufacture has been confirmed.(198) The workshop could not be located at the time of the survey. Samples of clay, nos. 66-72), were obtained south of the main habitation area near a Roman bridge which crosses a wadi. This site is opposite the town. The first series of samples was taken 50 meters east of the bridge on the southern side of the stream bed. No occupational debris was observed here, but at the same elevation, approximately 5 meters west of the bridge, ashlar blocks, perhaps from opus africanum pillars, were visible. The modern ground surface should be approximately the same as it was during the

197. Peacock (1982) 38-39.
198. LRP.295-296. Typical products are illustrated in LRP 149-155.

Roman occupation since the road leading across the bridge is covered by only 0 to 25 cm of soil. It is reasonable to assume the clays do not represent post Roman alluvium (see Figure 3.12-13). The opposite side of the gully is about 1.5 meters lower than the sample site. The elevation is approximately 100 meters above sea level.

Site 14 - Oudna B. (Figures 3.12 and 3.13)

Another clay bed was located about 200 meters further east of the bridge. It was exposed where the wadi had cut into the steep side of the hill occupied by the Roman town. This was directly below a bath complex, identified by E. Wightman during a visit to the site. The elevation of the clay bed is about 100 meters, 40 meters below the top of the Henchir Oudna at this point. Part of the bank had been removed by quarrying a 2 meter thick layer of soil.

Two samples were taken: Sample 73 at 1 meter below ground surface, and Sample 74 at 30 cm directly below the first sample.

Site 15 - Thuburbo Maius. (Figures 3.7 and 3.8)

Two different clay beds were located at the Roman town of Thuburbo Maius. This settlement is southwest of Oudna, adjacent to the Oued Miliane. Samples were taken here to obtain more data on the clays of this drainage basin. Construction of the foundation for a museum building at the entrance to the site revealed a layer of clay immediately below the modern ground surface (see Figure 3.8). Samples 75 and 76 were obtained at a depth of 50 cm on opposite sides of the building. According to Mr. Sharabi, guardian of the site in June 1980, material "de cette sorte qu'on trouve à plusieurs endroits" is used locally for manufacturing pottery. One further sample was taken at the Oued Miliane

southeast of the town. This sample was purified and the fractions given sample numbers 78 and 79.

Site 16 - Mahrine. (Figures 3.14 and 3.15)

Soil samples were taken at several locations in the vicinity of the pottery works at Mahrine whose products were analyzed as part of this project (see Figure 3.15). A group of samples was obtained from the banks of a wadi 75 meters from the base of the hill where the manufactory was located. A modern aqueduct crosses the wadi at this point. Although the stream bed is about 2.5 meters below the surface of the adjacent ground, the banks slope at an angle of about 45 degrees and are partly covered by thick vegetation. Consequently it was not possible to distinguish individual layers of soil. It seems likely that this material is not post Roman alluvium. Eroded material would have been deposited further east where the gradient decreases at an elevation of about 65 meters. There may have been some erosion of the slope to the north, but the exposed level of occupation on the hillside suggests that the terrain had not altered drastically since the site was abandoned.

The four samples, nos. 82 - 85, were taken at approximately 1 meter below the modern ground surface where vegetation was sparse. Numbers 82 and 83 were recovered from the southern side of the wadi with a 6 meter interval between them. Numbers 84 and 85 were taken from the northern bank. Material excavated to construct one of the supports for the aqueduct was also sampled, no. 88, Sample 85 was levigated and the component portions were analyzed as nos. 86 and 87. It must be stressed that these five samples may be composite samples of material mixed from portions of other strata by erosion of the sloping bank of the wadi.

Samples for analysis were taken from a patch of clay within the area where pottery manufacture took place. An oval area of 2 meters in diameter was noted because of the complete absence of vegetation. Closer examination revealed a patch of clay, apparently too dense to support plant growth unlike much of the surrounding area. Testing showed the deposit was at least 10 cm deep. At the southeastern edge of this vegetation free area, rubble and mortar walls protruded about 1 meter from the ground surface. These included the corner of a building and a circular construction. The function of these could not be determined without excavation, but the circular feature showed no signs of vitrification or degradation one would expect to observe in a kiln or furnace. It might be the remains of a cistern. In any case, two samples of the clay, nos. 80 and 81, were taken since this soil might have been brought there to provide raw material for pottery making. The disposition of this material is shown in Figure 3.15.

Site 17 - Sidi Thabet. (Figure 3.14)

At the junction of routes P8 and C31, 14 kilometers northwest of Carthage, a stratum of argillaceous soil, approximately 1.5 meters thick, had been exposed by road construction. The stratum occurs slightly above the level of P8 at the base of a vertical embankment, 8 to 10 meters high. Two samples were taken, nos.89 and 90, two meters apart, from the centre of the stratum. The location of this site is shown on Figure 3.14.

Site 18 - Oued Medjerda. (Figure 3.14)

Route P8 crosses the Oued Medjerda, 28 kilometers from Tunis. At this point, erosion exposed two superimposed strata at the modern ground surface approximately 4 meters above the bottom of the stream channel. One sample was

analyzed from each stratum, nos. 91 and 92. Their locations are shown on Figure 3.14.

Site 19 - Utica. (Figures 3.14 and 3.16)

Prospecting for argillaceous soils in the vicinity of the Roman town of Utica was not very fruitful; however, a single deposit was found a short distance west of the access road, 1.4 kilometers north of the intersection with route P8 (Tunis/Bizerte) and 1 kilometer south of the Utica museum. The deposit occurrs on a hillside at an elevation of about 35 meters above sea level. This land is now used as an apple orchard, but no other signs of occupation could be found. Terracing by machinery had exposed two layers of argillaceous soil beneath a thick covering of sandy loam. A sample was taken from each one, nos. 93 and 94, at the points indicated in Figure 3.16.

Site 20 - Tiddis A. (Figures 3.17)

A group of samples was also collected a considerable distance from Carthage at Tiddis, Algeria. The Roman town, Castellum Tidditanorum, is situated on a high plateau southwest of Constantine. Since red-gloss pottery was manufactured here,(199) clay samples were sought for the purposes of comparison with material from Carthage. The Roman settlement is on a steep hillside. Argillaceous soils were located along the eastern edge of the urban area approximately 10 meters from what excavators believe were settling tanks used for processing clay. These features are located on the edge of the built up portion of the town at the base of the slope. The kilns where pottery was fired are located within the town, some distance away (see Figure 3.17)

199. Berthier (1972).

Sample 95 was taken from the stratum of soil 50 cm below the ground surface. The soil sample may not be from an undisturbed natural deposit, since this stratum was exposed by a drainage ditch. Approximately 5 meters west of what excavators believe were bath buildings, a 50 cm thick stratum of clay below several occupational layers was sampled, no. 96. The upper surface of the clay stratum was 3 meters below the present ground surface. It is quite possible that this soil is composed of material transported to its present location for packing a foundation trench.. There is no published stratigraphical information about this excavation at Tiddis which could clarify the function of this stratum.

Site 21 - Tiddis B. (Figure 3.17)

Two other samples, nos. 97 and 98, are composed of soil removed during the excavation of tombs in the cemetery east of the Roman town. There are no published plans on which to base a map showing the precise sampling locations. An interval of 10 meters separated the samples. The excavations had reached a depth of about 1.5 meters.

Site 22 - Tiddis C

One further sample, no. 99, was taken of surface soil approximately 4 kilometers northeast of Tiddis. The nearest landmark is the cylindrical mausoleum of the Lolli family which is located in the middle of agricultural land. When the site was visited a standing crop of wheat covered the site. The sample was taken from the ground surface at a point 10 meters west of the monument.

SECTION 3.2

ANALYTICAL PROCEDURES AND PHYSICAL PROPERTIES

Samples of 100 - 500 grams were collected in polyethylene bags. These were allowed to dry before storage and shipment. Samples were divided into two portions: one was stored with material from the Canadian excavations in the Museum at Carthage; the others were brought to Ottawa for processing and analysis. The plasticity of potential samples was gauged by roll testing in the field during collection. This method of evaluation may seem crude, but cohesiveness and the capacity to form a thin roll are characteristics which Roman potters would probably have used as a guide to selecting clays. Clay samples were placed in a double envelope of polyethylene bags. These were placed on a granite slab and the contents were crushed with a hammer. A portion of the crushed material was then ground in an agate mortar. After drying for eight hours at 100 degrees Celsius ground portions were fused for DCP analysis. An aliquot of dried material was also used for determining loss on ignition. These procedures were the same as those used to prepare pottery samples, except that the clay samples were not washed.

Portions of crushed clay were examined under 20X magnification for inclusions. The results of this examination are reported in Table 3.1. Most of the clays contained at least some fine sand. Mica was detected in only a few samples. Angular grains of a dark brown mineral occur in at least some of the clays in every deposit, although they are more abundant in some. These appear

to be identical to the dark inclusions detected in many of the pottery samples. Many of the clays have small bits of white material which is presumably calcium carbonate. It is possible that some of these white inclusions are calcium sulphate. Gypsum quarries are reported at Thuburbo Maius. (200)

Other samples, especially clays near the ground surface, contain a few small land snail shells. This is of some interest since their decomposition could affect the calcium concentration, in particular, of clay and pottery made from such clay. Visible pieces of snail shell were removed before clay samples were pulverized, but it is likely that smaller, undetected pieces were included with analyzed portions of some samples. Pieces of organic matter, principally root hairs, were also removed from samples before grinding.

The results of this examination are presented in Table 3.2. The inclusions which occur naturally in the clay samples do not reveal any striking anomalies between deposits which would distinguish them from one another. The possible exception to this is mica which seems relatively rare. It appears in the clay strata at Oudna, Tiddis, Byrsa, Mahrine, Hamilcar, Mjerda, and Nabeul. Although it does not occur in all strata, most of the major deposits contain a stratum with some mica. Micaceous layers were found in most of the deposits at Carthage.

It would be possible to differentiate between the clay mineral types encountered in various deposits using x-ray diffraction. Unfortunately this could not be included in the analytical program. The results from an XRD examination would have considerable scientific interest, but because the crystalline structure of clay minerals is altered by heat the technique has

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200. Lezine (1968) 7.

limited utility for matching clay deposits with fired ceramics, the material analyzed in the major portion of this study. One unfired sherd of coarse ware was recovered with the material from the kiln excavated on the Canadian Site, sample no. 433. It is hoped that when funds and equipment become available this sample, along with a selection of raw clays, can be analyzed by XRD.

The clay samples were evaluated for their suitability as raw material by a test firing. Portions of 1 to 10 grams were mixed with enough deionized water to render them workable. They were kneaded by hand and shaped into briquettes. Rubber gloves were worn for this procedure. The gloves were washed and rinsed with deionized water between samples. The briquettes were approximately 0.5 cm thick and varied in size from 1 to 2 cm square. The color of these pieces was recorded using a Munsell Soil Color Chart, 1975 Edition. After drying for 48 hours at ambient temperature and humidity, they were fired in batches of 25 to 30 pieces in an electric muffle furnace. The furnace was brought to 1000 plus/minus 50 degrees Celsius. This temperature was maintained for three hours. The furnace was then turned off and allowed to cool before the test pieces were removed. This temperature was selected because it approximates the range of temperatures which have been established for red-gloss pottery production. After firing the color of each piece was recorded and the durability of the fired pieces was then assessed. The results from this experiment are summarized in Table 3.2.

Several samples were selected for qualitative measure of the effect which washing might produce on chemical composition. 200 milliliters of deionized water were added to 10-50 grams of crushed clay. The container was then closed and shaken for about 3 minutes. The water was poured into

another container carrying suspended clay along with it. The two fractions were evaporated to dryness at 100 degrees Celsius. Portions were then ground and subjected to the same experimental procedures and analyses as the other samples of pottery and clay.

The strength of the test pieces was gauged by breaking them with the hands. A few of the pieces simply crumbled at being touched. These included samples of argilliferous sand from Carthage, Nabeul and Utica. These were categorized as "weak/crumbly". The next category, "weak" could be broken by exerting very little pressure with one thumb, while the sample was held between two fingers. Samples which fractured only when pressure was applied by pressing with both thumbs as a fulcrum, fortune cookie fashion, were classed as "moderately strong". This group was as durable as many pottery sherds from Carthage and consequently the clays were considered as satisfying the minimum criteria for pottery production. In practice they might have been rejected if better clays were available.

The next category of highest durability was assigned to those pieces which could be broken only by asserting the maximum pressure with two hands. Samples with this strength were categorized as "strong". Test pieces which could not be broken by hand were assigned to one of three categories. The first of these, "very strong" (V.strong) consisted of briquettes which could be broken only with a commercial tile cutter. Samples of the most durable briquettes showed traces of a glassy layer forming on their surface. These were grouped under the heading of "partially vitrified" (p.vitr). The final category was reserved for samples whose test pieces had a uniform glassy surface and which also showed signs of losing their shape. In two instances when the furnace

over-heated to about 1100 degrees Celsius, samples in this category simply melted forming a pool of glass.

It is recognized that this crude and rather subjective measuring technique does not produce results which could be reproduced with a high level of precision. The firing test itself was not designed to produce data which could be subjected to rigorous analysis. There was no pretense of reproducing the firing conditions or the clay working techniques used for ARS manufacture. Although temperature was controlled, the kiln atmosphere was not monitored and the uneven coloration of some test pieces indicates that it fluctuated during firing. Under these circumstances precise measurements of hardness, porosity or shrinkage would produce results which would make direct comparison between individual clays and Roman pottery meaningless. A far more comprehensive experimental program would be necessary to obtain accurate measurements of the effects produced by firing these clays. What the results of the firing tests do show is that usable ceramics could have been produced from most of the samples collected in the field. In many instances durable pottery, of a quality comparable to ARS, would have resulted from utilizing relatively impure clays.

It may well be asked whether there is a lower limit to the amount of clay mineral which must be present in an unfired clay to produce usable pottery. The quantity required is governed by several factors in addition to how much hydrated aluminium silicate is present. If clay is fired to sufficiently high temperatures for impurities such as calcium to cause incipient vitrification of the clay matrix and the mineral temper, a sufficiently durable product may result. If one considers the case of ARS it seems that 14 to 10% of alumina by weight was the norm. It is not possible to determine what equivalent weight of

clay this represents unless one knows which clay mineral was used to make the pottery. The ratio of silicon to aluminium varies from 2 to 1 for pure kaolinite to 4 to 1 for illite and montmorillonite; however, aluminum often replaces some of the silica and portions of the iron and other elements in the crystal lattice. These substitutions can lower this ratio considerably. By examining the composition of ARS, it can be seen that the most common ratio of silica to alumina is approximately 3.5 to 1. This ratio is reported along with the chemical abundances in Appendix VI. The values for this parameter include the silica present in non-plastic tempering materials. If one uses the higher ratio to estimate the amount of clay mineral in the samples analyzed here, one can obtain a rough estimate of the maximum amount of clay mineral which each sample could contain.(201)

Examination of the spectrometric data indicates that many of the clays have silica-alumina ratios in excess of 4. These are listed in Appendix VIII. The values suggest that most of the clays located during this study would have needed at least some purification to render them suitable for producing African Red Slip. The alumina-silica ratios of the test pieces which performed poorly are generally quite high. The alumina content shows that several of these samples would contain less than 10% by weight of clay mineral. It is important to note that some samples with relatively little clay mineral, produced durable ceramic. Sample 4 from the Hamilcar beds contained only 1.6% alumina but it made a moderately strong ceramic. Although Sample 13 from the Canadian excavation site had only 3% alumina, the fired briquette was rated as "very strong". This sample also contained about 26% CaO, which may have increased the

201. Tite et al. (1980) 111-112.

durability of the test piece. Calcareous clays are noted for producing ceramics with high compressive strength. (202)

Some of the poor quality briquettes were made from samples with an excessive amount of impurities. Comparing the results obtained with clays from Mahrine illustrates this phenomenon. Sample 85 produced a weak test piece. A portion of this clay was fractioned. The briquette made with the coarse fraction (Sample 86) also yielded a weak ceramic when fired, but the fine fraction showed improved strength. Similar behavior was observed for Sample 10 from the Canadian Site. A moderately strong ceramic resulted from firing the clay. When the raw clay was fractionated, the coarse portion could not be shaped at all, while the fine fraction produced a "very strong" ceramic, more durable than that produced from the original, unprocessed clay.

It is interesting to note that some of the weak briquettes were made with clays having more than 10% calcium oxide and from 7 to 17% aluminium oxide and, therefore, a relatively large amount of clay mineral. Sample 82, for example, has silica/alumina ratio quite compatible with what occurs in ARS. This strength of this briquette may have been diminished by the size of the sand particles observed in the sample and the other argilliferous soils from this site. The presence of numerous snail shell fragments may have prevented the formulation of a strong matrix in the fired example, or introduced stress in the unfired briquette during drying. It is reasonable to suspect that washing or slaking this clay could improve its quality since the fine portion of the levigated sample from this deposit was more durable.

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202. Tite et al. (1980) 118-120.

The firing tests were made on essentially usable clays. The fact that many of the clays with compositions within the range observed in ARS began to vitrify at 1000 degrees Celsius suggests the artisans could have obtained perfectly acceptable results by firing these clays at slightly lower temperatures. It should be remembered that those clays which did not perform well could have been mixed with other clays, or purified and subsequently incorporated into various pottery fabrics. Preliminary treatment might have rendered them suitable for ceramic production. Soaking the clays or "curing" them in a humid environment might improve their performance by saturation with water or by allowing bacterial action to reduce particle size. All of these factors would need to be evaluated by a much more comprehensive testing program before one could be absolutely certain that the clays which performed poorly in the firing test were rejected by Roman craftsmen.

A majority of the clays exhibited at least a slight shift in color after being fired. The results in this case have little value in determining whether or not a particular clay could have produced a specific color of pottery because the kiln atmosphere was not constant. Briquettes placed near the kiln vents sometimes displayed two different colors. Again one must consider whether or not clays were mixed either deliberately or by inadvertently cutting into more than one stratum when the raw material was quarried. One would need to make a systematic comparison of color shifts under oxidizing and reducing conditions to evaluate the potential range of colors which a given clay could produce. Nevertheless, the firing tests make it clear that Roman potters at Carthage had access to clays which could produce pottery in hues ranging from 10R to 2.5Y with the full range of values and intensities. The relationship

between the color of raw clay and fired clay is governed by many factors. One can observe from the firing experiment that artisans at Carthage could have used more than one clay source to produce pottery with the colors exhibited by ARS and by the coarse ware made on the Canadian site.

The consistent selection of calcareous clays for certain pottery fabrics and siliceous clays for other fabrics, raises an intriguing question. It is not known how the Roman potters made this distinction. They certainly did not have sophisticated analytical equipment at their disposal, nor did they have the theoretical basis for categorizing materials which has developed within the last two centuries of our era. They presumably made empirical observations, based on the behavior of clays as they were washed, shaped and fired under various conditions.(203) Ultimately it seems reasonable to suppose that the characteristics of a particular clay when fired determined its suitability for ceramic production. Attic potters used test pieces to monitor kiln temperature and atmosphere.(204) The skill of Roman potters suggests they were quite capable of performing similar operations at least for determining whether or not specific clays would yield the desired result.

Potters at Carthage searching for new clay sources would have needed to test a fairly wide variety of clays. Given the compositional variability within most of the available clay beds, picking the appropriate clay for making either ARS or buff ware at random would have offered a very low probability of success. One might wonder if there were properties of the natural clays which could aid in narrowing the choice of clays which a potter would need to test.

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203. Picon et al. (1975) 195FF.
204. Farnsworth, M. "Draw Pieces as Aids to Direct Firing". AJA. 67 (1963) 72-75.

Color is certainly one of the most obvious characteristics to consider. The clays at Carthage exhibit a fairly wide range of color. The colors of the clays analyzed for this project are listed in Table 3.1. They are represented graphically in Figures 3.18 and 3.19. It can be seen that the clays containing more than 15% CaO have colors ranging from 10R to 2.5Y although most exhibit hues between 2.5Y and 5YR. The largest number have values that range from 4 to 8. The chroma, or intensity of color, is less diverse. Most of the calcareous clays sampled in this study have a chroma of 4. The clays with less than 15% CaO have a more restricted range of hues. They are relatively evenly distributed among the 5 categories, sharing this spectrum displayed by the calcareous clays.

The spectrum of color values is virtually identical for all of the clays, irrespective of CaO context. The clays with less than 10% CaO have the largest percentage of chroma designations between 6 to 8. Consequently, there seems to be a tendency for the clays with less CaO to display a redder, more intense chroma than the calcareous clays. Because there there are exceptions which cause overlap between groups, color is a poor indicator of composition in the clays from this region. The presence of white inclusions detected in many of the clay samples would also help to identify clays containing calcium. Roman potters would, of course, have relied on the behavior of the clays, not on an evaluation of their chemical composition to select their materials.

Whatever firing procedures were used to make the various fabrics analyzed in this study, the potters selected either calcareous clays or clays with a low CaO content preferentially. They could have used the color of the raw clay to choose an assortment of raw materials for further testing. Clays

which did not perform well in subsequent steps of the manufacturing process would have been eliminated from the initial group. Unfortunately, there is no descriptive information in the literary corpus which describes the steps followed by Roman potters in preparing raw clays for the subsequent steps of pottery manufacture. The graffiti from La Graufesenque indicate that workers were assigned to specific tasks such as digging clay, applying slip or burnishing pottery, and stoking kilns.(205) The details of these procedures can only be surmised; but one might suspect that the behavior of clays when washed, or the shrinkage of shaped vessels could also be used as criteria for rejecting clays as unsuitable. It is reasonable to suppose any untried raw materials would have been subjected to the appropriate fabrication procedures and the results evaluated on the basis of the artisan's experience before a decision was taken on whether or not to use a specific clay.

All of the clays analyzed for the present study could have been used for making pottery. Searches for other specific means of detecting calcareous clays with the technology available to the potters of Roman Carthage led to a simple experiment. A common qualitative technique for detecting limestone is to place a drop of hydrochloric acid on the material. The carbonate reacts with the acid and bubbles of carbon dioxide are released. Hydrochloric acid was simply not available in Roman times, but acetic acid in the form of vinegar would have been plentiful. Several samples of clay from Carthage with varying amounts of CaO were treated with vinegar to see if this substance could be used to detect calcium carbonates. Amounts of about 0.1 grams of ground clay were placed in a test tube. About 2 milliliters of vinegar were then added to each

205. See Chapter 1, Section 1.

one. All of the clays showed some reaction without any agitation. The clays with less than 1% CaO emitted a few bubbles. Activity subsided after about 60 seconds. The clay containing 13% CaO instantaneously produced a froth which rose to a height of about 2 cms. The reaction slowed after about 30 seconds, but continued for about one hour. It seems clear from this experiment that vinegar can be used to distinguish clays with an elevated percentage of CaO.

These is no proof that potters at Carthage or anywhere else in the Roman world actually used this qualitative test. A search of potential literary sources has not turned up any evidence for potters using vinegar or any other substance for testing the quality of clay; however, two references to vinegar are worthy of mention in this context. A frequently cited passage in Pliny refers to miners quenching heated rocks with vinegar to splinter them.(206) It is generally believed that this account should not be taken literally. Perhaps he or his informatants have confounded descriptions of an assay technique where vinegar was used to test for carbonate content. Vitruvius provides a clearer description of the use of vinegar as a chemical reagent. He describes the preparation of basic copper acetate, by exposing copper filings to vinegar in a closed container.(207) This recipe was employed for manufacturing the green pigment verdigris. These passages demonstrate that Roman craftsmen used vinegar for chemical procedures; and they imply that knowledge of its properties was common if not widespread. The references do not prove that Roman potters ever attempted such experiments. However, the descriptions of these processes are examples of a large body of empirical knowledge which was applied by craftsmen working with a variety of materials including metals, minerals and

206. Hist. Nat. 33, 70.
207. de architectura, 7,12,1.

numerous organic substances. These industrial techniques were employed in workshops scattered throughout the Roman world.(208) It would not have been unusual if potters subjected their materials to simple assays using reagents commonly utilized by their contemporaries. Thus, in addition to the standard procedures for refining and firing clay, craftsmen could have used other simple, empirical methods to isolate calcareous clays for inclusion or exclusion from their raw material supply.

208. Various passages illustrating the empirical knowledge of Greek and Roman craftsmen are provided by Cohen and Drabkin (1975). K.D. White's recent work is also informative. White (1984).

SECTION 3.3

CHEMICAL COMPOSITION OF CLAYS

There is a rather wide range in the composition of the various soils. This is not unusual considering the number of samples and the diversity of their physical environments. What does seem surprising is the extent of variability within particular deposits of relatively pure clays. Results from the DCP determinations of chemical composition for the clay samples appear in Appendix VIII. Appendix IX reports the frequencies of occurrence for the elemental abundances listed in Appendix VIII. The frequencies are presented as two separate distributions: one for the clays from Carthage and one for the clays from the other sample sites. The frequency diagrams clearly illustrate the wide range of compositions available in the argillaceous soils found at Carthage and at the other locations in Northern Tunisia. When one compares the two sets of historgrams it becomes obvious that the ranges of concentration occurring in the Carthage clays are the same as the distributions found in the clays from other locations. The diagrams also show that many of the soils have much less clay mineral than the minimum required for producing ARS and the other ceramics analyzed in this study. Even if one restricts discussion to the samples which contain amounts of clay comparable to those found in the ceramics from Carthage, the variation within and between deposits is significant in many instances. It is important to observe that the frequencies for the Carthage deposits show essentially the same distributions as those displayed by the other deposits.

The elemental abundances vary considerably in the clays with an aluminium oxide concentration of 10% or more. Iron and calcium are the two other major constituents which exert the strongest influence on the color and strength of the fabrics examined here. The magnitude of the variation in iron content is relatively small in comparison to the fluctuation of calcium The clay bearing strata from the Hamilcar bed with nearly the same amount of alumina have calcium compositions which vary from 1 to 25 percent. (See sample nos. 1-6.) The Byrsa deposit which has a somewhat more homogeneous alumina content also displays a wide range of CaO abundances although that parameter is more constant in the strata with higher concentrations of alumina. These are the two deposits at Carthage which provided the largest selection of clays. The deposits in the vicinity of the La Malga cisterns appear more homogeneous, but the samples may represent a blend of different clays.

The clays from Oudna and Nabeul which occurred in clearly defined strata, offer additional insights into the variability within a single deposit. The material from Nabeul A is quite uniform, although Sample 56 has nearly twice the iron content or the adjacent stratum. It is especially interesting to observe that the concentration of iron in a second sample from the same stratum, no.55, varies almost by the same amount. Sample 53 has a tenfold greater abundance of manganese than the other strata, but this element often displays a wide range of values. The soils from the Nabeul B site, a short distance away, are much more heterogeneous. Calcium concentrations fluctuate considerably in strata containing essentially equivalent amounts of aluminum oxide.

The Oudna group is quite consistent, although calcium oxide, once again, and silica vary appreciably in certain instances. The high silica content and relatively low amounts of alumina indicate that these argillaceous soils would have required purification to raise the clay content to levels acceptable for ARS manufacture. The remaining clays represent groups too small to warrant detailed assessment of compositional variability. Anomalies do appear, however, which seem to distinguish clays from different deposits. Manganese oxide concentrations above 1000 ppm occur consistently in the clays from Thuburbo Maius, the two sites near the Medjerda west of Carthage and in the soils sampled at Tiddis. Some of the clays at Carthage also contain large amounts of manganese, but the majority do not. This trace element in particular has potential for helping identify specific deposits in this region.

The data from samples fractioned by agitation in water gives an indication of how washing might alter the composition of raw clay. (See Table 3.3) As one might expect, the percentage of silica is generally higher in the coarser portions. This presumably reflects the settling of heavier sand particles. The differences in the amount of alumina between decanted and settled portions is not always pronounced. Particle size probably accounts for this somewhat erratic behavior. A more thorough pulverization and longer slaking times before agitation would probably have increased the relative amounts of alumina in the fine fractions. Even the cursory washing increased the purity of the clays from Mahrine and Hamilcar. In both cases the alumina content was increased by 1% by the separation process. Further washing would be required to raise the alumina concentration of the Mahrine clay to the levels measured in pottery manufactured nearby.

Calcium concentrations were higher in the decanted portions of the samples. This is somewhat surprising since calcium carbonate has a low solubility in water. Apparently the carbonate occurs in particles small enough to be held in suspension with the clay for the brief interval of time before the fine fraction was separated. Iron exhibited the same behavior as calcium which suggests it generally occurred as a component of the clay mineral. Titanium behaved relatively consistently. It was usually associated with the fine clay fraction, but it was more abundant in the coarse portion of the clay from Thuburbo Maius. Virtually identical concentrations of titanium were measured in the two portions of the levitated sample from the Gamart deposit. Generally, this element seems to be associated with the clay mineral, but Ti may occur in heavier particles of non-plastic material in the anomalous samples.

Magnesium and sodium are found most commonly in water soluble form; and these elements are frequently components of clay minerals. As one would expect, both MgO and NaO concentrations were slightly greater in the fine fractions with one exception. A nearly three-fold greater amount of sodium was detected in the coarse fraction than that in the fine fraction of the Thuburbo Maius sample. The abundance of sodium in the coarse fraction of the clay from Thuburbo Maius was nearly three times greater than the amount measured in the fine fraction. It would be necessary to conduct a petrological examination of this clay to determine what minerals in the sample could account for this anomaly.

The two trace elements, manganese and chromium, exhibited similar patterns of distribution. Manganese was sometimes more abundant in the decanted portion and in other instances it was present in greater amounts in the coarse

fraction. The difference in concentration, however, was often insignificant. The variation observed between the abundances of Mn in the two portions of the sample from Thuburbo Maius was only 30 ppm in 500. The confidence limits established for the spectrometric data indicate that a difference of this magnitude could occur from random error in the experimental procedure. Chromium, likewise, was not associated with a particular clay fraction. Abundances for this element also show that the washing procedure did not increase Cr concentrations appreciably in the decanted portions of most of the samples. Levigating the clay from Mahrine did result in a 70% increase in the amount of chromium in the fine clay fraction. Other research has indicated that the trace element manganese, in particular, is often found with the heavier mineral inclusions which commonly occur in clays.(209) The levigation procedure applied to the raw materials from the Carthage region suggests the distribution of this elements may be different in some of the North African clays than it is in argillaceous soils from other areas.

There are, on the other hand, anomalous abundances of manganese in some of the material from Carthage. The La Malga clays samples which were taken in relatively close proximity to each other exhibit disparate Mn concentrations. Sample 26, for example, contained 277 ppm of Mn, in contrast to sample 27 which contained 1338 ppm of this oxide. A similar degree of variation is observable in the data obtained from the Byrsa deposit. Sample 36 had nearly five times as much manganese as that found in sample 35. These samples were taken from adjacent strata within the deposit. There are also instances when manganese abundances fluctuate markedly in pottery samples of the same fabric. (See

209. Hart and Adams (1983) 182.

Appendix VI.) An extreme case is the coarse ware sample no. 421. whose MnO content greatly exceeds the mean value for the group.

The washing experiment did not modify radically the abundances of the constituents measured in the raw clays. In fact, because the differences observed between the fine and the coarse fractions were often within the standard deviation, the lesser variations may simply arise from the random experimental error. This fact does not mean that one could expect the same behavior from the various chemical components if the clays had been purified by a more complex process. Since silica and the other elements which comprise most of the sample can be found either in the clay matrix or in non-plastic inclusions, their behavior during washing depends on the form in which they occur. Possibly, longer settling times would allow for more complete separation, but a more detailed investigation seems warranted for evaluating the effects of various washing procedures on the dispersal of principal components and trace elements North African clays and in the pottery made from them.

The results from the clay analyses were surprising since the geology of the region is considered quite uniform. There was some doubt about the utility of analyzing samples which could have proven to be essentially identical. The extreme variability at Carthage and within individual deposits poses very substantial difficulties for deciding where potters obtained their raw material. The range of concentrations, represented by the frequency diagrams in Appendix XI, demonstrates that two clays from separate deposits can appear virtually identical. Also, because the individual clay beds contained so many unique strata, discriminant analysis comparing groups of clay samples, or comparing single clays with the ARS, would have been a useless exercise.

Furthermore, the very low alumina content of many of the clays indicates they could not have been used for ARS manufacture without considerable modification. This would alter their composition sufficiently to make positive identification of sources an impossible task using chemical abundances alone. Although the clays were not compared with the ARS pottery using multivariate statistical procedures, general observations on the relationship between the fine ware and the local raw materials can be made from the elemental abundances as they stand.

The fact that siliceous clays were used for ARS manufacture does eliminate several deposits at Carthage as potential sources for raw materials. The La Malga and Gamart clays are much too calcareous for making ARS pottery. Several of the clays from the deposits on the Canadian site could have been used with extensive purification for ARS production. The Byrsa has the most pure siliceous clay and the deposits show good uniformity. It is a likely candidate on chemical grounds, but it would have been inaccessible in Roman times. One of the strata in the Hamilcar bed (Sample 7) contains a clay which could have purified relatively easily to reach the appropriate alumina/silica ratio, but its manganese abundance is much higher than the average value of the ARS pottery. If mixed with the adjacent layer during quarrying the Mn abundance would be closer to the range found in the ARS.

The compositional range of the Hamilcar strata makes this clay bed the best candidate for raw materials among the deposits located in this survey. There are, of course, similar clays at other sites. Experimentation with different levigation procedures would be needed to fully evaluate the potential of this source. It should be noted that the clay bed adjacent to the pottery dump at Mahrine would have provided siliceous clays. The raw material would

have needed refining to match the characteristics of the ARS, but the proximity of the siliceous clay deposit to the manufactory suggests that this clay furnished raw material for the pottery workshops located at Mahrine.

An interesting problem is raised by the analysis of the clays from Tiddis. All of the samples had calcium abundances greater than 10%. (See nos. 95-99 in Appendix VIII.) If these samples are representative of the prevailing compositional pattern in the local clays it implies that the potters at Tiddis used calcareous pastes for manufacturing red-gloss pottery. Obviously, these ceramics must be analyzed to determine if such clays were actually used to make them. But, if red-gloss was produced at Tiddis with calcareous clays, circumstances different from those which influenced the ARS industry in Africa Proconsularis may have governed the development of table ware manufacture in Numidia. An examination of the ceramics from Tiddis would enlarge our knowledge about the evolution of ceramic technology in the African provinces. This might lead as well to a better understanding of the economic conditions and of the social climate in this portion of the Roman Empire.

Patterns of chemical composition shed some light on the potential sources of clays which could have been used to manufacture Fabric Types III and IV. It has been assumed they were made at Carthage. If this is true, material from the northern portion of the peninsula in the area between the Canadian site and Hamilcar could have furnished the necessary siliceous clays, but the clays examined in this study could not have been used in their natural state. A positive identification of the sources used for making ARS at Carthage has not

been made. There remains the obvious possibility that the actual sources were not located by the preliminary survey. It is said that clay deposits also exist near Sidi Bou Said; and there are probably others in locations which were not sampled. It is also worth considering the alternative that facilities producing ARS were not on the peninsula of Carthage. A survey with the primary goal of locating manufactories at Carthage should be considered. Since kilns usually have high thermoremanant magnetism, a magnetometer survey would be appropriate. The open areas near the Hamilcar clay bed would be an obvious place to begin a program of exploration.

Producers of coarse ware and "Italic" lamps would have had a much wider choice of resources at Carthage because of the prevalence of calcareous clays. Furthermore, the high silica content of the coarse ware suggested the possibility that natural clays might have been used with little or no purification. The clay samples with more than 10% alumina were included in the final discriminant analysis with the coarse ware and lamps to test their compatibility with these ceramics.

The results are summarized in Appendix V. A plot of the discriminant scores appears in Figure 2.5f. Comparing this graph with Figures 2.5a-e, the plots of the discriminant scores for the coarse ware and for the third century lamp fabrics, shows that several clay samples fall within the cluster of values for some of these ceramics; but the classification procedure assigned 0 within-group probabilities to most of the clay samples. This should be interpreted as an indication that they do not really match the composition of the ceramics.

Several of the Carthage clays contain clay minerals in amounts which should make them adequate raw material sources for coarse ware manufacture. But generally these clays contain too much calcium, and either too little or too much alumina to have been used without modification for production of the coarse ware fabric CW IA and for the subgroup CW IB. Assuming the clays are representative of the site as a whole, the potters must have blended or purified their raw materials. The exceptions to this generality are the clays from La Malga and Gamart. These are the most probable sources identified by the discriminant analysis as sources for materials used to produce the coarse ware; but it would be misleading to claim that they were the ones exploited. Compositions which would result from mixing either the clays in the immediate vicinity of the kiln or the soils at Hamilcar could provide an equally good match with the ceramic. Discriminant scores for membership in the coarse ware groups CW IA and IB - made in this kiln on the Canadian Site - were higher for the Nabeul clays than the scores were for the clays from Carthage. This could be interpreted to mean clays from Nabeul were used for making this pottery. This highly improbable conclusion illustrates the risk of relying uncritically on resource analysis for provenience studies in this region.

The lamp fabrics are rather more closely compatible with the natural clays if one allows for modification of the raw materials. Fabric LMP II has the highest calcium abundances, which make it most similar to the Gamart and La Malga clays. The variability within the other clay beds, however, makes it impossible to rule out any single source.

A more ambitious analytical program incorporating petrological examination of raw clays and of clays subjected to different purification procedures might lead to a positive identification of the sources used for coarse ware production at Carthage. An investigation of this kind could also

help to determine whether or not any of the lamp fabrics could have been made there. The chemical abundances presented here have identified good candidates among the various clay deposits in the vicinity of Carthage for inclusion in a more comprehensive program combining experimentation and laboratory analysis.

SECTION 3.4

SUMMARY REMARKS

Archaeology is the study of human activity. Its ultimate goal is to derive plausible reconstructions of the past by interpreting the patterns visible in those cultural materials which have survived. One can easily lose sight of that goal in research focused on phenomena which, presumably, the original makers and users rarely, if ever, considered at all. But one must be cautious when interpreting the data from laboratory examination. Scientific techniques extend our perception one step closer to the artifacts than our senses normally allow. But extrapolation from this vantage point is perilous because we are one step removed from the consciousness of the craftsmen who did not possess our analytical tools. Furthermore, there are uncertainties inherent in sampling procedures and in the other aspects of the analytical process itself. Reconstructing the situation in which the North African ceramics were created becomes a difficult task when one is faced with such limitations. In spite of this, the chemical properties of the pottery from Roman Carthage do enhance our knowledge of the local ceramics industry. A number of tentative hypotheses have been proposed here which cannot be discussed profitably without additional data. Leaving those aside, there are several conclusions which should be stressed.

This investigation has demonstrated that ARS was produced from siliceous clays. The evidence leads to the conclusion that the potters probably chose these raw materials deliberately. The analyses have shown that siliceous clays are relatively rare in the vicinity of Carthage. This finding supports

the assertion that these raw materials were not selected haphazardly. The discussion of firing methods and kiln design suggested that the fabrication techniques may have encouraged potters to avoid calcareous clays. The physical characteristics of the red-gloss pottery and what is known about the pyrotechnology used in Roman Africa lead to the conclusion that ARS manufactures employed methods quite different from those used in European workshops to produce Samian ware. There are details of the ARS production processes which remain obscure. Clarification of these uncertainties will require petrological examination, firing tests and other analyses. The utilization of siliceous clay and technical differences between ARS and the red-gloss from European factories indicate that the African pottery developed independently from the Italic industry.

We cannot be absolutely certain that immigrants did not participate in ARS production; but the clays and methods used to make ARS strongly suggest the major Samian factories in Italy and in Gaul were not the principal training ground for the African potters. The possibility that ARS fabrication techniques derive from local North African traditions needs evaluation. The continuity of manufacturing processes in this region should be assessed by a thorough investigation of pre-Roman fabrication techniques, specifically the methods used for making Punic ceramics of all kinds. These, like the African red-gloss pottery, have been neglected to the detriment of our knowledge about the interaction within the artisan community during the Roman period.

The existence of distinct composition groups of ARS and of lamps is more difficult to interpret. The groups isolated from the Carthage pottery may result from inconsistencies in manufacturing technique, or from the naturally

high variability in the local clay sources. A broader chronological range of ARS from Carthage should be tested to elaborate the pattern of variability. The results must be compared with quantitative typological information to understand the significance of differences observed with chemical analyses. The same observations are relevant when considering the groups of third century lamps. Relationships between fabrics cannot be elucidated without more data derived from securely dated material. What this study has shown is that there are significant variations in elemental abundances between the lamp fabrics. This is promising for provenience studies of these ceramic objects.

The Late Roman Cooking Wares, LRCW I etc., certainly merit more scrutiny. The fact that one sample of LRCW I had virtually the same composition as the red-gloss pottery may not be purely coincidental. Because the local clays certainly needed purification, it is less likely that the identical compositions result from chance. Since similar firing techniques were also used to make some ARS and certain types of coarse pottery, it seems reasonable to suspect that table ware manufacturers collaborated with the producers of utilitarian pottery in North Africa. The details of this cooperation, if it existed, are obscure. It might have extended only as far as the preparation of raw material and sharing kiln space.

Because there has been no careful, stratigraphic excavation of known ARS production facilities in Africa Proconsularis, the kind of evidence which has helped to understand the complexities of the European red-gloss industry is not available. Multivariate statistics can be used in conjunction with chemical analyses to identify some of the production from the known manufactory at Mahrine. One group of the Mahrine ceramics is chemically indistinguishable from other ARS fabrics. Until sufficiently large amounts of material from this site and from others like it are analyzed, future provenience studies of North

African ceramics will be severely hampered.

Matching chemical characteristics of clay beds with pottery composition does not appear to offer a solution to the lack of provenienced reference groups in North Africa. Data presented in this report have pinpointed the location of silicious clays, but they have not identified the specific source of the raw materials used to make the ARS which was analyzed. The spectrometric data have identified unsatisfactory clay sources at Carthage and at other sites. The failure to associate a single clay deposit with a specific pottery fabric may mean that the raw material supply was not located by the preliminary survey of the Carthage area. The compositions of the clays in this region do imply that potters would have needed to refine these soils to obtain a suitable paste. This would have produced sufficiently great alterations in most cases which would mask the original composition of the clay.

It has been suggested that provenience studies could utilize the concept of a "zone d'incertitude" based on geological regions.(210) Within this framework pottery could be assigned to a relatively finite area, rather than a specific site, from determinations of elemental abundance. This approach may not be applicable to the North African situation considering the extreme variability within individual clay beds. In any case, future provenience studies should include a representative selection of clay samples to evaluate the significance of differences between ceramic groups. Although clays have

210. Picon et al. (1975) 198.

been tested in conjunction with ceramics in other parts of the Mediterranean, (211) the number of samples has often been quite small. This analysis of argillaceous soils from Carthage demonstrates that a large number of samples are necessary to characterize the raw materials available in a geographical area of relatively restricted size.

Although complete discrimination between ceramic fabrics was not achieved, the present study has demonstrated that the potential exists for successful provenience studies of ARS and other North African ceramics. Much more could be learned with a greater expenditure of time and money on laboratory examination of African Red Slip. It might be possible to find separation parameters for different ARS fabrics using trace element analysis. This approach should be considered seriously since the results obtained with the direct current plasma analyses of major constituents are encouraging. The archaeological significance of this pottery warrants further investigation. Hopefully the questions raised by the results presented here will encourage others to undertake additional research. A number of avenues are still unexplored in the field of North African pottery studies. Much remains to be accomplished.

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211. See above: pp. 6-7.

TABLE 3.1

VISIBLE INCLUSIONS IN CLAY SAMPLES

SMP	SAND	MICA	BROWN GRIT	CALCIUM # CARBONATE	ORGANIC	OTHER
CARTHAGE: HAMILCAR						
1	C ***		F *			
2	M+C ***	F *	F *	M **		
	C **					
3	M+C ***	F *	F *	M **		
4	C ***		F *			
5	C ***		F *			
6	M+C **		F *			
7	M+C ***		F *			
8+	M+C ***		F *			
9++	M **					
CARTHAGE: CANADIAN SITE						
10	M **		F *	M **		
11+	M **		F *	F+M **		
12++	M **		F *	F+M **		
13	F ***		F **	M **		
14	C **		F **			
15	M+C **		F **	M *		
16	M+C **		F *	M *		
17	M+C **		F **	F **		
18	M+C		F *			
19	C **		F *	F+M **		SNAIL SHELL **
20	F+M ***		F *			
21	M+C ***		F **	F *		
22	F+M **		F *			
23	F+M ***		F *			
24	F+M ***			M+C **		

F = FINE TEXTURE
M = MEDIUM
C = COARSE
# = AND OR SULPHATE

* = OCCASSIONAL
** = COMMON
*** = ABUNDANT
*** = VERY ABUNDANT

\+ = COARSE FRACTION OF PREVIOUS SAMPLE
++ = FINE FRACTION OF PREVIOUS SAMPLE

TABLE 3.1

VISIBLE INCLUSIONS IN CLAY SAMPLES (cont)

SMP	SAND	MICA	BROWN GRIT	CALCIUM CARBONATE	ORGANIC	OTHER
CARTHAGE: LAMALGA						
25	F **			F+M ***		
26	F+M **			F+M ***		
27	F+M **		F *	F+M ***		
28	F **		F *	F+M ***		
29	F **			F **		
30	F **			F **		
CARTHAGE: COLLINE DE JUNON						
31	F **	F *	F *	M **		
CARTHAGE: BYRSA						
32	F *					
33	F *			M **		
34	F *		F *			
35	M+C **					
36	M+C **			M+C **		
37	M+C **					
38	M+C **					
39	M **		F *	C		
40	M **		F *			
41	M+C **		F *			
42+	M+C **		F *			
43++	M+C **		F *			
44	F **	F **				
CARTHAGE: GAMART						
45	F **	F **	F *	M **	F **	SNAIL SHELL *
46	M+C **		F *	F **	F **	SNAIL SHELL **
47	F+M ***			F+M **		
48	F+M **		F *	F+M **		
49+	F+M **			F+M **		
50++	F+M **			F **		
51	F **			C **		

TABLE 3.1

VISIBLE INCLUSIONS IN CLAY SAMPLES

SMP	SAND	MICA	BROWN GRIT	CALCIUM CARBONATE	ORGANIC	OTHER
NABEUL: SITE A						
52	M+C **			F *		
53	M **		F *	F *		
54	F **	F *		F *		
55	M **	F *	F *	F *		
56	F **			F *		
57	F **			F *		
58	F **	F *		F *		
NABEUL: SITE B						
59	F **	F *		F *		
60	F+M **		F *	M *		
61	M+C **			M **		
62	C ****					
63	F **	F *		F **		
64	M **	F *	F *	M **		
65	F **	F *		M **		
OUDNA						
66	F **	F **		F *		SNAIL SHELL **
67	F+M **			F *		
68	F+M **					
69	F+M **	F *		M **		
70	M **			F **		
71	M **			M *		
72	F **			F *		
73	M+C **					
74	M+C **			F *		
THUBURBO MAIUS						
75	F **		F *	M *		SNAIL SHELL *
76	F **		F *	M *		SNAIL SHELL *
77	M **		F *	M *		
78+	M **		F *			
79++	M *		F *			

TABLE 3.1

VISIBLE INCLUSIONS IN CLAY SAMPLES (cont)

SMP	SAND	MICA	BROWN GRIT	CALCIUM CARBONATE	ORGANIC	OTHER
MAHRINE						
80	F+M **		F *	F *	F *	SNAIL SHELL **
81	M+C **		F+M *	F *	F *	SNAIL SHELL **
82	M+C **		F+M **	M *	F *	SNAIL SHELL **
83	M+C **		F+M **	M *	F *	
84	F+M **		F *	F *	F *	
85	F+M **	F *	F *	F *	F *	SNAIL SHELL *
86+	F+M **	F *	F *	F *	F *	SNAIL SHELL *
87++	F **	F *	F *	F *	F *	SNAIL SHELL *
88	F ***		F **	F *	F *	
SIDI THABET						
89	F ***			M *		
90	F ***			M *		
OUED MEDJERDA						
91	F ***	F *	F **	F *		
92	F **			F *		
UTICA						
93	M+C ***	F *		F **	F **	
94	F+M **	F *		F **	F **	
TIDDIS						
95	M+C ***	F **		F+M **	F *	SNAIL SHELL *
96	M+C **			F+M **		
97	F **	F **		F+M **	F *	SNAIL SHELL *
98	F+M **			F+M **	F *	SNAIL SHELL *
99	F+M **	F **		F *	F *	

TABLE 3.2

PROPERTIES OF RAW AND FIRED CLAYS

CARTHAGE: HAMILCAR

SMP	COLOR RAW	COLOR NAME	COLOR FIRED	COLOR NAME	DURABILITY
1	5YR 5/6	YELLOWISH RED	2.5YR 5/8	RED	W / CRMB
2	7.5YR 6/6	REDDISH YELLOW	10YR 7/8	YELLOW	V.STRONG
			+7.5YR7/6	REDDISH YELLOW	
3	7.5YR 6/6	REDDISH YELLOW	7.5YR 7/6	REDDISH YELLOW	V.STRONG
4	5YR 6/6	REDDISH YELLOW	2.5YR 5/8	RED	M.STRONG
5	10YR 5/6	YELLOWISH RED	10R 3/1	DARK REDDISH GRAY	STRONG
6	10YR 5/8	YELLOWISH BROWN	10R 4/6	RED	STRONG
7	10YR 5/8	YELLOWISH BROWN	10R 4/4	WEAK RED	P.VITR
8*	10R 4/6	RED	10R 3/2	DUSKY RED	P.VITR
9**	5YR 5/6	YELLOWISH RED	10R 3/2	DUSKY RED	P.VITR

CARTHAGE: CANADIAN SITE

SMP	COLOR RAW	COLOR NAME	COLOR FIRED	COLOR NAME	DURABILITY
10	7.5YR N/7	LIGHT GRAY	7.5YR 7/8	REDDISH YELLOW	M.STRONG
11*	7.5YR N/7	LIGHT GRAY	-----NONPLASTIC--------		
12**	5YR 5/1	GRAY	7.5YR 6/6	REDDISH YELLOW	V.STRONG
13	5YR 6/6	REDDISH YELLOW	10R 4/3	WEAK RED	V.STRONG
14	2.5YR 6/8	LIGHT RED	5YR 7/2	PINKISH GRAY	STRONG
15	2.5YR 6/8	LIGHT RED	2.5YR 4/2	WEAK RED	STRONG
16	2.5YR 6/6	LIGHT RED	5YR 6/2	PINKISH GRAY	V.STRONG
17	10YR 7/4	VERY PALE RED	10YR 8/3	VERY PALE BROWN	WEAK
18	5YR 6/6	REDDISH YELLOW	5YR 7/4	PINK	M.STRONG
19	2.5Y 8/2	WHITE	2.5Y 6/2	LIGHT BROWNISH GRAY	M.STRONG
20	10R 6/8	LIGHT RED	2.5YR 6/6	LIGHT RED	M.STRONG
21	10R 6/8	LIGHT RED	7.5YR 7/4	PINK	WEAK
22	2.5YR 6/8	LIGHT RED	10R 8/4	VERY PALE BROWN	M.STRONG
			+ 5YR 6/8	REDDISH YELLOW	
23	2.5YR 6/6	LIGHT RED	2.5YR 3/4	DARK REDDISH BROWN	M.STRONG
24	5YR 8/3	PINK	5YR 8/1	WHITE	WEAK

* COARSE FRACTION OF PREVIOUS SAMPLE
** FINE FRACTION OF PREVIOUS SAMPLE

TABLE 3.2 PROPERTIES OF RAW AND FIRED CLAYS (cont)

CARTHAGE: LAMALGA

SMP	COLOR RAW	COLOR NAME	COLOR FIRED	COLOR NAME	DURABILITY
25	5YR 6/6	REDDISH YELLOW	7.5YR 6/8 +7.5YR 7/6	REDDISH YELLOW REDDISH YELLOW	V.STRONG
26	7.5YR 6/6	REDDISH YELLOW	7.5YR 5/6	STRONG BROWN	V.STRONG
27	5YR 6/6	REDDISH YELLOW	5YR 3/2	DARK RED BROWN	VITR
28	7.5YR 8/4	PINK	5YR 6/2	PINKISH GRAY	M.STRONG
29	10YR 7/4	VERY PALE BROWN	10YR 5/6	YELLOWISH BROWN	P.VITR
30	10YR 7/4	VERY PALE BROWN	10YR 5/6	YELLOWISH BROWN	P.VITR

CARTHAGE: COLLINE DE JUNON

SMP	COLOR RAW	COLOR NAME	COLOR FIRED	COLOR NAME	DURABILITY
31	2.5YR 6/6	LIGHT RED	10R 4/1	DARK REDDISH	P.VITR

CARTHAGE: BYRSA

SMP	COLOR RAW	COLOR NAME	COLOR FIRED	COLOR NAME	DURABILITY
32	2.5YR 6/6	LIGHT RED	10R 4/2	WEAK RED	P.VITR
33	10R 6/6	LIGHT RED	5YR 6/3	LIGHT REDDISH BROWN	P.VITR
34	10YR 7/4	VERY PALE BROWN	2.5YR 4/2	WEAK RED	P.VITR
35	5YR 7/3	PINK	5YR 7/4	PINK	V.STRONG
36	5YR 8/3	PINK	10R 6/3	PALE BROWN	M.STRONG
37	5YR 6/6	REDDISH YELLOW	5YR 4/3	REDDISH BROWN	V.STRONG
38	2.5YR 5/6	RED	5YR 4/1	DARK GRAY	P.VITR
39	5YR 7/4	PINK	7.5YR 7/6	REDDISH YELLOW	STRONG
40	10YR 7/6	YELLOW	10R 3/3	DUSKY RED	P.VITR
41	5YR 6/6	REDDISH YELLOW	10R 4/3	WEAK RED	V.STRONG
42*	10R 5/8	RED	5YR 4/2	DARK REDDISH GRAY	V.STRONG
43**	5YR 5/6	YELLOWISH RED	5YR 4/2	DARK REDDISH GRAY	V.STRONG
44	10YR 8/4	VERY PALE BROWN	5YR 7/4	PINK	V.STRONG

CARTHAGE: GAMART

SMP	COLOR RAW	COLOR NAME	COLOR FIRED	COLOR NAME	DURABILITY
45	10YR 7/4	VERY PALE BROWN	10YR 8/3	VERY PALE BROWN	V.STRONG
46	5YR 7/4	PINK	5YR 8/4	PINK	M.STRONG
47	5YR 4/4	REDDISH BROWN	5YR 6/6	REDDISH YELLOW	WEAK
48	10YR 7/4	VERY PALE BROWN	10R 4/3	BROWN	V.STRONG
49*	10YR 5/4	YELLOWISH BROWN	2.5Y 8/4	PALE YELLOW	V.STRONG
50**	10YR 6/4	LIGHT YELLOWISH BROWN	10YR 8/4	VERY PALE BROWN	V.STRONG
51	WHITE		7.5YR 6/4	WHITE	V.STRONG

* COARSE FRACTION; ** FINE FRACTION.

TABLE 3.2

PROPERTIES OF RAW AND FIRED CLAY

NABEUL: SITE A

SMP	COLOR RAW	COLOR NAME	COLOR FIRED	COLOR NAME	DURABILITY
52	10R 6/6	LIGHT RED	5YR 7/3 + 10R 6/6	PINK LIGHT RED	P.VITR
53	5YR 6/6	REDDISH YELLOW	7.5YR 3/2	DARK BROWN	VITR
54	2.5YR 6/4	LIGHT REDDISH BROWN	2.5YR 4/3	DARK REDDISH BROWN	VITR
55	10YR 6/4	LIGHT YELLOWISH BROWN	10R 3/2	DUSKY RED	VITR
56	10YR 6/6	BROWNISH YELLOW	10R 2.5/1	REDDISH BLACK	VITR
57	5YR 6/4	LIGHT YELLOWISH BROWN	10R 2.5/1	REDDISH BLACK	VITR
58	5YR 6/4	LIGHT REDDISH BROWN	2.5YR 3/2	DUSKY RED	VITR

NABEUL: SITE B

SMP	COLOR RAW	COLOR NAME	COLOR FIRED	COLOR NAME	DURABILITY
59	7.5YR 6/4	LIGHT BROWN	5YR 5/2	REDDISH GRAY	VITR
60	5YR 5/6	YELLOWISH RED	7.5YR 4/2	BROWN	P.VITR
61	7.5YR 7/6	REDDISH YELLOW	5YR 3/1	VERY DARK GRAY	VITR
62	7.5YR 7/8	REDDISH YELLOW	7.5YR 7/6	REDDISH YELLOW	WEAK
63	2.5YR 5/6	RED	2.5Y 6/2	PALE RED	VITR
64	7.5YR 6/6	REDDISH YELLOW	2.5YR 2.5/2	VERY DUSKY RED	V.STRONG
65	10R 6/8	LIGHT RED	10R 4/2	WEAK READ	VITR

OUDNA

SMP	COLOR RAW	COLOR NAME	COLOR FIRED	COLOR NAME	DURABILITY
66	2.5YR 5/4	REDDISH BROWN	10YR 4/2	WEAK RED	VITR
67	5YR 5/3	REDDISH BROWN	10R 6/6	LIGHT RED	P.VITR
68	10R 5/1	REDDISH GRAY	2.5YR 6/4	LIGHT REDDISH BROWN	V.STRONG
69	5YR 5/3	REDDISH BROWN	10R 6/6	LIGHT RED	P.VITR
70	2.5YR 5/4	REDDISH BROWN	2.5YR 6/4	LIGHT REDDISH BROWN	P.VITR
71	10YR 6/4	LIGHT YELLOWISH BROWN	10YR 7/2	LIGHT GRAY	STRONG
72	7.5YR 6/6	REDDISH YELLOW	5YR 7/2	PINKISH GREY	M.STRONG
73	7.5YR 6/6	REDDISH YELLOW	10YR 7/2	LIGHT GREY	STRONG
74	7.5YR 6/6	REDDISH YELLOW	10YR 7/4	VERY PALE BROWN	M.STRONG

* COARSE FRACTION OF PREVIOUS SAMPLE; ** FINE FRACTION OF PREVIOUS SAMPLE.

TABLE 3.2

PROPERTIES OF RAW AND FIRED CLAYS

THUBURBO MAIUS

SMP	COLOR RAW	COLOR NAME	COLOR FIRED	COLOR NAME	DURABILITY
75	10R 6/6	LIGHT RED	10R 5/8	RED	P.VITR
76	10R 6/6	LIGHT RED	10R 5/8	RED	P.VITR
77	5YR 7/4	REDDISH YELLOW	5YR 6/6	PINK	V.STRONG
			+5YR 8/4	PINK	
78*	5YR 7/4	REDDISH YELLOW	7.5YR 6/6	REDDISH YELLOW	V.STRONG
79**	5YR 7/4	REDDISH YELLOW	5YR 5/6	YELLOWISH RED	V.STRONG
			+5YR 8/4	PINK	

MAHRINE

SMP	COLOR RAW	COLOR NAME	COLOR FIRED	COLOR NAME	DURABILITY
80	10R 6/3	PALE RED	10R 3/2	DUSKY RED	P.VITR
81	5YR 6/4	LIGHT REDDISH BROWN	5YR 4/4	REDDISH BROWN	M.STRONG
82	10YR 6/4	LIGHT YELLOWISH BROWN	10R 4/6	RED	WEAK
83	10R 5/6	RED	2.5YR 5/8	RED	M.STRONG
84	10R 4/6	RED	10R 4/8	RED	WEAK
85	10R 4/6	RED	10R 4/8	RED	WEAK
86*	10R 4/6	RED	10R 4/8	RED	WEAK
87**	10R 3/6	DARK RED	10R 4/8	RED	M.STRONG
88	10R 4/6	RED	10R 3/2	DUSKY RED	P.VITR

SIDI THABET

SMP	COLOR RAW	COLOR NAME	COLOR FIRED	COLOR NAME	DURABILITY
89	7.5YR 7/4	PINK	2.5Y 6/6	OLIVE YELLOW	V.STRONG
90	7.5YR 7/4	PINK	2.5Y 6/6	OLIVE YELLOW	V.STRONG

OUED MEDJERDA

SMP	COLOR RAW	COLOR NAME	COLOR FIRED	COLOR NAME	DURABILITY
91	10R 6/4	PALE RED	2.5YR 5/8	RED	V.STRONG
92	2.5YR 6/4	LIGHT REDDISH BROWN	5YR 5/6	YELLOWISH RED	VITR

* COARSE FRACTION OF PREVIOUS SAMPLE; ** FINE FRACTION OF PREVIOUS SAMPLE

TABLE 3.2

PROPERTIES OF RAW AND FIRED CLAYS (cont)

UTICA

SMP	COLOR RAW	COLOR NAME	COLOR FIRED	COLOR NAME	DURABILITY
93	5YR 7/6	REDDISH YELLOW	5YR 5/6	YELLOWISH RED	WEAK
94	7.5YR 7/4	PINK	7.5YR 3/2	DARK BROWN	V.STRONG

TIDDIS

SMP	COLOR RAW	COLOR NAME	COLOR FIRED	COLOR NAME	DURABILITY
95	2.5YR 5/6	RED	5YR 6/8	YELLOWISH RED	M.STRONG
96	10R 5/8	RED	10R 4/8	RED	V.STRONG
97	10R 5/8	RED	10R 5/8	RED	STRONG
98	5YR 5/8	YELLOW RED	5YR 7/6	REDDISH YELLOW	M.STRONG
99	10R 5/6	RED	10R 5/8	RED	P.VITR

TABLE 3.3

COMPOSITION OF LEVIGATED CLAY SAMPLES

CARTHAGE: HAMILCAR

SMP	Si*	Al*	Ca*	Fe*	Mg*	Na*	Ti*	Mn+	Cr+	WT. % Fraction
7 O	66.4	15.5	1.71	6.10	1.45	.176	.977	1050	168	
8 C	71.5	12.1	1.42	4.89	1.24	.144	.843	1018	149	35.6
9 F	65.3	16.5	1.94	6.40	1.60	.203	1.012	1210	195	64.4
F-C	-6.2	+4.4	+0.52	+1.51	+.36	+.059	+.169	+192	+ 46	
F-O	-1.1	+1.0	+0.23	+0.30	+.15	+.027	+.035	+160	+ 27	

CARTHAGE: CANADIAN SITE

SMP	Si*	Al*	Ca*	Fe*	Mg*	Na*	Ti*	Mn+	Cr+	WT. % Fraction
10 O	37.3	6.4	24.7	3.15	1.41	.399	.438	1275	67	
11 C	47.6	5.5	21.3	2.51	1.27	.288	.356	1126	77	30.0
12 F	37.5	7.0	25.0	3.23	1.56	.423	.443	1278	75	70.0
F-C	-10.1	+1.5	+3.7	+0.72	+.29	+.135	+.087	+152	- 2	
F-O	+ 0.2	+0.6	+0.3	+0.08	+.15	+.024	+.005	+ 3	+ 8	

CARTHAGE: BYRSA

SMP	Si*	Al*	Ca*	Fe*	Mg*	Na*	Ti*	Mn+	Cr+	WT. % Fraction
41 O	64.8	14.9	.29	6.05	2.55	.260	.890	197	197	
42 C	65.5	13.4	.26	5.63	2.44	.239	.855	123	216	38.7
43 F	64.2	14.1	.30	6.05	2.52	.280	.912	142	192	65.3
F-C	-1.3	+0.7	+.04	+0.42	+.08	+.041	+.057	+ 19	- 24	
F-O	- .6	-0.8	+.01	0	-.03	+.020	+.022	- 55	- 5	

* Wt. % oxide
\# ppm oxide

O = Unlevigated sample. C = Coarse Fraction
F + Fine Fraction

TABLE 3.3 (CONT)

COMPOSITION OF LEVIGATED CLAY SAMPLES

CARTHAGE: GAMART

SMP	Si*	Al*	Ca*	Fe*	Mg*	Na*	Ti*	Mn+	Cr+	WT. % Fraction
48 O	37.0	13.8	24.0	5.53	1.81	.384	.740	558	134	
49 C	38.0	13.2	19.9	4.75	1.73	.447	.746	502	107	41.9
50 F	36.3	14.2	24.4	5.57	2.01	.167	.757	470	147	58.1
F-C	-1.7	+1.0	+4.5	+.82	+.28	-.280	+.011	-32	+ 40	
F-O	-0.7	+0.4	+0.4	+.04	+.20	-.217	+.017	-88	+ 13	

THUBURBO MAIUS

SMP	Si*	Al*	Ca*	Fe*	Mg*	Na*	Ti*	Mn+	Cr+	WT. % Fraction
77 O	39.0	13.3	21.07	4.84	1.68	.328	.807	1200	96	
78 C	37.0	13.1	20.85	4.77	1.59	.314	.817	1283	104	45.7
79 F	37.6	13.0	21.70	4.76	1.62	.400	.770	1094	94	54.3
F-C	-0.6	-0.1	+0.85	-.01	+.03	+.086	-.047	-189	-10	
F-O	-1.4	-0.3	+0.63	-.08	-.06	+.072	-.037	-106	- 2	

MAHRINE

SMP	Si*	Al*	Ca*	Fe*	Mg*	Na*	Ti*	Mn+	Cr+	WT. % Fraction
85 O	83.4	7.4	2.14	3.43	.68	.112	.548	432	128	
86 C	86.3	4.1	.70	2.48	.64	.059	.484	349	102	45.1
87 F	72.2	9.3	3.53	3.92	.85	.164	.688	514	174	54.9
F-C	-14.1	+5.2	+2.83	+1.44	+.21	+.105	+.204	+165	+ 72	
F-O	-11.2	+1.9	+1.39	+0.49	+.17	+.052	+.140	+ 82	+ 46	

* Wt. % oxide
\# ppm oxide

O = Unlevigated sample. C = Coarse Fraction
F + Fine Fraction

FIGURE 3.1

MAP OF SAMPLE SITES AT CARTHAGE

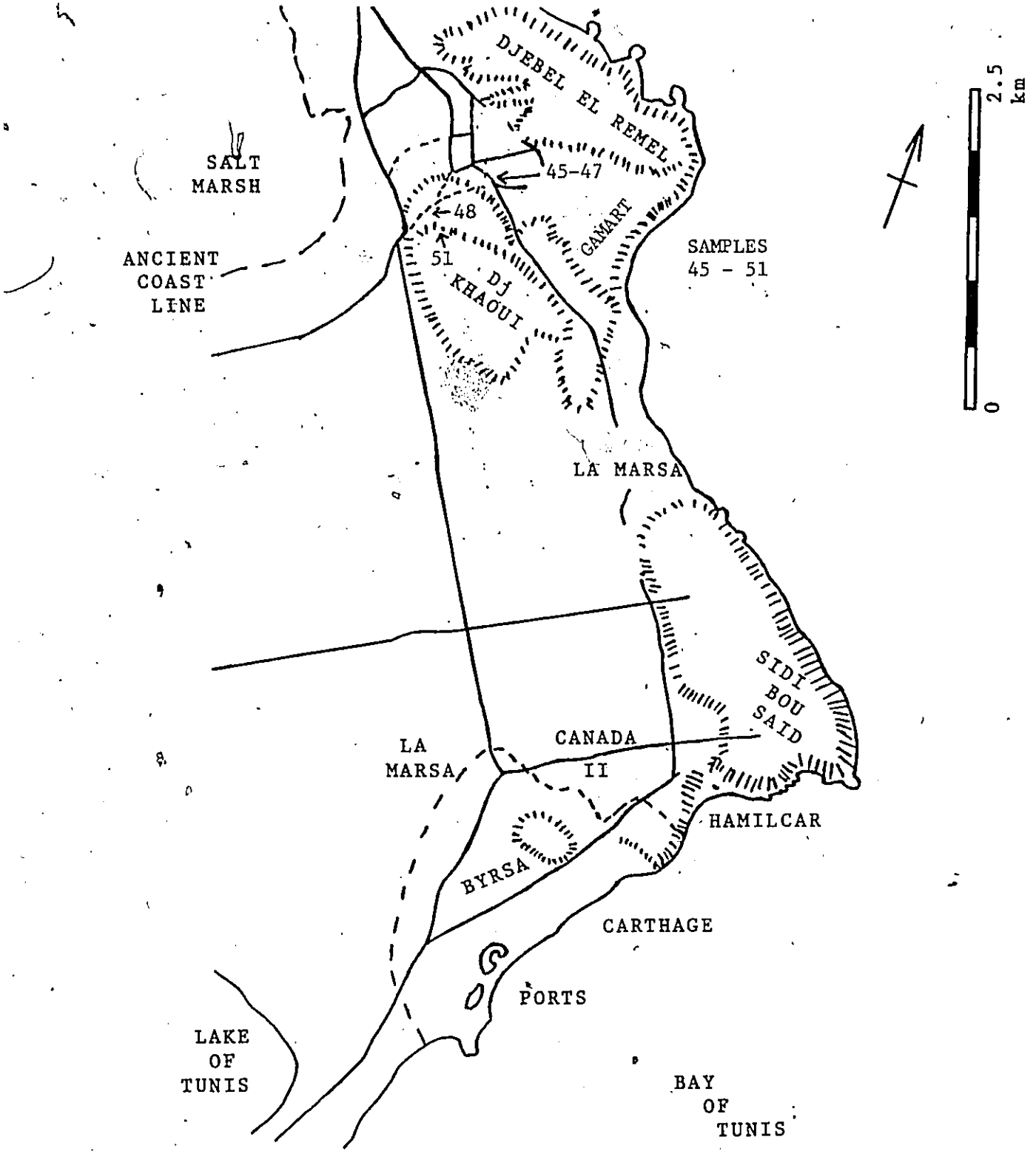
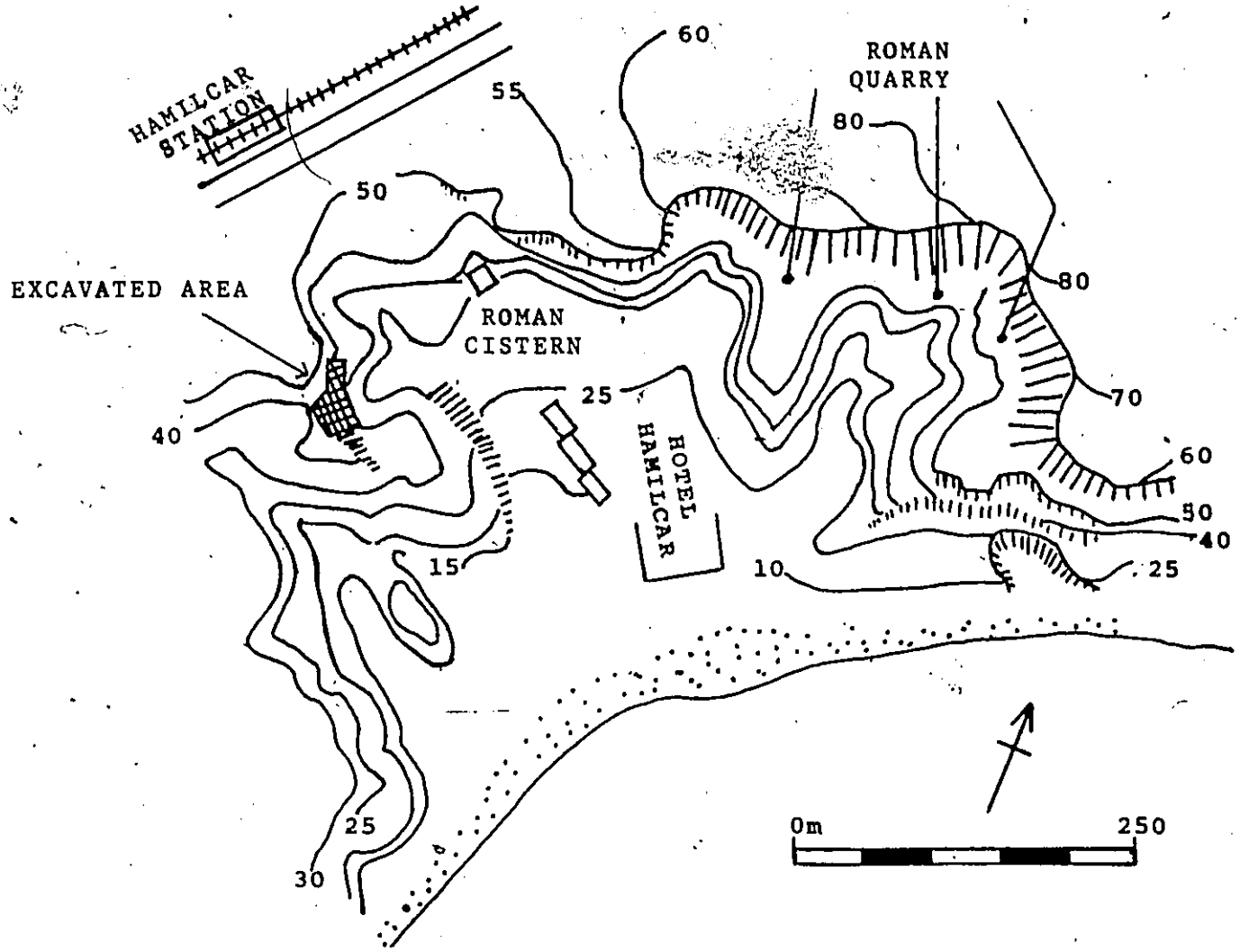


FIGURE 3.2a HAMILCAR SAMPLE SITE



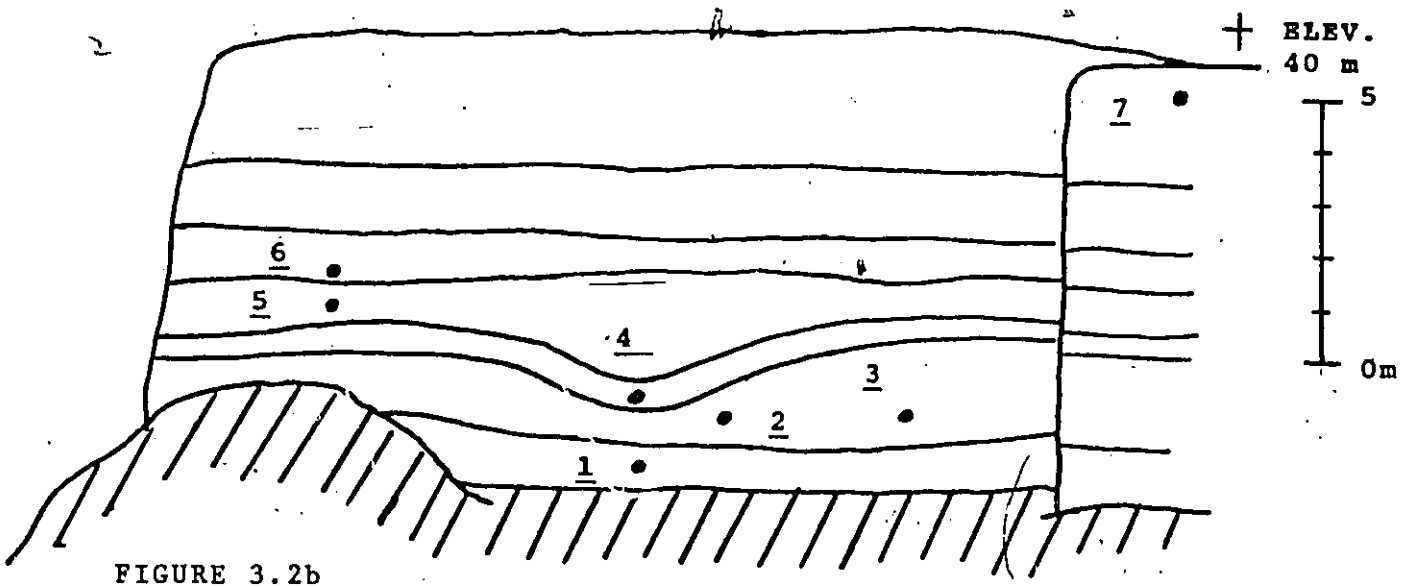


FIGURE 3.2b
HAMILCAR SAMPLE LOCATIONS

FIGURE 3.3

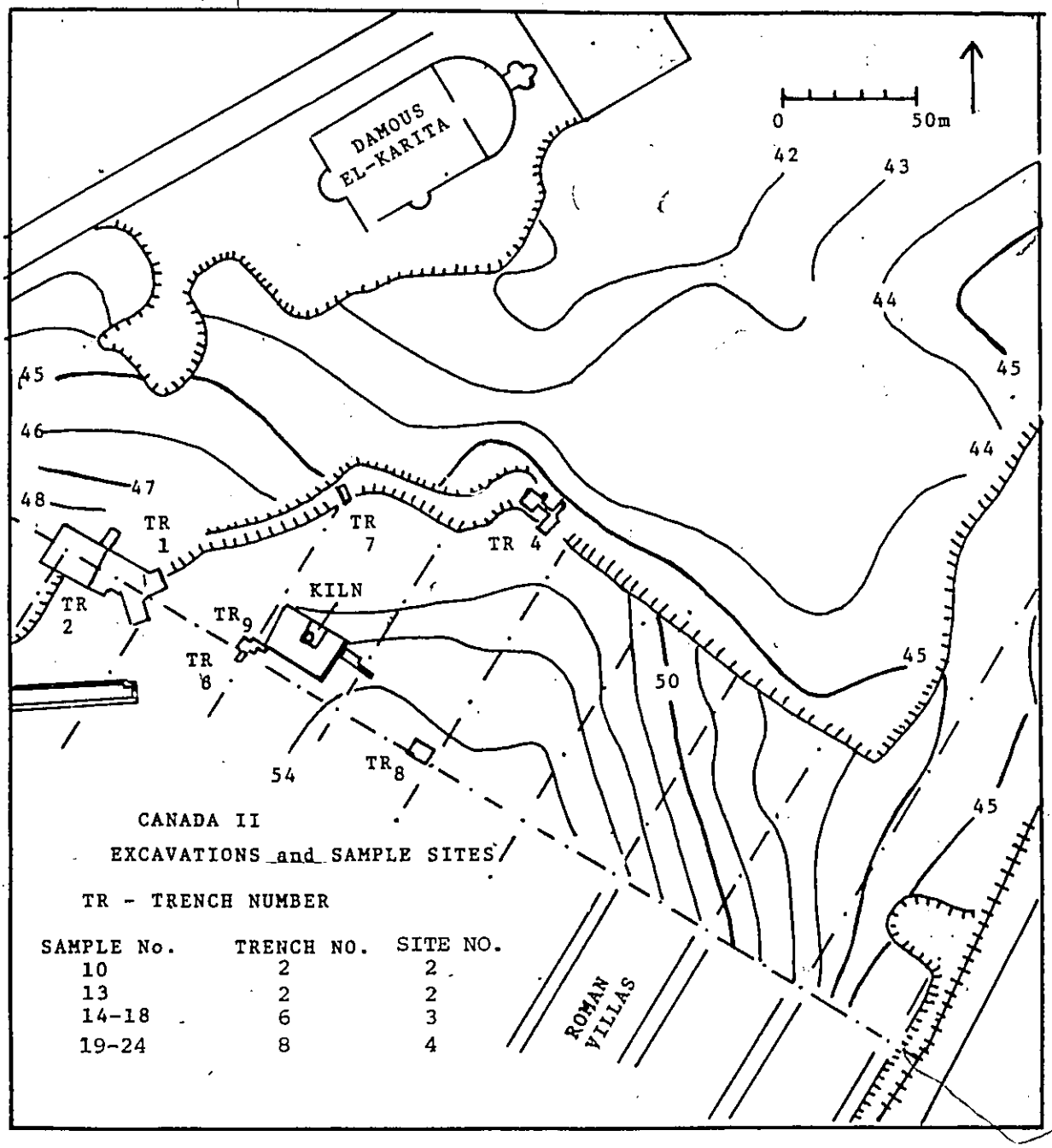

DAMOUS EL-KARITA
0
50m
42
43
44
45
46
47
48
TR 1
TR 2
TR 7
TR 4
KILN
TR 9
TR 6
TR 8
50
54
ROMAN VILLAS
CANADA II
EXCAVATIONS and SAMPLE SITES
TR - TRENCH NUMBER
SAMPLE No. TRENCH NO. SITE NO.
10 2 2
13 2 2
14-18 6 3
19-24 8 4

FIGURE 3.4. LA MALGA SAMPLE SITES
LA MALGA

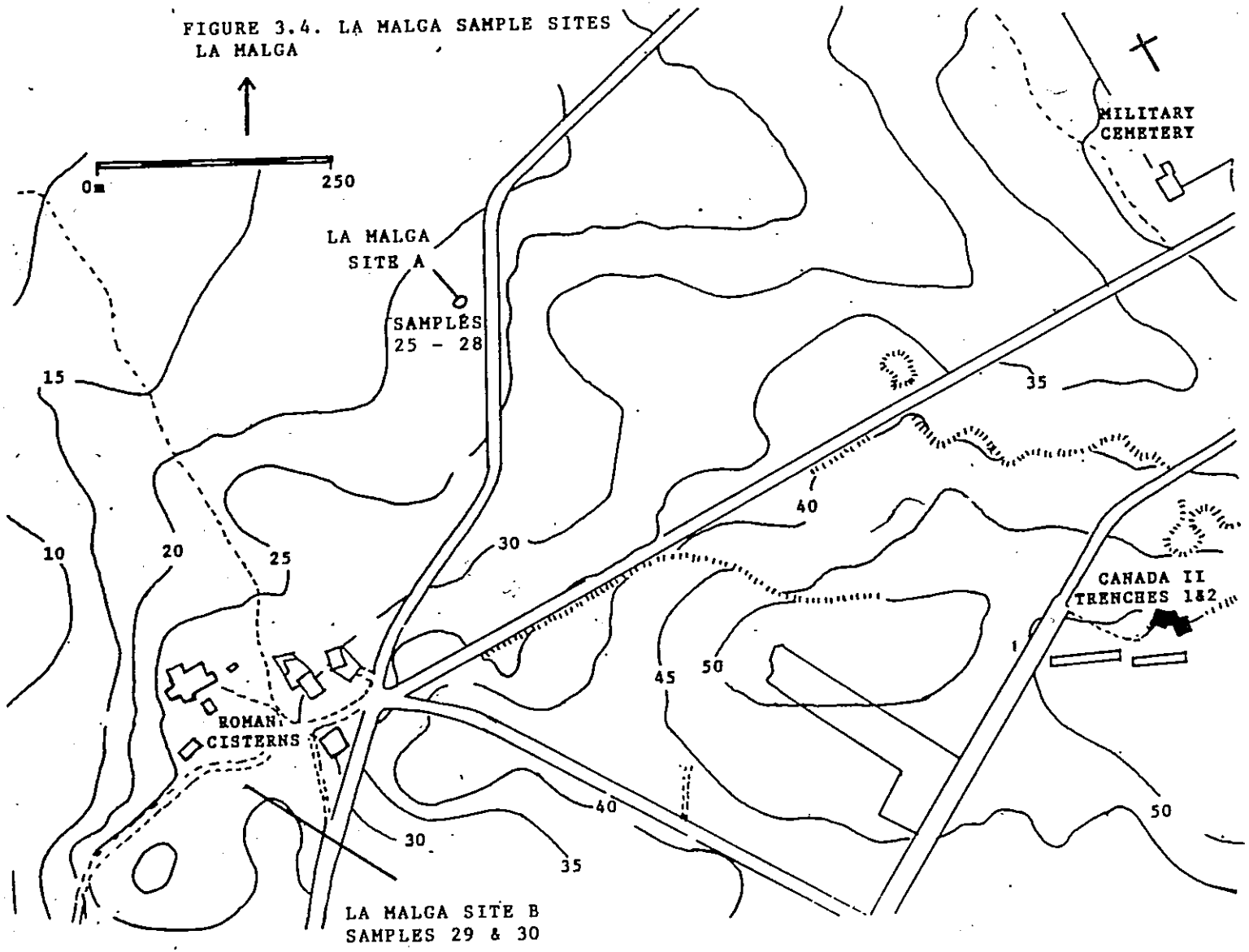


FIGURE 3.5

LOCATION OF BYRSA AND
COLLINE DE JUNON SAMPLE SITES.

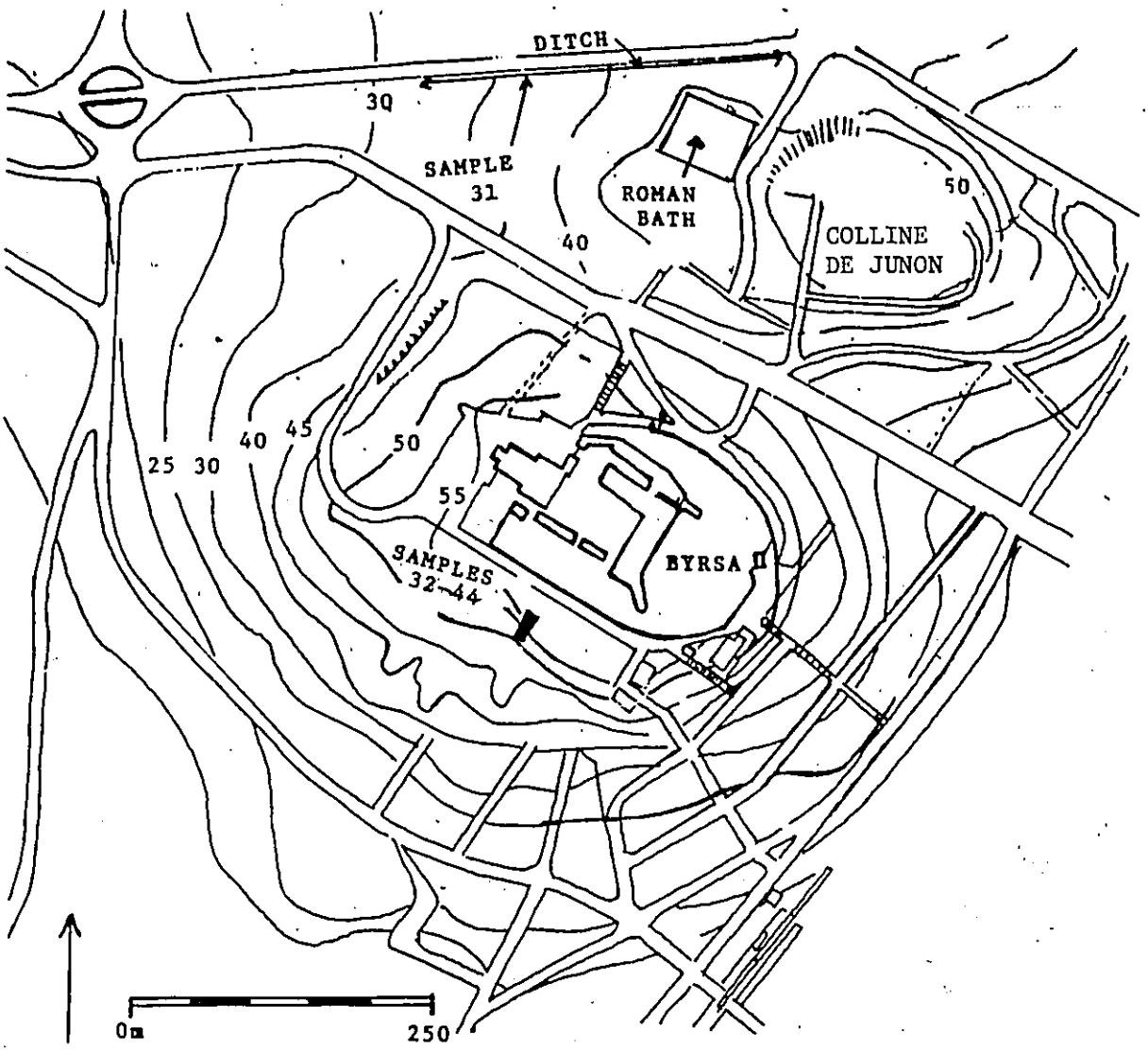


FIGURE 3.6

BYRSA SITE:
LOCATION OF
SAMPLES
34 - 41

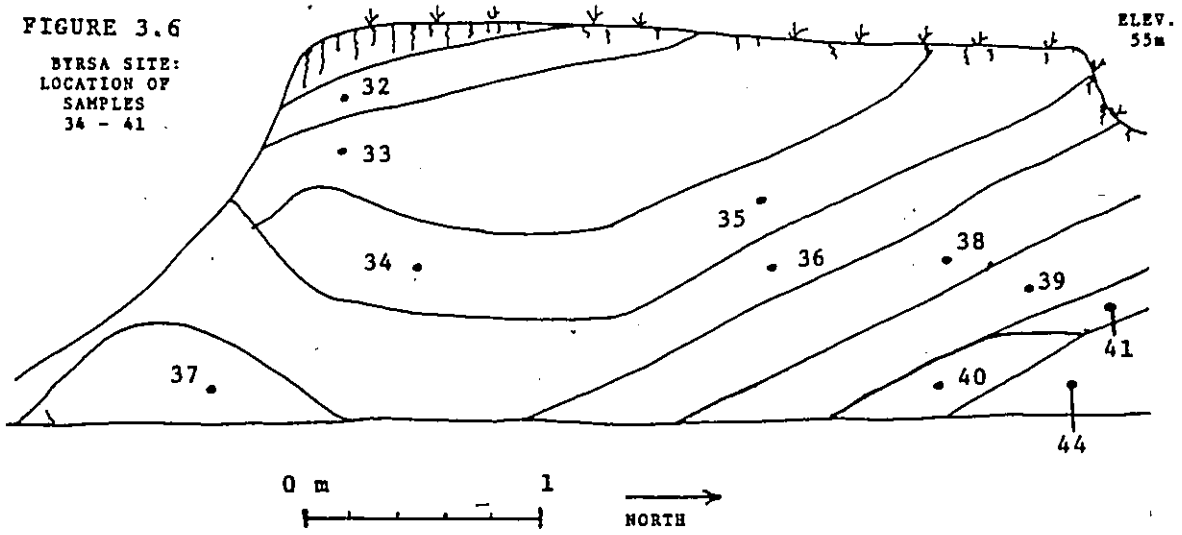


FIGURE 3.7

SAMPLE SITES
SOUTH AND EAST OF CARTHAGE

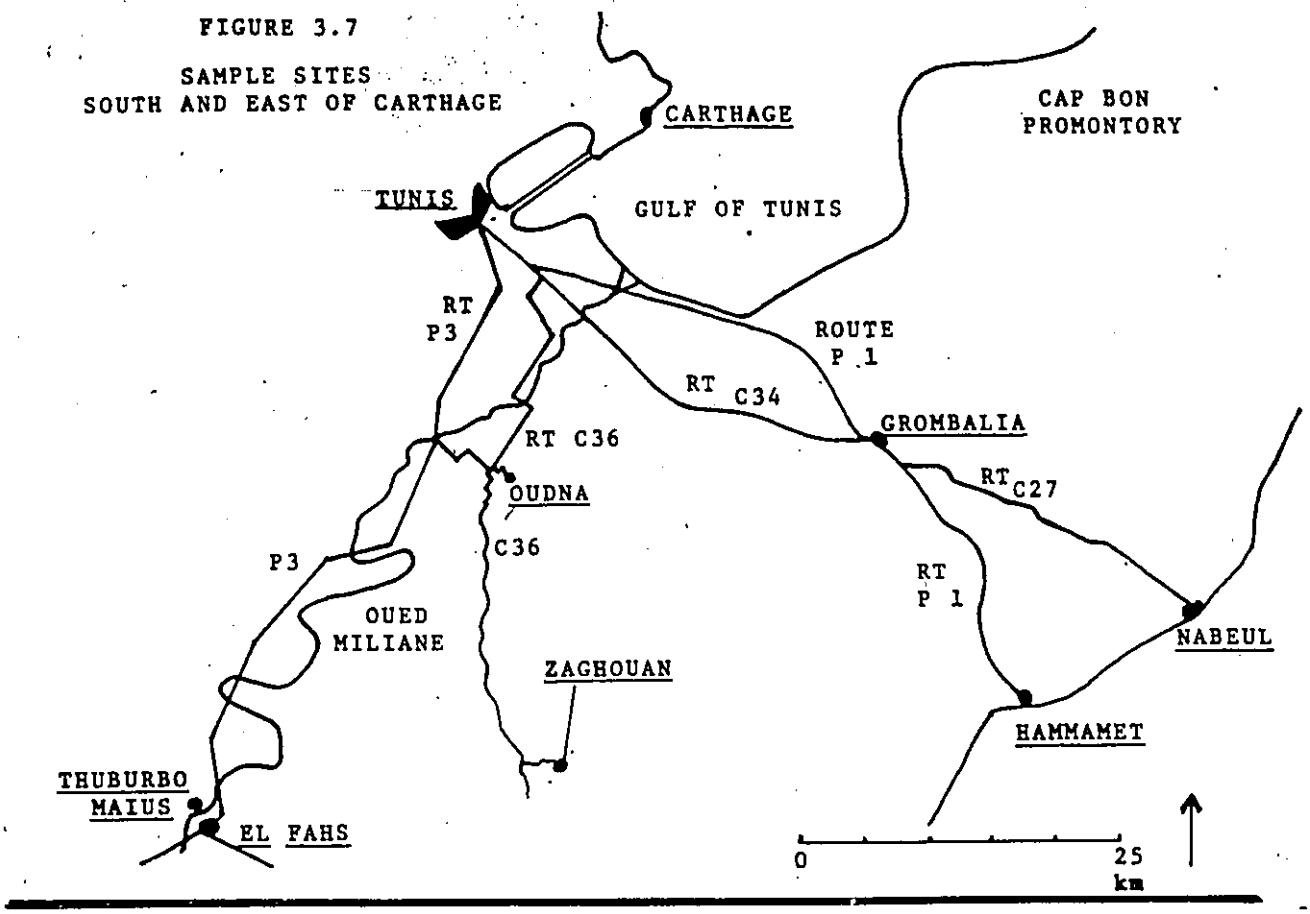


FIGURE 3.8
THUBURBO MAIUS SAMPLE SITES

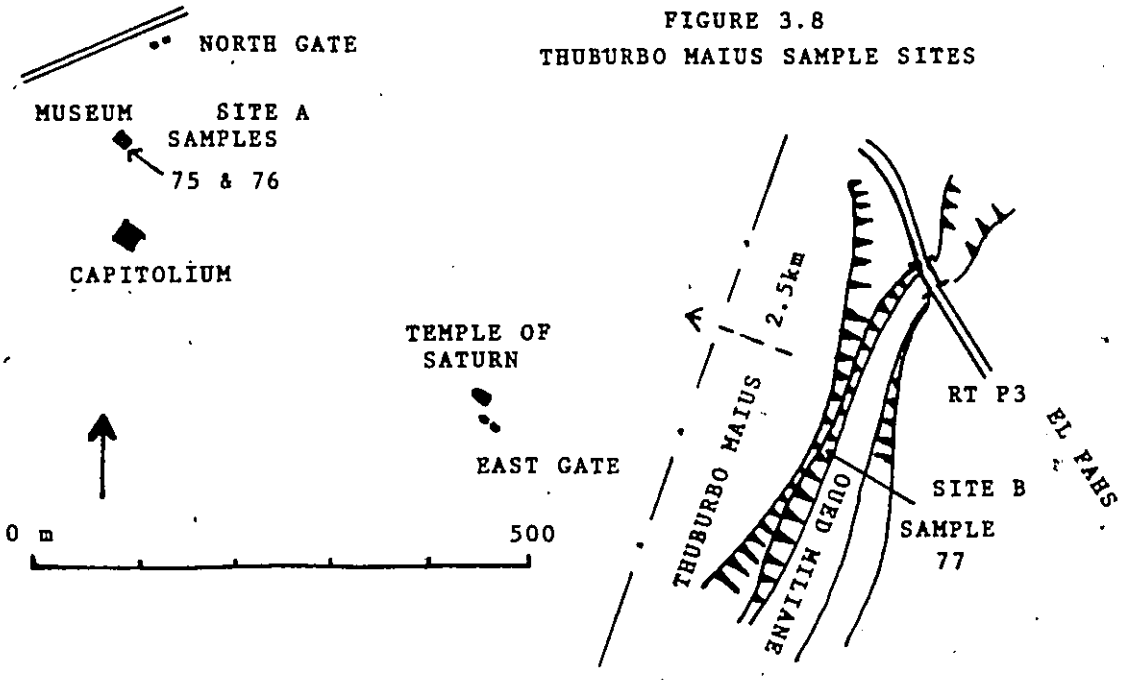


FIGURE 3.9.

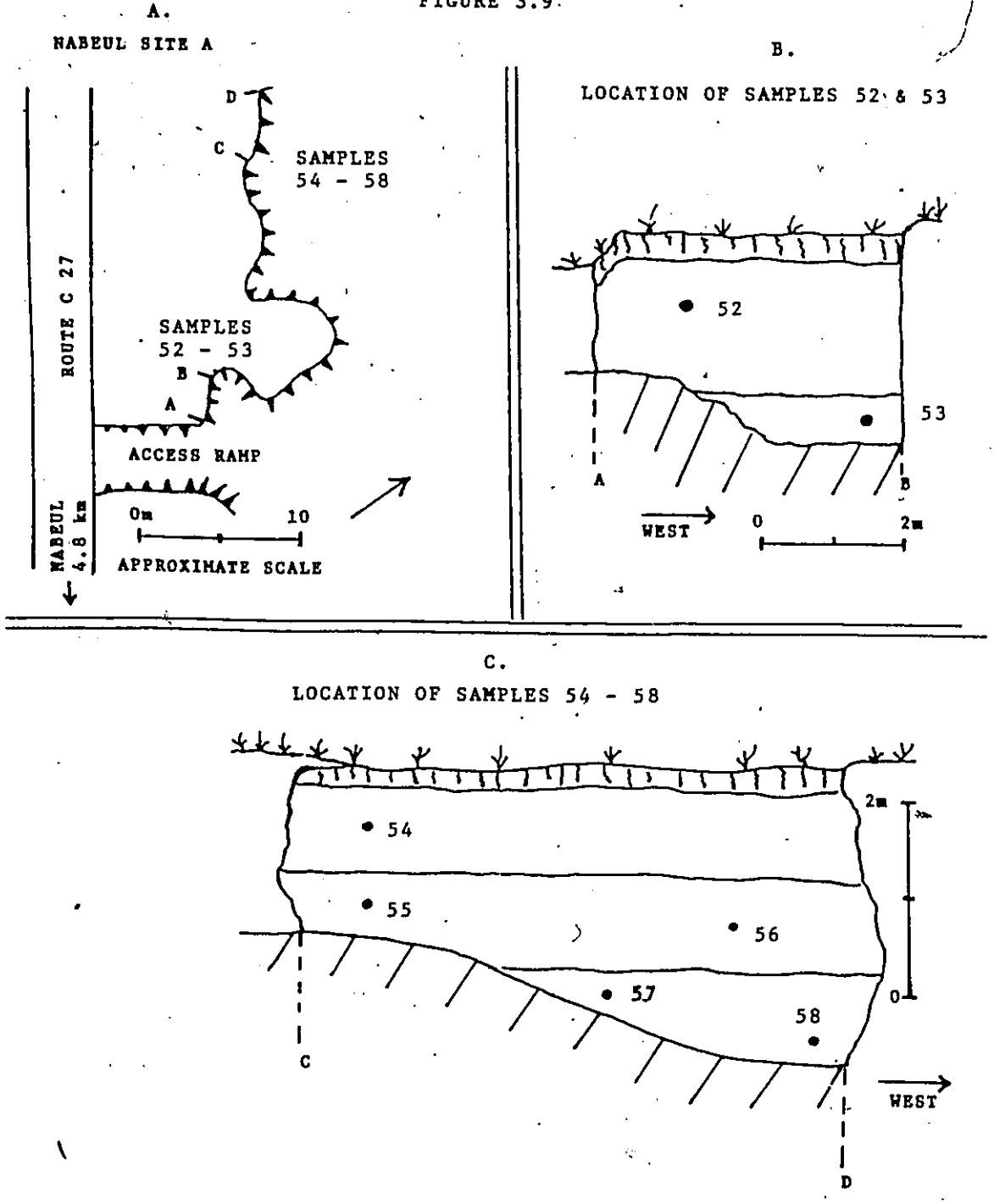

A.
NABEUL SITE A
D
C
SAMPLES
54 - 58
SAMPLES
52 - 53
B
A
ACCESS RAMP
ROUTE C 27
NABEUL
4.8 km
0m
10
APPROXIMATE SCALE
B.
LOCATION OF SAMPLES 52 & 53
52
53
A
B
WEST
0
2m
C.
LOCATION OF SAMPLES 54 - 58
54
55
56
57
58
2m
0
C
D
WEST

FIGURE 3.11 NABEUL SITE B: CONFIGURATION OF STRATA

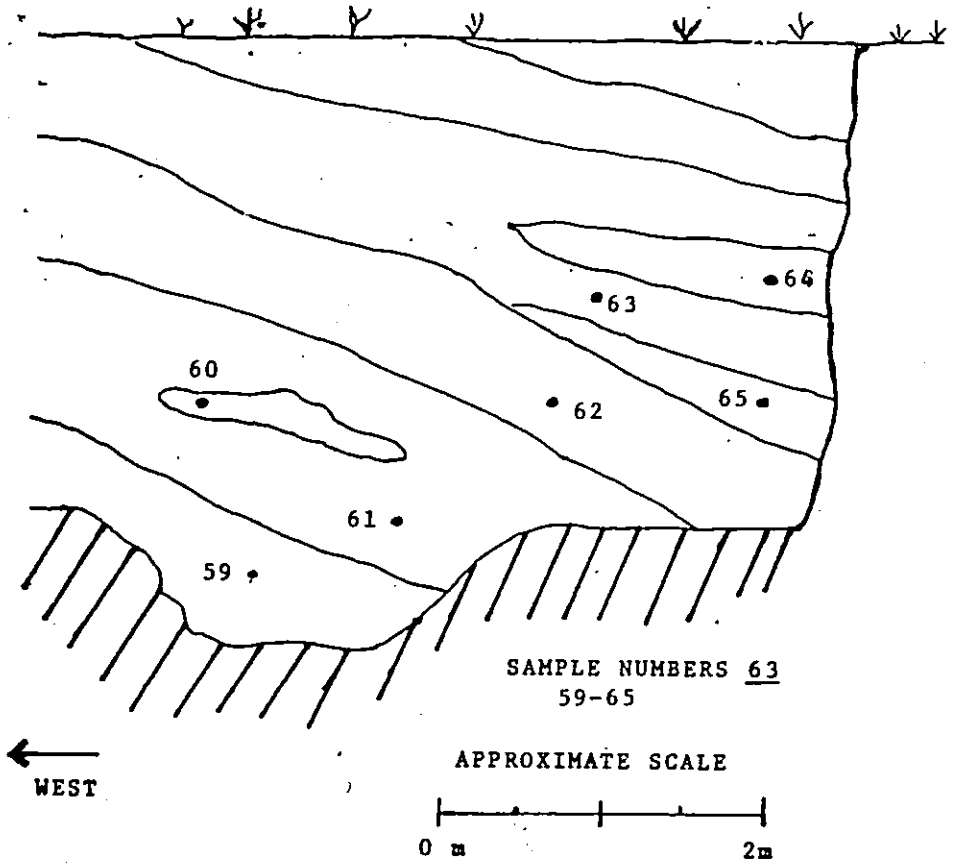


FIGURE 3.10 NABEUL SAMPLE SITE LOCATIONS

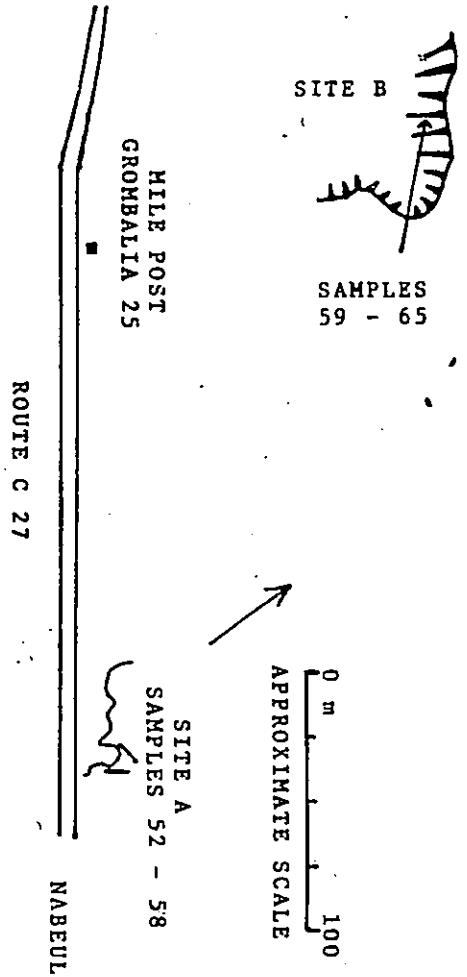


FIGURE 3.12

OUDNA SAMPLE SITES

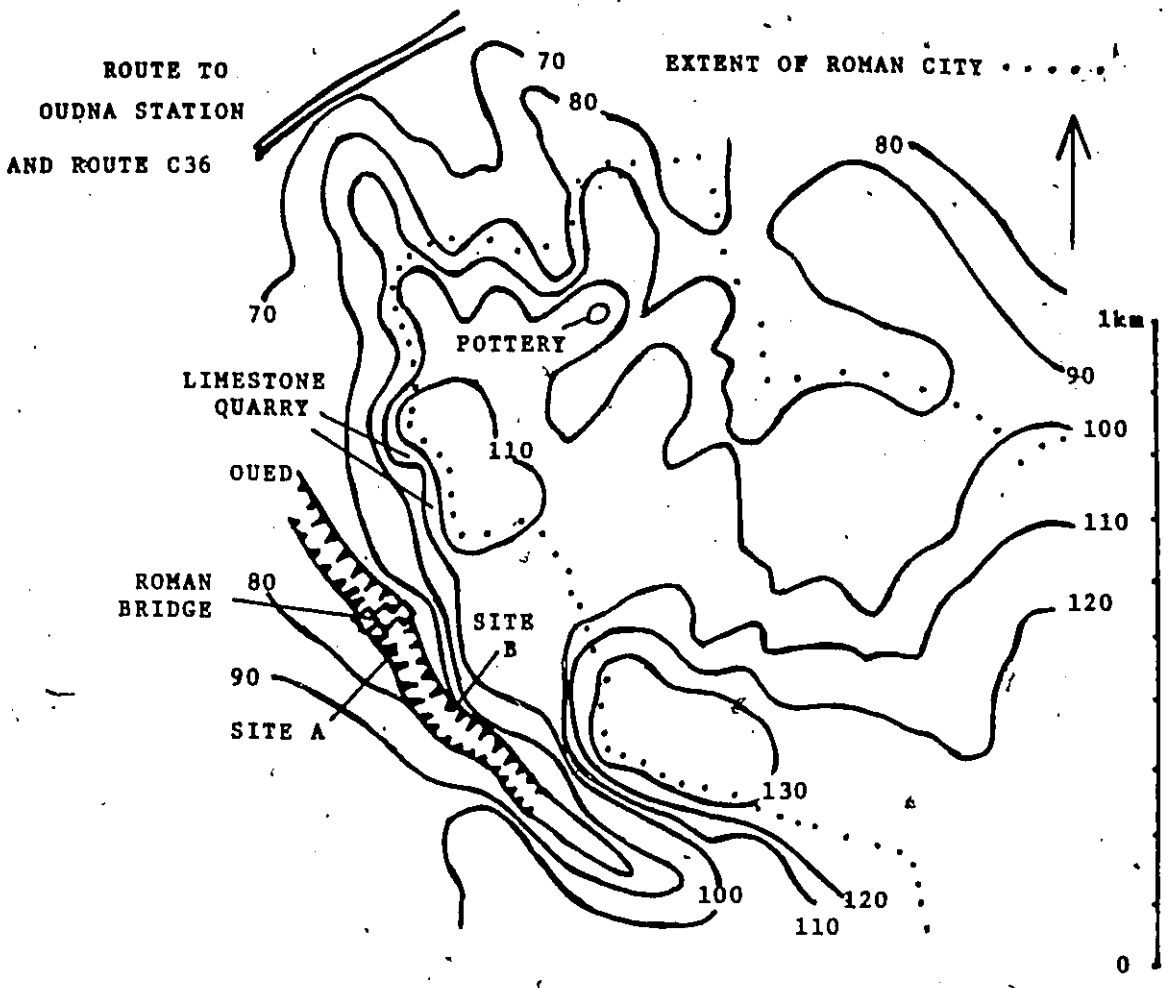
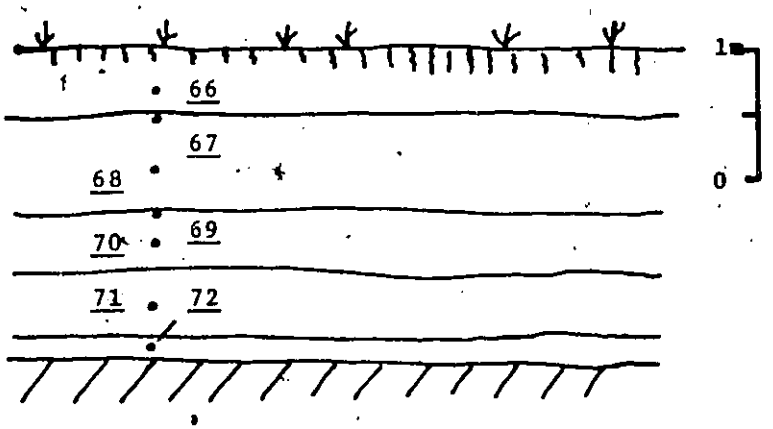


FIGURE 3.13

OUDNA SITE A:
DISPOSITION
OF STRATA

SAMPLES
66 - 72



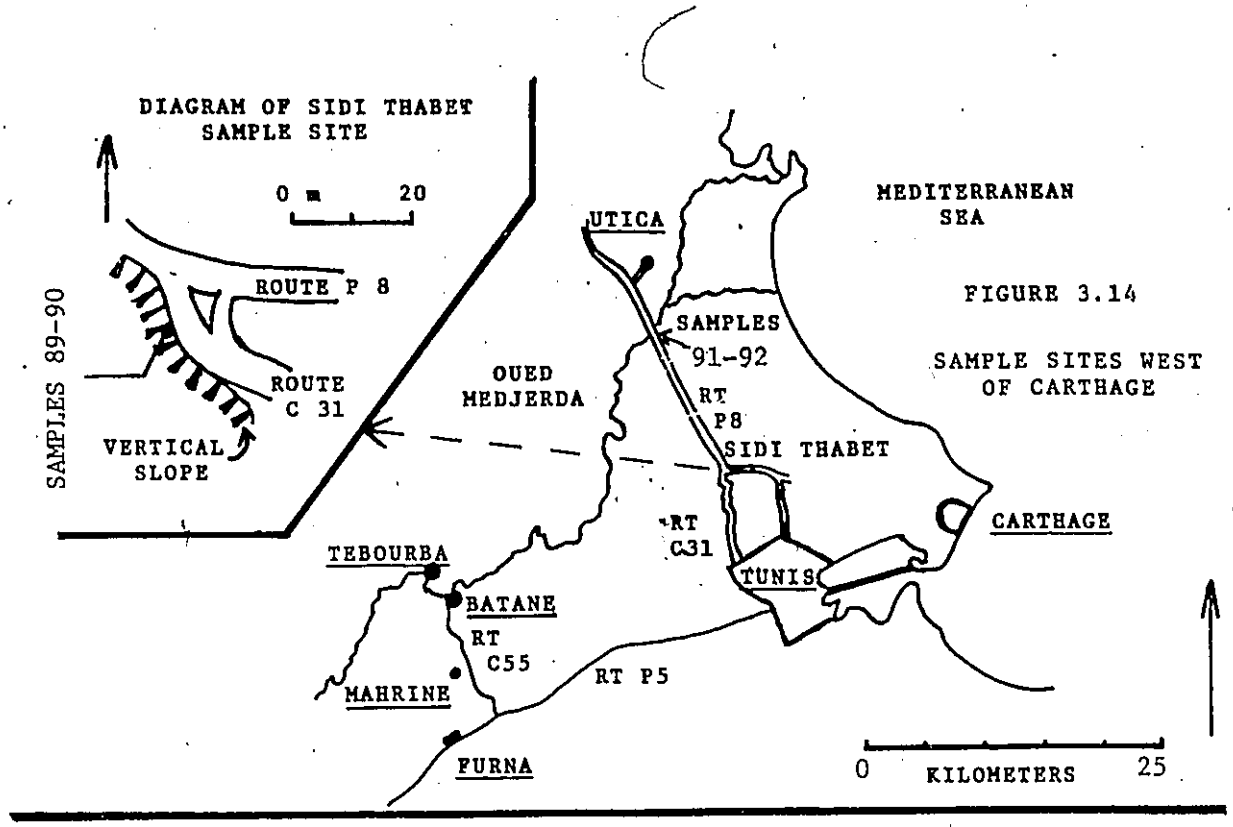


FIGURE 3.14

SAMPLE SITES WEST OF CARTHAGE

FIGURE 3.15

LOCATION OF SAMPLE SITES ON THE SOUTHEASTERN FLANK OF DJEBEL MAHRINE

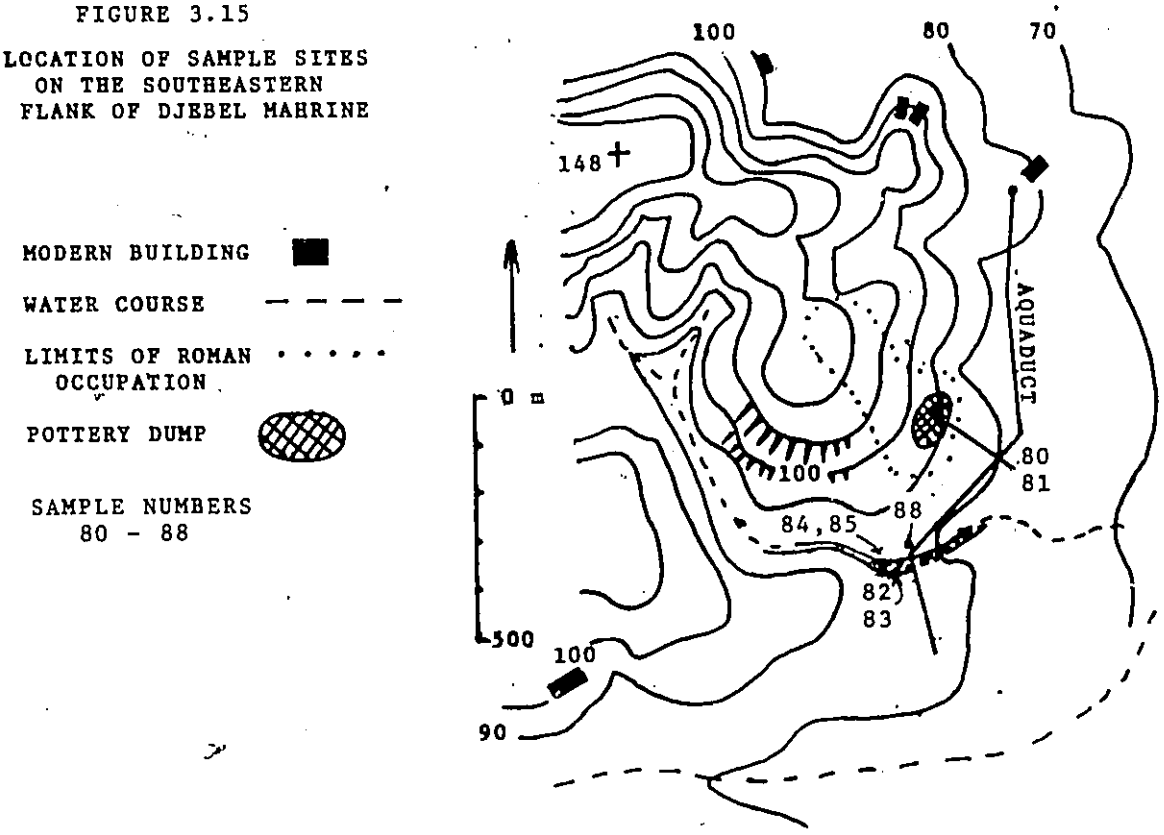


FIGURE 3.16

UTICA SAMPLE SITE

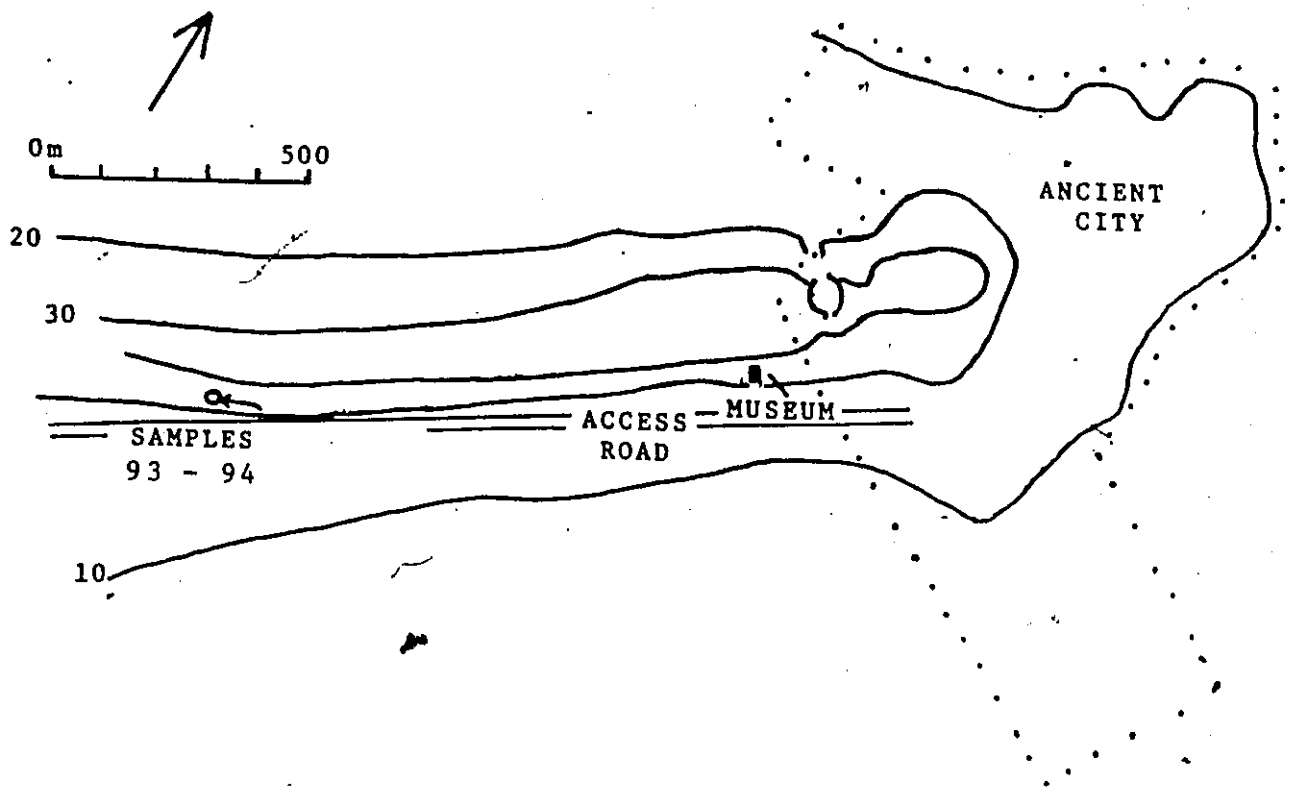
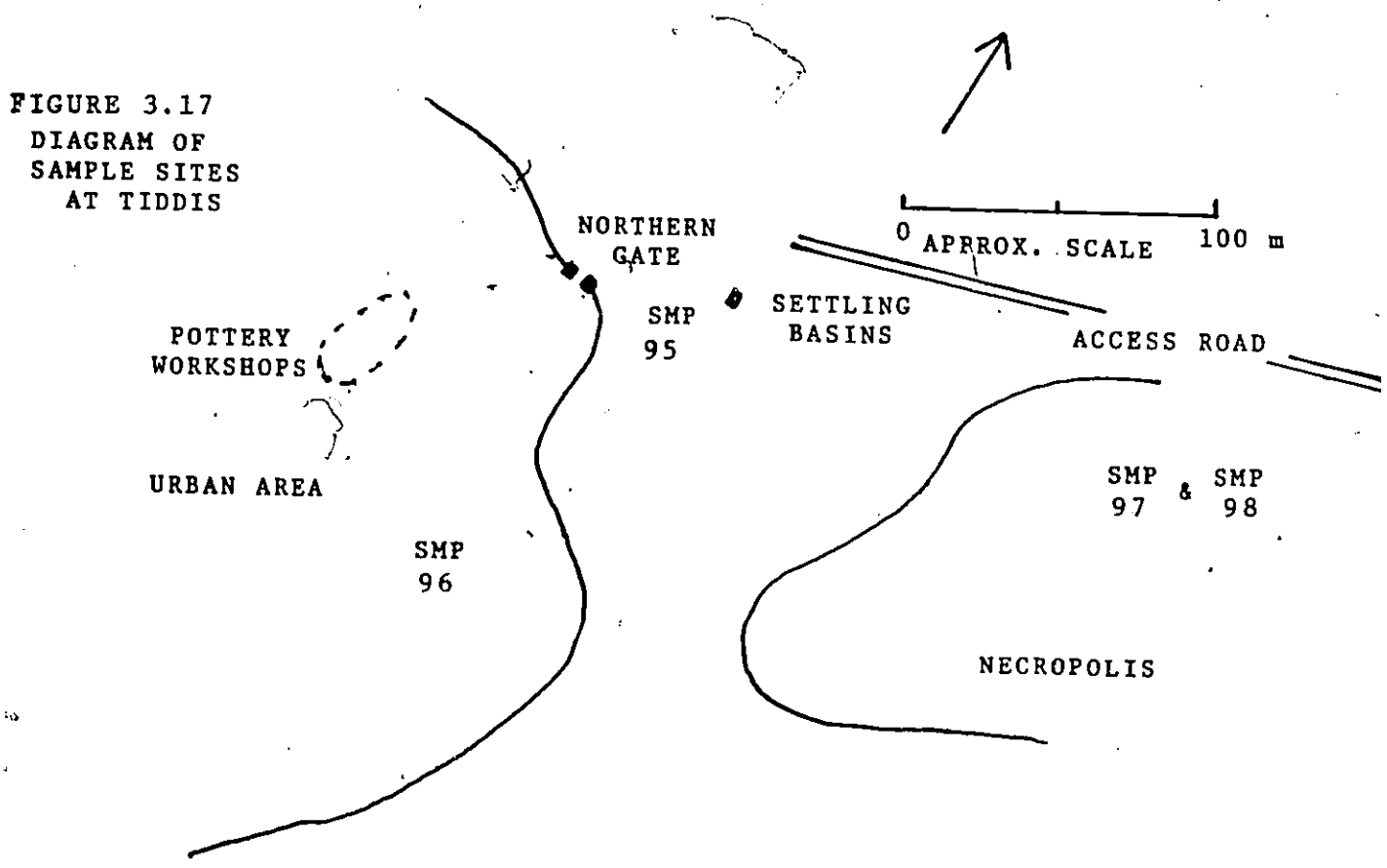


FIGURE 3.17

DIAGRAM OF SAMPLE SITES AT TIDDIS



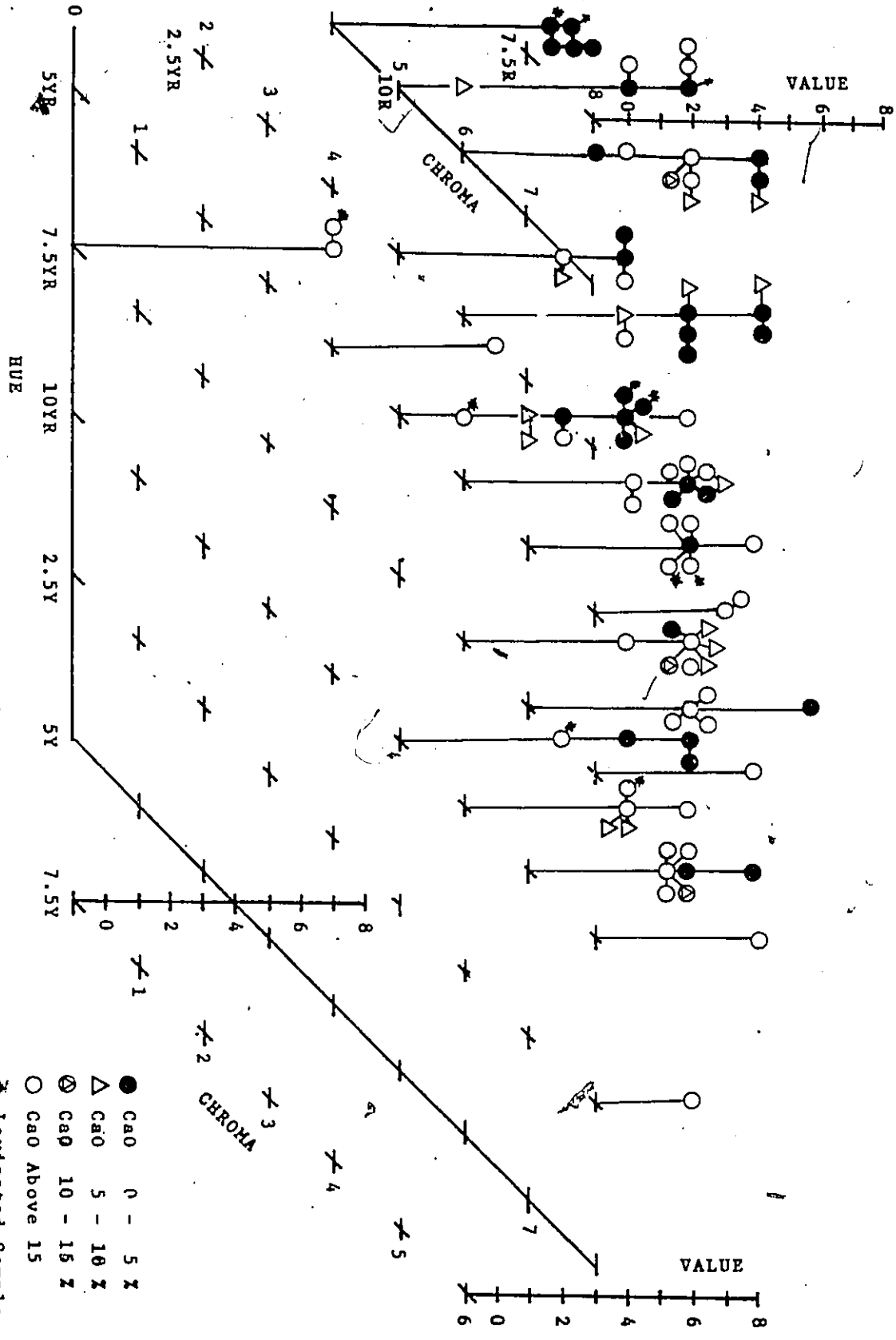
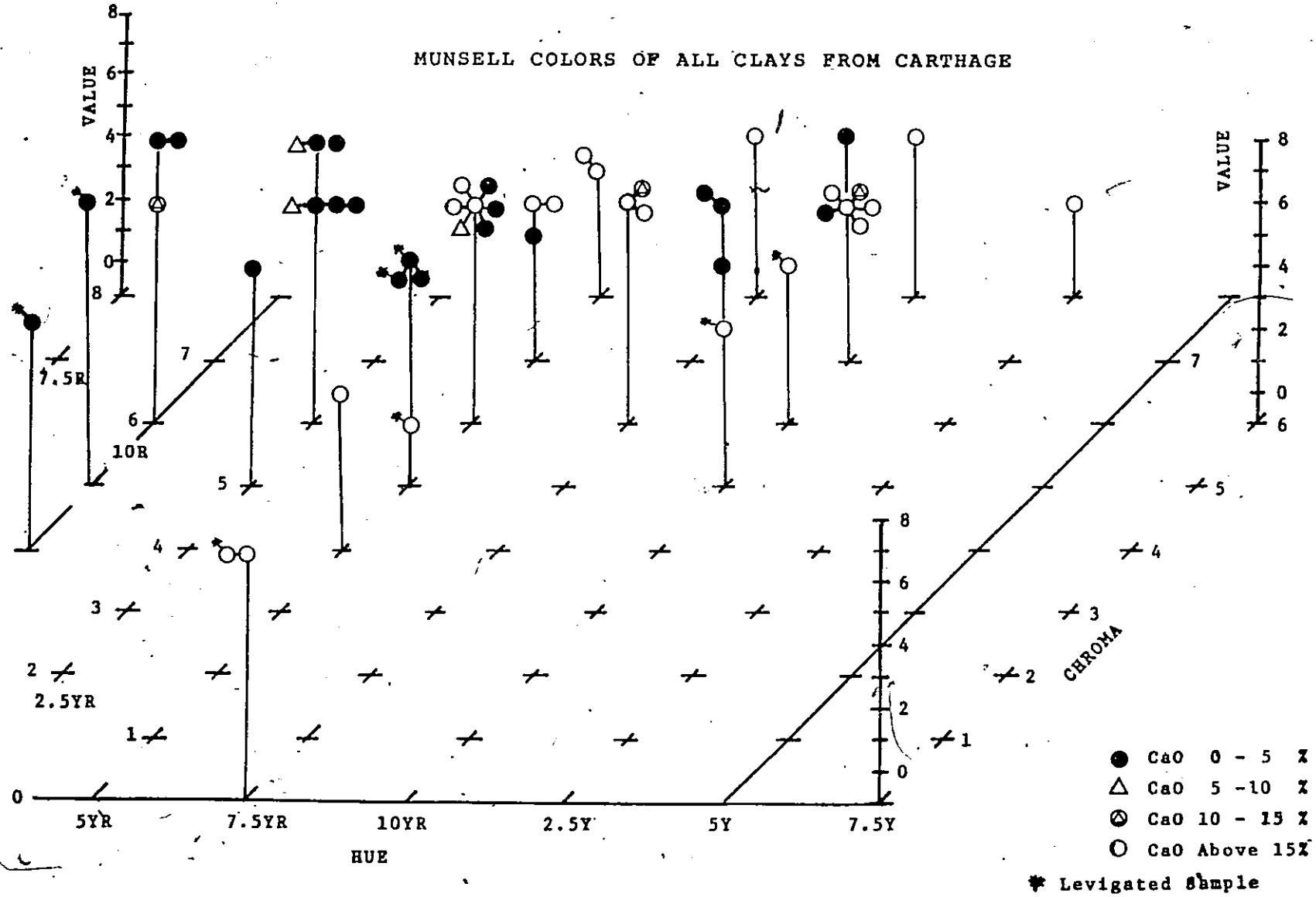

MUNSELL COLORS OF ALL CLAY SAMPLES
VALUE
CHROMA
HUE
5YR
2.5YR
7.5YR
10YR
2.5Y
5Y
7.5Y
7.5R
10R
CaO 0 - 5 %
CaO 5 - 10 %
CaO 10 - 15 %
CaO Above 15
Levigated Sample

FIGURE 3.18

FIGURE 3.19

MUNSELL COLORS OF ALL CLAYS FROM CARTHAGE



APPENDIX I.
FIRST DISCRIMINANT ANALYSIS: CLASSIFICATION RESULTS

SAMPLES FROM LOCI 1F30-36

CASE SEQNUM	SMP NUM	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP	P(D/G)	P(G/D)	2ND HIGHEST GROUP	P(G/D)	DISCRIMINANT SCORES...		
54	126	YES	43	43	0.9523	0.6245	42	0.2078	-0.1796	-2.5764	0.2815
									-0.1176	-0.4877	-0.7252
55	127	YES	43 **	63	0.9173	0.6161	49	0.1378	0.0891	-1.3443	-0.0124
									-0.2350	-0.6508	0.5279
56	128	YES	43	43	0.9764	0.5199	49	0.2269	0.1290	-1.9296	0.2936
									0.0263	-0.4079	-0.6707
57	129	YES	43	43	0.7800	0.4429	53	0.2970	-1.5300	-0.5852	1.2793
									0.8235	0.6592	-0.4882
58	130	YES	43	43	0.9991	0.6504	42	0.1098	-0.4672	-1.7869	0.8482
									0.5341	0.2035	0.0908
59	132	YES	43	43	0.1396	0.7780	42	0.1943	-0.9528	-2.1039	2.8655
									2.0264	0.6968	1.4335
60	133	YES	43	43	0.9446	0.8131	49	0.1020	-0.2129	-2.0529	2.1563
									-0.4106	0.6826	0.0086
61	134	YES	43	43	0.9457	0.8343	49	0.0880	-0.1160	-2.0709	1.9333
									-0.5441	0.4169	-0.5038
62	135	YES	43	43	0.9623	0.6488	42	0.1835	-0.7326	-1.6851	1.1054
									-0.1497	-0.2596	-1.4598
63	136	YES	43	43	0.6284	0.5280	49	0.2888	0.3814	-2.0868	1.7168
									-0.3435	-0.0479	-1.0610
64	138	YES	41 **	43	0.2451	0.4155	42	0.2276	-0.6027	-1.0914	0.5295
									-0.5761	-1.0331	0.4293
65	139	YES	42 **	43	0.9998	0.7139	42	0.1378	-0.5069	-1.7330	0.6814
									0.6335	0.3459	0.0097
66	140	YES	43	43	0.7880	0.3524	42	0.2550	-0.3506	-1.3572	0.1243
									-0.7815	-1.0253	-0.3484
67	141	YES	43	43	0.9863	0.6240	42	0.2809	-0.5721	-2.2605	0.7498
									0.5009	0.5443	0.3648
68	142	NO	43 **	42	0.1190	0.7878	43	0.1619	-1.1052	-2.4970	0.1224
									1.2636	0.9098	-0.5839
69	143	YES	42	42	0.8779	0.3850	43	0.3850	-0.3252	-1.9515	0.8963
									0.0753	-0.7786	0.5287
70	144	YES	42 **	43	0.9294	0.4910	42	0.2434	-0.0531	-2.0841	0.6479
									-0.3984	-1.0598	-0.3336
71	145	YES	41 **	49	0.1742	0.3834	41	0.2692	1.8223	-1.4094	1.1389
									-2.1697	-1.2759	1.3698
72	146	YES	43	43	0.8590	0.8305	42	0.0955	-0.2665	-2.7515	1.7118
									0.2877	0.9766	0.2741
73	147	NO	43	43	0.1566	0.7297	42	0.2406	-0.7565	-2.8212	2.2001
									1.3286	2.1793	1.0978

* GROUP CODE	FABRIC GROUP	* GROUP CODE	FABRIC GROUP	* GROUP CODE	FABRIC GROUP	* GROUP CODE	FABRIC GROUP	* GROUP CODE	FABRIC GROUP
* 30	MA I	* 43	F III	* 53	M III	* 63	N III	* 70	L I
* 41	F I	* 49	F IX	* 54	M IV	* 64	N IV	*	
42	F II	*				* 67	N VII	* 99	UNASSIGNED

APPENDIX I.

FIRST DISCRIMINANT ANALYSIS: CLASSIFICATION RESULTS

SAMPLES FROM LOCI 1F32 - 36

CASE SEQNUM	SMP NUM	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP	P(D/G)	P(G/D)	2ND HIGHEST GROUP	P(G/D)	DISCRIMINANT SCORES...		
74	148	YES	42 **	30	0.7530	0.3499	54	0.2523	0.2771	0.0427	-0.4336
									1.3416	0.2970	-0.0753
75	150	YES	42 **	43	0.9879	0.5732	42	0.1731	0.3620	-1.7658	0.5228
									0.7600	0.6483	0.5014
76	151	YES	43	43	0.9883	0.6380	42	0.1907	-0.3430	-2.3614	0.4012
									-0.2894	0.1811	-0.7144
77	152	YES	42 **	43	0.9735	0.6101	42	0.2877	-0.7054	-2.0681	0.8485
									0.7351	-0.1673	-0.7898
78	153	YES	43	43	0.9992	0.5409	63	0.1548	-0.4256	-1.1714	0.7947
									0.3720	0.2790	0.4920
79	155	YES	43	43	0.7520	0.4726	42	0.2561	-0.7397	-1.2309	1.6783
									-0.0089	-0.4842	1.0931
80	157	YES	43	43	0.9932	0.7841	42	0.0585	-0.5890	-1.2920	1.2825
									-0.3539	0.1292	0.7532
81	158	YES	41 **	43	0.1854	0.4016	42	0.3986	-0.8617	-0.9548	1.7192
									0.9510	1.2044	-1.9076
82	159	YES	43	43	0.9905	0.6737	49	0.1733	-0.0295	-1.9374	0.9075
									-0.7449	0.5941	0.1575
83	160	NO	43	43	0.3887	0.5000	42	0.4118	-0.7505	-2.2041	0.3030
									0.9214	0.8661	0.4311
84	161	YES	43	43	0.9656	0.6706	49	0.1010	0.0066	-1.6542	0.8257
									-0.0534	0.7027	0.6690
85	162	YES	43 **	53	0.8971	0.3510	54	0.3271	-0.8675	0.3509	-0.2478
									-0.5492	-0.2951	1.5239
86	163	YES	43	43	0.9339	0.5984	49	0.1662	-0.0235	-2.0285	0.2969
									-0.0762	0.3116	0.1484
87	164	YES	42 **	64	0.7887	0.3451	53	0.2609	-0.8441	-0.5796	0.0376
									0.0012	0.3659	-0.2455
88	167	YES	49 **	43	0.9924	0.5034	53	0.1166	-0.3022	-1.3947	0.0751
									-0.5686	0.3034	0.6071
89	168	YES	49 **	43	0.9718	0.5088	42	0.2219	0.4574	-2.3796	0.2233
									0.3238	0.3153	-0.1930
90	169	YES	49 **	43	0.9683	0.6373	49	0.1581	0.1986	-2.3485	0.6618
									-0.3746	-0.3707	-1.0161
91	170	YES	49 **	64	0.0171	0.4379	63	0.2972	0.7706	-2.0784	1.9582
									-1.0955	-0.1275	1.5227
92	171	YES	49	49	0.5213	0.6738	43	0.1454	2.8198	-1.1016	-0.3757
									-0.2183	0.3034	-0.4006
93	172	YES	49 **	43	0.9326	0.4857	42	0.1365	0.0995	-1.2522	0.0982
									0.6724	-0.9141	-0.5466
94	175	YES	43 **	63	0.9201	0.3012	53	0.2590	-0.1842	0.3107	0.0824
									0.5378	-0.1492	-0.1542
95	176	YES	43	43	0.5630	0.6174	42	0.1634	-0.4972	-1.7224	0.0601
									-0.4035	-0.4801	-0.7246

* GROUP CODE	FABRIC GROUP	* GROUP CODE	FABRIC GROUP	* GROUP CODE	FABRIC GROUP	* GROUP CODE	FABRIC GROUP	* GROUP CODE	FABRIC GROUP
* 30	MA I	* 43	F III	* 53	M III	* 63	N III	* 70	L I
* 41	F I	* 49	F IX	* 54	M IV	* 64	N IV	*	
42	F II	*				* 67	N VII	* 99	UNASSIGNED

APPENDIX I.

FIRST DISCRIMINANT ANALYSIS: CLASSIFICATION RESULTS

SAMPLES FROM LOCUS 1M7

CASE SEQNUM	SMP NUM	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP P(D/G)	P(G/D)	2ND HIGHEST GROUP P(G/D)	DISCRIMINANT SCORES...		
96	179	YES	53 **	30 0.3297	0.6568	54 0.1464	-0.6220	0.1066	-2.0332
							0.5935	-1.7529	1.0275
97	181	YES	53 **	30 0.9261	0.5004	53 0.2276	-1.2210	0.5914	-0.8344
							0.9167	-0.3137	-0.6200
98	182	YES	54 **	53 0.9822	0.4475	54 0.2363	-1.2220	0.4781	-0.3343
							0.4247	-0.5009	-0.4432
99	183	YES	54	54 0.9352	0.4429	30 0.2351	0.1763	1.4556	-1.2083
							0.1756	-0.4240	-0.7703
100	184	NO	54 **	30 0.8471	0.5126	54 0.2677	-0.1304	-0.0418	-1.4227
							0.2512	0.4851	-0.5968
101	185	YES	53	53 0.0622	0.7440	54 0.1542	0.2756	0.1264	-0.6097
							-0.1069	-2.7891	0.4190
102	186	NO	53 **	30 0.0042	0.8814	54 0.0848	0.7711	1.8448	-1.4947
							2.0712	-1.9169	-1.2727
103	187	YES	54 **	53 0.9935	0.3427	63 0.2147	-1.1999	0.4619	-0.1035
							0.8364	-0.2059	-0.4362
104	188	YES	54 **	64 0.8334	0.5000	54 0.1712	-0.7165	0.7439	-0.4495
							1.1679	0.6056	0.8017
105	189	YES	54 **	43 0.2682	0.3046	54 0.1738	0.4335	-0.0788	0.3552
							-1.6155	-0.4786	-0.3343
106	191	YES	53 **	63 0.9211	0.6240	43 0.1075	0.0932	0.0954	1.6819
							-0.7405	-0.1607	-0.0578
107	193	YES	53 **	63 0.9759	0.6031	53 0.1746	-0.6162	0.2669	0.8460
							0.4224	-0.8899	-0.5533
108	194	YES	54	54 0.4623	0.4544	63 0.1499	1.0193	0.3448	-0.2436
							-2.4904	0.3777	0.9771
109	195	NO	54	54 0.1106	0.5807	30 0.1420	-0.2642	1.2727	-0.4249
							-2.6979	0.8774	2.3876

GROUP CODE	FABRIC GROUP	GROUP CODE	FABRIC GROUP	GROUP CODE	FABRIC GROUP	GROUP CODE	FABRIC GROUP	GROUP CODE	FABRIC GROUP
30	MA I	43	F III	53	M III	63	N III	70	L I
41	F I	49	F IX	54	M IV	64	N IV		
42	F II					67	N VII	99	UNASSIGNED

APPENDIX I.
FIRST DISCRIMINANT ANALYSIS: CLASSIFICATION RESULTS.

SAMPLES FROM LOCUS 1M7

CASE SEQNUM	SMP NUM	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP P(D/G)	P(G/D)	2ND HIGHEST GROUP	P(G/D)	DISCRIMINANT SCORES...		
110	196	YES	53	53	0.9026 0.5852	54	0.2072	-0.6652	0.4943	-0.2728
								0.3037	0.0565	-1.1000
111	197	YES	54 **	53	0.7651 0.5889	43	0.1960	-0.2259	-0.0701	1.0149
								1.0531	0.3878	-0.3672
112	198	YES	53 **	54	0.4137 0.4926	30	0.2516	-1.2995	0.1019	-0.6469
								-1.6432	1.6426	-0.2104
113	199	YES	53 **	43	0.4991 0.6332	53	0.1568	-1.0435	-0.4382	1.9115
								1.6887	1.3658	-0.7097
114	200	YES	53 **	63	0.9463 0.4656	53	0.2024	-0.3133	-0.1768	0.5534
								0.0310	-0.0614	-0.1591
115	201	YES	54 **	63	0.4465 0.7012	54	0.1213	0.3749	0.4326	-0.5039
								-1.2867	1.5016	1.2546
116	202	YES	54	54	0.7584 0.4318	30	0.1933	-0.6740	1.5673	-0.7076
								-1.4815	0.9775	-1.0825
117	203	YES	54	54	0.6101 0.5439	30	0.2077	1.4561	0.2471	-1.0011
								0.8210	0.6325	0.0375
118	204	YES	53	53	0.7947 0.5284	63	0.2483	-1.3638	1.4305	0.8255
								0.8851	0.4551	0.9562
119	207	YES	53 **	63	0.7783 0.6382	54	0.1017	-0.4262	0.7862	0.8224
								-0.4810	-0.4499	0.4027
120	210	YES	53 **	64	0.9772 0.6932	54	0.1342	0.2283	0.3529	-0.5311
								0.1823	0.5924	-0.0611
121	211	YES	53 **	43	0.7384 0.3303	63	0.1784	0.2179	-0.6283	1.0713
								-1.4199	1.1616	-0.2132
122	212	NO	53 **	43	0.3911 0.3574	42	0.1840	-0.1990	-0.5729	1.6579
								-0.4375	1.6765	0.0389
123	213	YES	54 **	53	0.9011 0.3085	54	0.2472	-1.0240	-0.1627	0.2393
								0.0461	-0.3161	-0.6186
124	215	YES	53	53	0.7697 0.6000	54	0.1524	0.0341	-0.1185	-0.6711
								0.8150	-0.7262	0.9562
125	216	YES	54 **	64	0.7828 0.4920	30	0.2384	-0.6323	0.8401	-1.5255
								0.1823	0.5924	-0.0611

* GROUP CODE	FABRIC GROUP	* GROUP CODE	FABRIC GROUP	* GROUP CODE	FABRIC GROUP	* GROUP CODE	FABRIC GROUP	* GROUP CODE	FABRIC GROUP	* GROUP CODE	FABRIC GROUP
* 30	MA I	* 43	F III	* 53	M III	* 63	N III	* 70	L I		
* 41	F I	* 49	F IX	* 54	M IV	* 64	N IV	*			
42	F II	*				* 67	N VII	* 99	UNASSIGNED		

APPENDIX I.

SAMPLES FROM MAHRINE — FIRST DISCRIMINANT ANALYSIS: CLASSIFICATION RESULTS

CASE SEQNUM	SMP NUM	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP P(D/G) P(G/D)	2ND HIGHEST GROUP P(G/D)	DISCRIMINANT SCORES...		
125	226	YES	30 **	63 0.9923 0.6032	64 0.1722	-1.0655	0.1008	-0.2742
						0.5779	0.3260	0.6413
127	227	YES	30 **	43 0.9882 0.4889	42 0.1162	0.2140	-1.1856	0.1845
						0.6315	-0.2686	0.1329
128	228	YES	30	30 0.9481 0.5163	54 0.2131	-0.8596	0.1474	-0.9191
						-0.4035	-0.4363	1.4122
129	229	NO	30 **	63 0.9892 0.4811	64 0.1965	-0.7378	0.4360	-0.4127
						-0.0577	-0.4627	0.9138
130	230	YES	30	30 0.0000 0.5040	54 0.3207	1.1531	0.3074	-3.5166
						-2.0786	4.9581	0.6079
131	231	YES	30	30 0.9299 0.8786	54 0.0655	-0.9849	-0.3883	-2.0063
						0.1194	-0.0365	1.3285
132	232	YES	30	30 0.9999 0.6929	54 0.1276	-0.4998	-0.2303	-1.5067
						0.0570	-0.1949	0.5036
133	233	YES	30	30 0.9995 0.4672	54 0.1705	-0.8031	-0.2759	-1.0547
						-0.0019	0.1557	-0.0168
134	234	YES	30	30 0.9786 0.8144	54 0.0789	-1.0786	-0.0835	-1.5445
						1.0040	-0.6842	0.1653
135	235	YES	30 **	63 0.8259 0.4202	30 0.2250	-0.5595	0.0742	-0.9768
						0.4483	-0.4529	1.8509
136	236	YES	30	30 0.0155 0.7115	53 0.1138	-0.5662	1.3553	-0.2584
						-0.0951	-2.4824	1.9664
137	237	YES	30	30 0.9953 0.6130	54 0.1685	-0.6520	-0.4451	-1.1333
						-0.2378	-0.1955	-0.3114
138	238	YES	30	30 0.9001 0.5906	54 0.1292	-0.9468	0.3020	-0.8296
						0.9730	-0.0198	1.2815
139	239	YES	30 **	53 0.6658 0.2900	30 0.2703	-0.7990	-0.6725	-0.4241
						0.8361	0.6814	-0.1710
140	240	YES	30	30 0.7278 0.8407	54 0.0562	-0.6875	-0.9383	-1.4881
						0.1669	-0.0485	-0.9250
141	241	YES	30	30 0.9479 0.9673	54 0.0220	-0.6800	0.5427	-3.1155
						-0.5109	-0.1597	-1.0093
142	242	YES	30	30 0.9822 0.7695	54 0.0957	-0.7500	-0.4101	-1.7706
						-0.6270	-0.4522	-1.0845
143	243	YES	30	30 0.8808 0.9816	54 0.0136	-1.3768	0.6911	-3.1436
						-0.1256	0.2985	-0.6071
144	244	YES	30	30 0.8306 0.9879	54 0.0080	-1.1090	0.7636	-3.5454
						-0.4002	-0.9134	-0.4846
145	245	YES	30	30 0.3991 0.9913	54 0.0067	-0.9835	1.5558	-3.8982
						-0.8349	-0.3257	-1.0848
146	246	YES	30	30 0.2339 0.5376	54 0.1937	-0.8319	2.3086	-1.9107
						0.7495	-0.3255	-2.1012
147	247	YES	30	30 0.1939 0.9803	63 0.0101	-1.4376	1.8954	-3.6406
						-0.7262	-0.6014	-1.3380
148	248	YES	30	30 0.9754 0.9532	54 0.0303	-1.0002	-0.2473	-2.5046
						0.6292	0.6124	-0.3982
149	249	YES	UNGRPD	30 0.9108 0.7533	54 0.1280	-1.0081	0.0233	-1.8473
						0.0555	0.0463	-0.7252

* GROUP CODE	FABRIC GROUP	* GROUP CODE	FABRIC GROUP	* GROUP CODE	FABRIC GROUP	* GROUP CODE	FABRIC GROUP	* GROUP CODE	FABRIC GROUP
* 30	MA I	* 43	F III	* 53	M III	* 63	N III	* 70	L I
* 41	F I	* 49	F IX	* 54	M IV	* 64	N IV	*	
42	F II	*				* 67	N VII	* 99	UNASSIGNED

APPENDIX I.

SAMPLES FROM LOCUS 1N17 FIRST DISCRIMINANT ANALYSIS: CLASSIFICATION RESULTS.

CASE SEQNUM	SMP NUM	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP P(D/G)	P(G/D)	2ND HIGHEST GROUP	P(G/D)	DISCRIMINANT SCORES...		
150	250	YES	64	64	0.9672 0.7686	63	0.1396	0.0371	0.6744	-0.6549
								1.1387	0.3882	0.1731
151	251	YES	63	63	0.8678 0.4872	53	0.3224	-1.1439	1.1435	0.1685
								1.0063	0.0571	0.9604
152	252	YES	64 **	63	0.9838 0.7991	64	0.0930	0.3597	0.6540	-0.3115
								0.0893	0.0506	0.6338
153	253	YES	63	63	0.9698 0.5666	53	0.2225	-0.2436	-0.2121	0.5600
								0.5620	-0.5788	0.1488
154	255	YES	63	63	0.9953 0.6561	53	0.1322	-0.5965	-0.2149	0.6106
								0.9266	-0.0264	-0.2663
155	356	NO	64 **	63	0.9482 0.6379	64	0.2871	0.1622	-0.4533	0.2130
								-0.7455	0.1196	-0.0024
156	357	YES	64 **	63	0.9101 0.6197	64	0.3380	-0.3405	1.0169	-0.0834
								0.0719	0.4015	-0.5769
157	358	YES	64	64	0.4189 0.6626	63	0.2898	0.2552	0.0319	-0.4117
								-0.3429	-0.8192	-0.1398
158	359	YES	63	63	0.9075 0.7571	30	0.0968	-0.7156	0.6995	-1.2318
								-0.5347	-0.2420	0.8937
159	362	YES	63	63	0.7871 0.8634	30	0.0546	-0.9081	1.3201	-0.8503
								0.8312	-0.1739	0.1025
160	363	YES	63 **	43	0.0000 0.6717	42	0.1317	-1.0888	-0.7568	1.7178
								-0.3249	4.7284	-3.2352
161	364	YES	63	63	0.9486 0.8340	53	0.0526	-1.1178	0.4594	-0.4583
								0.2557	0.6940	0.9762
162	365	YES	64	64	0.5748 0.4099	63	0.1661	-0.6943	-0.4012	-0.3118
								0.5960	1.5901	-0.5564
163	366	YES	63	63	0.9411 0.6307	53	0.1453	0.0771	-0.4193	0.5402
								-0.2698	-0.9713	-1.0511
164	367	YES	64	64	0.9534 0.8667	63	0.0591	0.5920	-0.5913	-0.6821
								-0.4582	-0.7184	0.1194
165	368	YES	63	63	0.9059 0.8020	64	0.1435	-0.5094	-0.1495	0.8624
								-0.7707	-0.5560	-0.0309
166	370	YES	64	64	0.5963 0.8258	63	0.1343	1.3503	-0.4684	-0.3462
								-1.5960	-0.1152	-1.0980
167	371	YES	63	63	0.7450 0.6927	53	0.1539	0.4771	-0.2316	-0.5310
								-0.3034	-0.5083	-0.1316
168	372	YES	63	63	0.6105 0.5610	43	0.2243	-0.0156	-0.5332	1.6773
								0.7013	-1.0665	-0.3802
169	373	YES	63	63	0.6496 0.3483	49	0.3369	1.6679	-0.8015	0.7647
								0.6655	-0.3912	0.0023
170	374	YES	63	63	0.9332 0.3820	43	0.3089	-0.3902	-0.8109	1.0382
								-1.2432	-0.2391	0.1728
171	375	YES	63 **	64	0.4969 0.7149	63	0.1141	-0.2814	-1.1360	-0.7626
								0.7013	-1.0665	-0.3802

* GROUP CODE	FABRIC GROUP	* GROUP CODE	FABRIC GROUP	* GROUP CODE	FABRIC GROUP	* GROUP CODE	FABRIC GROUP	* GROUP CODE	FABRIC GROUP
* 30	MA I	* 43	F III	* 53	M III	* 63	N III	* 70	L I
* 41	F I	* 49	F IX	* 54	M IV	* 64	N IV	*	
42	F II	*				* 67	N VII	* 99	UNASSIGNED

APPENDIX I.

SAMPLES FROM LOCUS 1N17 FIRST DISCRIMINANT ANALYSIS: CLASSIFICATION RESULTS.

CASE SEQNUM	SMP NUM VAL	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP P(D/G) P(G/D)	2ND HIGHEST GROUP P(G/D)	DISCRIMINANT SCORES...		
172	376	YES	63	63 0.8480 0.5684	64 0.2790	0.7184	-0.2172	-0.9129
						-1.4330	-0.2472	-0.0403
173	377	YES	64	64 0.9289 0.8776	63 0.0772	-0.2575	-0.2304	0.6530
						-0.1609	-0.9119	0.0536
174	378	YES	67	67 0.3312 1.0000	49 0.0000	21.9685	-1.1544	-0.3991
						-1.0905	-0.7450	-0.7361
175	379	YES	67	67 0.3312 1.0000	49 0.0000	22.9615	1.3452	-0.5239
						1.1950	0.7494	0.7448
176	380	YES	64	64 0.9904 0.8207	63 0.1010	-0.1831	-0.1127	-0.4803
						0.2385	0.3731	1.1493
177	381	NO	64	64 0.9996 0.8475	63 0.0917	-0.2134	-0.2318	-0.7635
						-0.2172	0.1877	0.1789
178	382	YES	63	63 0.9027 0.3254	30 0.2010	-0.9978	0.1818	-0.7558
						0.4640	-0.1307	-0.0583
179	383	YES	63	63 0.9575 0.4119	53 0.2303	-0.5550	-0.5701	0.2695
						-0.4734	-0.4841	-1.2402
180	385	NO	63	63 0.1525 0.7453	64 0.1966	-1.5432	0.6477	1.1041
						1.6010	1.7431	1.5675
181	386	YES	63	63 0.8216 0.7635	53 0.1142	-1.4013	1.2234	0.0436
						0.9839	0.6922	0.9148
182	387	YES	64	64 0.9945 0.5559	63 0.2176	-0.3932	0.0242	-0.1565
						0.0985	0.3897	0.8561
183	388	YES	63 **	64 0.7963 0.7591	63 0.0689	0.7532	-1.1557	0.4218
						-0.2655	-1.1898	-0.0206
184	389	NO	63 **	30 0.0339 0.8897	54 0.0714	-1.2440	-0.4973	-2.0679
						0.6079	0.6618	-1.2490
185	390	YES	63 **	30 0.8965 0.3822	54 0.3774	-0.4154	0.7768	-0.9791
						0.7101	0.7212	0.5222
186	391	YES	63	63 0.6063 0.5522	30 0.2292	-1.8770	0.7788	-0.4914
						1.1015	0.6444	1.3074
187	392	YES	63 **	30 0.3030 0.4518	63 0.3850	-1.8436	0.9761	-1.8478
						-0.6872	0.8127	0.0076
188	393	YES	64	64 0.9621 0.7317	63 0.1520	-0.9131	-0.4822	-0.4990
						-0.4911	-0.7679	-0.2712
189	394	YES	64	64 0.9421 0.9171	63 0.0764	-0.8019	0.7983	-0.1769
						0.7521	0.4658	0.0185
190	395	YES	64	64 0.9763 0.6935	63 0.1254	-0.7870	-0.2623	-0.1903
						0.6915	0.5652	0.3159
191	396	YES	63	63 0.9742 0.5994	53 0.1675	-0.4208	1.0034	-0.5631
						-0.2271	0.5462	-0.1870
192	398	YES	63	63 0.4651 0.7974	43 0.0733	0.1099	0.1816	0.6000
						-0.5525	-1.1213	-0.8063
193	399	YES	64	64 0.8246 0.4979	63 0.3089	0.4217	0.2381	-1.3050
						-0.7724	-0.6061	-0.3210

* GROUP CODE	FABRIC GROUP	* GROUP CODE	FABRIC GROUP	* GROUP CODE	FABRIC GROUP	* GROUP CODE	FABRIC GROUP	* GROUP CODE	FABRIC GROUP
* 30	MA I	* 43	F III	* 53	M III	* 63	N III	* 70	L I
* 41	F I	* 49	F IX	* 54	M IV	* 64	N IV	*	
42	F II	*				* 67	N VII	* 99	UNASSIGNED

APPENDIX I.
FIRST DISCRIMINANT ANALYSIS: CLASSIFICATION RESULTS.

SAMPLES OF ARS LAMPS

CASE SEQNUM	SMP NUM	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP P(D/G)	P(G/D)	2ND HIGHEST GROUP P(G/D)	DISCRIMINANT SCORES...		
196	471	YES	70	70 0.0000	1.0000	54 0.0000	4.3834	6.7986	1.8141
							1.1205	0.0530	-0.1716
197	472	YES	70 **	63 0.0002	0.8180	70 0.0642	-0.2894	1.9749	-0.1481
							-0.1589	-0.3453	-4.7665
198	475	YES	70	70 0.0003	1.0000	53 0.0000	-1.6468	6.7624	4.3279
							0.7741	0.3992	-0.9062
199	476	YES	70	70 0.0000	1.0000	54 0.0000	-1.8517	6.5645	4.4051
							-5.8052	0.3659	1.1106
200	477	YES	70	70 0.5011	0.3212	53 0.2625	-1.5497	1.9592	0.6025
							0.8727	0.3641	1.6576
201	478	YES	70 **	63 0.7308	0.6005	64 0.2037	-1.4945	1.6128	-0.6196
							-0.0737	0.1090	1.1548
202	479	YES	70 **	30 0.0703	0.4107	53 0.2167	-1.9660	2.7063	-1.0009
							0.5783	1.0004	1.3608
203	482	YES	70	70 0.0000	0.5581	54 0.3518	5.3237	1.8093	0.3709
							1.5682	2.1426	1.3346
204	485	YES	70	70 0.0045	0.9941	53 0.0037	0.4133	3.2052	2.4954
							0.3747	-2.8262	-2.3819
205	487	YES	70 **	53 0.5180	0.4500	54 0.2591	-1.9529	1.3214	0.6223
							0.5985	-0.8257	0.0325
206	488	YES	70	70 0.0275	0.5068	54 0.2091	-1.2848	2.0207	0.9650
							-2.4236	0.7680	1.0678
207	489	YES	70	70 0.0133	1.0000	54 0.0000	1.6105	6.5858	1.8214
							1.6834	-0.7542	-0.6370
208	492	YES	70 **	63 0.3112	0.8429	53 0.0551	-1.4240	1.1228	1.6014
							1.1967	-0.4506	1.3129

* GROUP CODE	FABRIC GROUP	* GROUP CODE	FABRIC GROUP	* GROUP CODE	FABRIC GROUP	* GROUP CODE	FABRIC GROUP	* GROUP CODE	FABRIC GROUP
* 30	MA I	* 43	F III	* 53	M III	* 63	N III	* 70	L I
* 41	F I	* 49	F IX	* 54	M IV	* 64	N IV	*	
42	F II	*				* 67	N VII	* 99	UNASSIGNED

TABLE 2.

APPENDIX II.

SECOND DISCRIMINANT ANALYSIS

CLASSIFICATION RESULTS

SAMPLES FROM LOCI 1F 32-36

CASE SEQNUM	SAMPLE NUMBER	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP	P(D/G)	P(G/D)	2ND HIGHEST GROUP	P(G/D)
54	126	YES	43	43	0.9581	0.9993	53	0.0002
55	127	YES	UNGRPD	63	0.8904	0.9780	43	0.0171
56	128	YES	43	43	0.9240	0.9180	63	0.0815
57	129	YES	43	43	0.5201	0.8794	63	0.0713
58	130	YES	43	43	0.9894	0.9541	63	0.0452
59	132	YES	43	43	0.0823	0.9937	42	0.0062
60	133	YES	43	43	0.7928	0.9924	63	0.0075
61	134	YES	43	43	0.7225	0.9979	63	0.0020
62	135	YES	43	43	0.9509	0.9987	63	0.0009
63	136	YES	43	43	0.2833	0.9247	63	0.0750
64	138	YES	43	43	0.1488	0.5379	42	0.4082
65	139	YES	43	43	0.9990	0.9945	63	0.0048
66	140	YES	43	43	0.7096	0.9237	42	0.0470
67	141	YES	43	43	0.9753	0.9922	42	0.0069
68	142	NO	UNGRPD	42	0.0933	0.9504	43	0.0486
69	143	YES	42	42	1.0000	0.7925	43	0.1805
70	144	YES	43	43	0.8812	0.9294	42	0.0593
71	145	YES	49	49	0.8015	0.9992	54	0.0004
72	146	YES	43	43	0.7367	0.9999	53	0.0001
73	147	NO	UNGRPD	43	0.0617	0.9955	42	0.0045
74	148	YES	UNGRPD	53	0.5267	0.3814	30	0.2868
75	150	YES	43	43	0.9858	0.9757	63	0.0226
76	151	YES	43	43	0.9895	0.9991	42	0.0003
77	152	YES	43	43	0.9786	0.9994	53	0.0002
78	153	YES	43	43	0.9907	0.8744	63	0.1215
79	155	YES	43	43	0.4124	0.6327	42	0.2518
80	157	YES	43	43	0.9447	0.9713	63	0.0264
81	158	YES	43	43	0.0666	0.9995	54	0.0001
82	159	YES	43	43	0.9775	0.9883	63	0.0098
83	160	NO	UNGRPD	43	0.1583	0.9926	53	0.0062
84	161	YES	43	43	0.7893	0.9420	53	0.0492
85	162	YES	UNGRPD	53	0.6520	0.5819	54	0.2016
86	163	YES	43	43	0.7980	0.9363	53	0.0560
87	164	YES	UNGRPD	64	0.5501	0.8693	43	0.0547
88	167	YES	43	43	0.9177	0.8302	63	0.1319
89	168	YES	43	43	0.9783	0.9961	63	0.0013
90	169	YES	43	43	0.9721	0.9992	63	0.0003
91	170	YES	UNGRPD	64	0.0019	0.9080	63	0.0894
92	171	YES	49	49	0.8015	0.9753	43	0.0181
93	172	YES	43	43	0.8121	0.9054	63	0.0755
94	175	YES	UNGRPD	63	0.7650	0.7633	43	0.1008
95	176	YES	43	43	0.3407	0.9901	30	0.0059

GROUP	30	41	42	43	49	53	54	63	64	67	70	99
CODE												
FABRIC	MA I	F I	F II	FIII	FIX	MIII	M IV	NIII	N IV	N VII	L I	UNASSIGNED

SECOND DISCRIMINANT ANALYSIS

CLASSIFICATION RESULTS

SAMPLES FROM LOCUS 1M 7

CASE SEQNUM	SAMPLE NUMBER	SEL	ACTUAL GROUP		HIGHEST GROUP	PROBABILITY P(D/G)	GROUP P(G/D)	2ND HIGHEST GROUP	P(G/D)
196	179	YES	UNGRPD		30	0.0224	0.7917	64	0.1145
197	181	YES	UNGRPD		30	0.6369	0.5123	53	0.3927
198	182	YES	53		53	0.9983	0.8983	30	0.0821
199	183	YES	54		54	0.9109	0.6171	30	0.2417
100	184	NO	UNGRPD		30	0.5499	0.6671	54	0.1939
101	185	YES	53		53	0.0375	0.9982	49	0.0009
102	186	NO	UNGRPD		30	0.0041	0.9888	53	0.0056
103	187	YES	53	**	63	0.6400	0.3414	53	0.3035
104	188	YES	64		64	0.6905	0.9788	54	0.0070
105	189	YES	UNGRPD		63	0.0475	0.4021	43	0.3606
106	191	YES	63		63	0.8254	0.9375	43	0.0481
107	193	YES	63		63	0.9690	0.9358	43	0.0608
108	194	YES	54		54	0.5086	0.9046	64	0.0746
109	195	NO	UNGRPD		54	0.0748	0.9249	64	0.0554
110	196	YES	53		53	0.9510	0.9675	63	0.0112
111	197	YES	53		53	0.6312	0.9698	43	0.0254
112	198	YES	54		54	0.5656	0.9409	30	0.0295
113	199	YES	UNGRPD		43	0.2015	0.9935	53	0.0037
114	200	YES	63		63	0.8633	0.8990	43	0.0891
115	201	YES	63		63	0.4586	0.9917	54	0.0036
116	202	YES	54		54	0.6535	0.7122	30	0.1697
117	203	YES	54		54	0.6542	0.9376	30	0.0344
118	204	YES	53		53	0.6145	0.7213	63	0.2648
119	207	YES	63		63	0.8120	0.9853	43	0.0128
120	210	YES	64		64	0.9130	0.9756	54	0.0211
121	211	YES	UNGRPD		43	0.4532	0.8334	63	0.0750
122	212	NO	UNGRPD		43	0.1323	0.8211	64	0.1481
123	213	YES	53		53	0.7400	0.4726	43	0.3466
124	215	YES	53		53	0.7507	0.9823	63	0.0078
125	216	YES	64		64	0.7765	0.9799	30	0.0164

GROUP CODE	30	41	42	43	49	53	54	63	64	67	70	99
FABRIC	MA I	F I	F II	FIII	FIX	MIII	M IV	NIII	N IV	N VII	L I	UNASSIGNED

SECOND DISCRIMINANT ANALYSIS

CLASSIFICATION RESULTS

SAMPLES FROM MAHRINE

CASE SEQNUM	SAMPLE NUMBER	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP	P(D/G)	P(G/D)	2ND HIGHEST GROUP	P(G/D)
126	226	YES	UNGRPD	63	0.8545	0.6880	64	0.2954
127	227	YES	UNGRPD	43	0.9096	0.8677	63	0.0834
128	228	YES	30	30	0.7469	0.8572	53	0.0575
129	229	YES	30 **	64	0.8526	0.4995	63	0.4780
130	230	YES	30 **	54	0.0001	0.9926	30	0.0066
131	231	YES	30	30	0.7041	0.9881	64	0.0062
132	232	YES	30	30	0.9961	0.9494	63	0.0223
133	233	YES	30	30	0.9822	0.7800	63	0.1124
134	234	YES	30	30	0.9036	0.8991	53	0.0973
135	235	YES	UNGRPD	63	0.3607	0.6857	64	0.1595
136	236	YES	30 **	53	0.0015	0.5648	30	0.4230
137	237	YES	30	30	0.9689	0.8860	53	0.0397
138	238	YES	30	30	0.6817	0.7297	63	0.2250
139	239	YES	UNGRPD	53	0.5674	0.8528	43	0.0889
140	240	YES	30	30	0.3566	0.9302	43	0.0488
141	241	YES	30	30	0.9706	0.9991	54	0.0006
142	242	YES	30	30	0.9636	0.9770	63	0.0083
143	243	YES	30	30	0.8762	0.9997	54	0.0003
144	244	YES	30	30	0.8051	0.9999	54	0.0001
145	245	YES	30	30	0.3589	0.9999	54	0.0001
146	246	YES	30	30	0.2666	0.9337	63	0.0377
147	247	YES	30	30	0.1340	0.9994	63	0.0006
148	248	YES	30	30	0.9261	0.9954	53	0.0033
149	249	NO	UNGRPD	30	0.7432	0.7624	53	0.2159

GROUP CODE	30	41	42	43	49	53	54	63	64	67	70	99
FABRIC	MA I	F I	F II	FIII	FIX	MIII	M IV	NIII	N IV	N VII	L I	UNASSIGNED

SAMPLES FROM LOCUS 1N 17

CASE SEQNUM	SAMPLE NUMBER	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP	P(D/G)	P(G/D)	2ND HIGHEST GROUP	P(G/D)
150	250	YES	64	64	0.8650	0.9701	63	0.0274
151	251	YES	63	63	0.6947	0.8760	53	0.1081
152	252	YES	63	63	0.9853	0.9934	64	0.0060
153	253	YES	63	63	0.9514	0.9545	64	0.0167
154	255	YES	63	63	0.9825	0.9150	43	0.0831
155	356	NO	63	63	0.8563	0.8381	64	0.1592
156	357	YES	63	63	0.8319	0.9291	64	0.0706
157	358	YES	64	64	0.1695	0.5841	63	0.4149
158	359	YES	63	63	0.7443	0.9780	30	0.0153
159	362	YES	63	63	0.7501	0.9979	30	0.0019
160	363	YES	UNGRPD	43	0.0000	1.0000	54	0.0000
161	364	YES	63	63	0.9278	0.9963	30	0.0018
162	365	YES	64	64	0.2387	0.7936	43	0.1770
163	366	YES	63	63	0.9435	0.9569	43	0.0394
164	367	YES	64	64	0.9816	0.9994	42	0.0003
165	368	YES	63	63	0.8267	0.9728	64	0.0263
166	370	YES	64	64	0.3980	0.9636	63	0.0353
167	371	YES	63	63	0.7850	0.9888	53	0.0081
168	372	YES	63	63	0.5414	0.9548	43	0.0444
169	373	YES	63	63	0.6661	0.9075	43	0.0870
170	374	YES	63	63	0.8538	0.6541	43	0.3016

63 = N III, 64 = NIV

GROUP CODE	30	41	42	43	49	53	54	63	64	67	70	99
FABRIC	MA I	F I	F II	FIII	FIX	MIII	M IV	NIII	N IV	N VII	L I	UNASSIGNED

SAMPLES FROM LOCUS 1N 17

CASE SEQNUM	SMP NUM	SEL	ACTUAL GROUP		HIGHEST PROBABILITY GROUP	P(D/G)	P(G/D)	2ND HIGHEST GROUP	P(G/D)
171	375	YES	64		64	0.5411	0.9951	42	0.0047
172	376	YES	63		63	0.6392	0.7064	64	0.2861
173	377	YES	64		64	0.9618	0.9984	42	0.0012
174	378	YES	67		67	0.3214	1.0000	49	0.0000
175	379	YES	67		67	0.3214	1.0000	49	0.0000
176	380	YES	64		64	0.9809	0.9987	63	0.0011
177	381	NO	UNGRPD		64	0.9994	0.9983	63	0.0014
178	382	YES	63	**	64	0.8249	0.7201	63	0.1694
179	383	YES	63		63	0.8261	0.5657	43	0.4103
180	385	NO	UNGRPD		63	0.0450	0.8191	64	0.1776
181	386	YES	63		63	0.8316	0.9965	30	0.0016
182	387	YES	64		64	0.9764	0.9743	63	0.0219
183	388	YES	64		64	0.8849	0.9941	42	0.0051
184	389	NO	UNGRPD		53	0.0008	0.5174	30	0.4317
185	390	YES	UNGRPD		53	0.8305	0.4681	54	0.2700
186	391	YES	63		63	0.4501	0.9365	30	0.0526
187	392	YES	UNGRPD		63	0.0356	0.3909	30	0.3147
188	393	YES	64		64	0.9764	0.9970	63	0.0014
189	394	YES	64		64	0.8325	0.9976	63	0.0024
190	395	YES	64		64	0.9724	0.9958	63	0.0019
191	396	YES	63		63	0.9550	0.9648	30	0.0172
192	398	YES	63		63	0.3093	0.9914	43	0.0084
193	399	YES	64		64	0.7076	0.9396	63	0.0518

GROUP CODE	30	41	42	43	49	53	54	63	64	67	70	99
FABRIC	MA I	F I	F II	F III	FIX	M III	M IV	N III	N IV	N VII	L I	UNASSIGNED

SAMPLES OF ARS LAMPS

CASE SEQNUM	SAMPLE NUMBER	SEL	ACTUAL GROUP		HIGHEST PROBABILITY GROUP	P(D/G)	P(G/D)	2ND HIGHEST GROUP	P(G/D)
196	471	YES	70		70	0.0004	1.0000	54	0.0000
197	472	YES	UNGRPD		63	0.0000	0.9949	43	0.0039
198	475	YES	70		70	0.0018	1.0000	53	0.0000
199	476	YES	70		70	0.0000	1.0000	54	0.0000
200	477**	YES	70	**	63	0.1652	0.6509	53	0.3134
201	478	YES	UNGRPD		63	0.3841	0.6647	64	0.3226
202	479	YES	UNGRPD		53	0.0404	0.8126	30	0.1675
203	482	YES	70		70	0.0000	0.9173	49	0.0823
204	485	YES	70		70	0.0024	0.9995	53	0.0004
205	487	YES	UNGRPD		53	0.6727	0.9483	30	0.0360
206	488**	YES	70	**	53	0.0014	0.5679	54	0.2402
207	489	YES	70		70	0.0644	1.0000	53	0.0000
208	492	YES	UNGRPD		63	0.2767	0.9961	64	0.0030

53 = M III, 63 = NIII, 70 = L I

GROUP CODE	30	41	42	43	49	53	54	63	64	67	70	99
FABRIC	MA I	F I	F II	FIII	FIX	MIII	M IV	NIII	N IV	N VII	L I	UNASSIGNED

THIRD DISCRIMINANT ANALYSIS: CLASSIFICATION RESULTS

CASE SEQNUM	SMP NUM	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP P(D/G) P(G/D)	2ND HIGHEST GROUP P(G/D)	DISCRIMINANT SCORES...				
SAMPLES FROM LOCUS 2F 32-36										
54	126	YES	3	3 0.8233 0.6352	11 0.3021	-1.7380	-0.4980	-0.0964	-0.4416	-0.4523
55	127	YES	3	3 0.7197 0.8146	11 0.1524	-2.1187	-1.4278	-0.1422	-0.0843	0.1862
56	128	YES	3	3 0.6977 0.8678	11 0.1163	-1.9661	-1.4056	0.3426	-0.9581	0.2354
57	129	YES	11 **	3 0.8334 0.8474	11 0.1492	-0.5823	-2.2563	0.5552	0.0180	-0.4273
58	130	YES	3	3 0.8525 0.8598	11 0.1273	-1.4917	-1.7434	-0.3191	-0.1149	0.6247
59	132	YES	3	3 0.0200 0.9162	11 0.0811	0.2504	-2.9331	-1.0536	1.2899	2.4720
60	133	YES	3	3 0.5312 0.9177	11 0.0815	-0.4781	-2.9307	-0.5857	-0.1847	0.0440
61	134	YES	3	3 0.6436 0.9314	11 0.0676	-0.7485	-2.7514	0.3184	-0.6212	0.1695
62	135	YES	3	3 0.8524 0.7787	11 0.2106	-0.6367	-0.9419	-0.2230	-1.5212	-0.2014
63	136	YES	3	3 0.3484 0.9497	11 0.0499	-0.8025	-2.7267	-0.4654	-1.6860	0.0589
64	138	YES	11 **	3 0.5387 0.5823	11 0.2747	-0.9179	0.0939	-0.0837	-0.4265	1.7000
65	139	YES	3	3 0.9172 0.8000	11 0.1706	-1.4383	-1.4748	0.2675	0.2058	0.4930
66	140	YES	3 **	11 0.8383 0.4326	3 0.3154	-0.7220	0.7232	-0.4708	-0.6171	0.0578
67	141	YES	3	3 0.7247 0.6368	11 0.2814	-1.2603	-0.7087	-1.1118	0.3564	0.7840
68	142	NO	UNGRPD	4 0.0428 0.7842	3 0.1095	-1.7455	1.0459	-2.0023	-1.2145	2.6346
69	143	YES	11 **	4 0.6760 0.3751	3 0.3358	-0.4568	0.0621	-1.7205	-0.1244	1.1973
70	144	YES	3	3 0.8321 0.5743	11 0.3310	-0.8767	-0.2355	-0.9659	-0.7453	0.1302
71	145	YES	11	11 0.1610 0.7674	3 0.2026	1.2742	-0.6484	-0.5396	1.7141	-1.9514
72	146	YES	3	3 0.6678 0.7626	11 0.2292	-0.6488	-2.0819	-0.7272	0.9224	-0.3321
73	147	NO	UNGRPD	3 0.0704 0.7787	11 0.1936	-0.2858	-1.9527	-2.1025	1.3215	1.5913

GROUP	3	4	5	13	7	11
FABRIC TYPE	III	IV	MA IA	MA IB	L I	UNASSIGNED

APPENDIX III

THIRD DISCRIMINANT ANALYSIS: CLASSIFICATION RESULTS

CASE SEQNUM	SMP NUM	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP P(D/G)	P(G/D)	2ND HIGHEST GROUP P(G/D)	DISCRIMINANT SCORES...				
SAMPLES FROM LOCUS 2F 32-36											
74	148	YES	3	3	0.4905 0.4045	11 0.3993	-0.2154	0.1979	1.3580	0.4129	1.0159
75	150	YES	3	3	0.8318 0.7636	11 0.1966	-1.1476	-1.2031	-0.4046	0.3659	1.1522
76	151	YES	3	3	0.8283 0.6284	11 0.3204	-1.5172	-0.5066	-0.5887	-0.5078	-0.4819
77	152	YES	11 **	3	0.9916 0.6951	11 0.2783	-0.9172	-0.8084	-0.3820	-0.4797	-0.0167
78	153	YES	11 **	3	0.9624 0.7350	11 0.2375	-0.7780	-1.1952	-0.4237	0.3052	0.7250
79	155	YES	3 **	11	0.2920 0.3743	4 0.3525	0.8752	-0.4629	-2.0210	0.8250	0.3873
80	157	YES	3	3	0.8367 0.7684	11 0.2145	-0.7034	-1.8705	0.3987	0.9059	0.1162
81	158	YES	3	3	0.1395 0.3774	11 0.3469	1.5680	-0.3806	-1.3626	-1.3924	-0.3183
82	159	YES	3	3	0.8420 0.7033	11 0.2826	-1.0085	-1.5415	-0.4922	0.3996	-0.8357
83	160	NO	3 **	11	0.7663 0.4388	3 0.2778	-1.0443	0.1046	-0.5418	1.3560	0.2009
84	161	YES	11 **	3	0.7050 0.5524	11 0.4161	-0.5271	-1.2758	-0.3498	1.2876	-0.6577
85	162	YES	3 **	11	0.5319 0.6042	13 0.2123	0.0403	0.7891	-0.2448	1.9098	-0.6255
C6	163	YES	11 **	3	0.6954 0.5680	11 0.3840	-1.3680	-1.0178	-0.3238	0.7356	-1.0413
87	164	YES	11 **	4	0.8894 0.7492	11 0.1947	0.1239	0.8458	-1.9484	-0.0004	-1.1114
88	167	YES	3	3	0.7860 0.5501	11 0.3488	-1.5712	-0.7822	-0.0471	0.7925	-0.4272
89	168	YES	3	3	0.8691 0.6148	11 0.3153	-1.3442	-0.5345	-0.8851	-0.1100	0.1011
90	169	YES	4 **	3	0.9160 0.7148	11 0.2695	-1.1283	-0.9701	0.0126	-0.7385	-0.7879
91	170	YES	11 **	3	0.0218 0.8566	11 0.1207	-0.3532	-2.8561	-3.1523	0.0564	0.2342
92	171	YES	11 **	3	0.8000 0.6094	11 0.3462	-0.2655	-0.5805	1.5142	-0.0858	0.1068
93	172	YES	11 **	3	0.8297 0.7745	11 0.1863	-1.3796	-1.0155	1.1706	-0.4669	0.3293
94	175	YES	11 **	3	0.8221 0.6743	11 0.2856	-0.3630	-0.8150	1.4773	-0.0116	0.4265
95	176	YES	3	3	0.5485 0.5144	11 0.3026	-1.5838	-0.2118	1.5129	-0.1353	-0.2244

GROUP	3	4	5	13	7	11
FABRIC TYPE	III	IV	MA IA	MA IB	L I	UNASSIGNED

APPENDIX III

THIRD DISCRIMINANT ANALYSIS: CLASSIFICATION RESULTS

- CASE SEQNUM	SMP NUM	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP P(D/G)	P(G/D)	2ND HIGHEST GROUP P(G/D)	DISCRIMINANT SCORES...				
SAMPLES FROM LOCUS 1M 7											
96	179	YES	11 **	4 0.2776	0.6655	13 0.2227	-1.0064	2.9090	-0.9508	1.2003	-0.4732
97	181	YES	11 **	3 0.4499	0.4749	11 0.3136	-1.3592	-0.0500	1.8087	-0.1682	-0.0917
98	182	YES	11	11 0.8977	0.5873	3 0.3129	-0.3199	0.2707	0.9572	0.2297	-0.9480
99	183	YES	11 **	4 0.3932	0.5231	11 0.3919	0.9356	2.0464	0.1489	-0.4842	-0.7973
100	184	NO	UNGRPD	4 0.6227	0.6723	11 0.1274	-0.5982	2.4078	-0.4264	-0.5354	0.5225
101	185	YES	3 **	11 0.1086	0.8219	3 0.1035	0.3216	0.5226	0.7970	1.3797	-2.7376
102	186	NO	UNGRPD	5 0.0008	0.3664	11 0.2466	1.3280	2.8689	2.1976	-1.2548	2.0562
103	187	YES	11	11 0.9887	0.5034	3 0.3999	-0.1220	0.2954	0.1622	-0.2678	0.0409
104	188	YES	4	4 0.9194	0.8789	11 0.0914	0.6722	1.4266	-1.7121	0.7725	0.5946
105	189	YES	11 **	3 0.4745	0.6354	11 0.3321	-0.2258	-0.7542	2.1183	-0.2469	-0.3479
106	191	YES	3	3 0.4231	0.6632	11 0.3207	1.4261	-1.4529	-0.0024	-0.5769	-0.2846
107	193	YES	3	3 0.9324	0.7487	11 0.2437	0.2723	-1.0393	0.4476	-0.9110	0.3288
108	194	YES	4	4 0.5883	0.6435	11 0.3113	1.0964	1.3533	-1.0842	0.8546	-1.1724
109	195	NO	UNGRPD	4 0.1879	0.7164	11 0.2114	0.9916	1.8783	-1.1096	2.2599	-0.5724
110	196	YES	3 **	11 0.5852	0.4901	3 0.4872	-0.3178	-0.5094	1.1808	-0.3013	-1.6579
111	197	YES	3	3 0.4053	0.7131	11 0.2825	0.4703	-2.0209	1.3150	0.6063	-0.8831
112	198	YES	4 **	11 0.3207	0.6523	13 0.1789	-0.4481	1.3237	0.1449	0.8901	-1.9881
113	199	YES	3	3 0.5767	0.8707	11 0.1281	0.6397	-2.4329	0.5933	-0.0893	0.5355
114	200	YES	11 **	3 0.8070	0.8290	11 0.1606	-0.7750	-1.7853	1.3283	-0.1162	-0.0328

GROUP	3	4	5	13	7	11
FABRIC TYPE	III	IV	MA IA	MA IB	L I	UNASSIGNED

THIRD DISCRIMINANT ANALYSIS: CLASSIFICATION RESULTS

CASE SEQNUM	SMP NUM	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP	P(D/G)	P(G/D)	2ND HIGHEST GROUP	P(G/D)	DISCRIMINANT SCORES...				
SAMPLES FROM LOCUS 1N 7													
115	201	YES	3	3	0.7500	0.5151	11	0.3644	-1.0844	-0.8316	0.6728	1.1815	-0.1663
116	202	YES	11	11	0.4612	0.6738	3	0.2587	0.1493	0.7590	1.1371	-0.6888	-1.4727
117	203	YES	4	4	0.5527	0.7182	11	0.2080	1.1216	2.1008	-0.3099	0.4929	0.5293
118	204	YES	11	11	0.5245	0.6160	3	0.3487	1.3308	-0.7578	-0.4864	1.2923	-0.3993
119	207	YES	3	3	0.7895	0.6309	11	0.3473	0.6444	-0.6274	0.5892	-0.1633	0.9189
120	210	YES	4	4	0.9584	0.9566	11	0.0362	0.9473	1.8167	-1.8421	-0.1776	-0.0378
121	211	YES	11	11	0.6720	0.4987	3	0.3716	0.8776	-0.4378	-1.1818	-0.2267	-0.8135
122	212	NO	11 **	4	0.3832	0.6654	11	0.1994	1.7233	-0.1821	-2.1538	-0.1671	0.4582
123	213	YES	11	11	0.9400	0.6419	3	0.2479	0.3169	0.5914	0.2022	-0.0180	-0.7508
124	215	YES	3 **	11	0.7939	0.5970	3	0.2624	-0.6423	-0.1044	-0.1117	1.4600	-1.0389
125	216	YES	4	4	0.6118	0.9236	13	0.0348	-0.4335	2.6603	-1.1932	-0.2201	1.1721

GROUP	3	4	5	13	7	11
FABRIC TYPE	III	IV	MA IA	MA IB	L I	UNASSIGNED

SAMPLES FROM MAHRINE — THIRD DISCRIMINANT ANALYSIS: CLASSIFICATION RESULTS

CASE SEQNUM	SMP NUM	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP P(D/G) P(G/D)	2ND HIGHEST GROUP P(G/D)	DISCRIMINANT SCORES...				
126	226	YES	13 **	3 0.7041 0.4454	11 0.3594	-0.9727	0.0935	-0.7839	0.1839	0.9090
127	237	YES	13 **	3 0.9428 0.6997	11 0.2472	-1.1089	-1.0715	0.7749	0.3544	0.3094
128	228	YES	13	13 0.9590 0.5460	11 0.3155	-0.9801	1.2245	-0.0246	1.5023	0.0592
129	229	YES	13 **	11 0.9104 0.4676	3 0.2324	-0.4248	0.5629	-0.8192	0.5039	0.1516
130	230	YES	13 **	5 0.0842 0.4899	4 0.2523	-2.1040	3.5094	-0.9410	1.1190	-0.4418
131	231	YES	5 **	13 0.4503 0.6947	5 0.2297	-2.3050	2.2951	-0.2337	1.4145	0.7160
132	232	YES	5 **	13 0.9770 0.5979	11 0.1715	-1.9256	1.1787	0.5574	0.6211	0.2525
133	233	YES	13	13 0.9698 0.3716	11 0.3101	-1.7964	0.5934	0.5887	0.1800	-0.0622
134	234	YES	13	13 0.9428 0.5834	5 0.2209	-1.8919	1.2493	1.0737	0.6628	0.1878
135	235	YES	13	13 0.9255 0.5310	11 0.2716	-1.4998	0.4385	-0.3325	1.5389	0.7666
136	236	YES	13	13 0.1279 0.4936	11 0.3663	0.2122	0.2754	2.5323	2.2072	0.4849
137	237	YES	13	13 0.9230 0.3944	11 0.2923	-1.5288	1.1892	0.7642	0.0698	-0.2859
138	238	YES	13	13 0.8970 0.6150	11 0.2030	-1.2977	0.5286	0.6188	1.2413	1.4645
139	239	YES	13 **	3 0.3718 0.4866	11 0.2926	-1.6471	-0.6939	1.6897	0.8658	-0.3768
140	240	YES	5	5 0.8811 0.7791	13 0.1645	-2.4156	1.1521	1.9320	-0.1916	0.0087
141	241	YES	5	5 0.9821 0.9951	13 0.0045	-3.0390	2.5040	1.8004	-0.7906	-0.4067
142	242	YES	5	5 0.8545 0.8433	13 0.0839	-2.5523	1.2102	1.2531	-0.8459	-0.8022
143	243	YES	5	5 0.8794 0.9949	13 0.0049	-2.9100	3.3330	1.0185	-0.6130	0.6508
144	244	YES	5	5 0.8929 0.9982	13 0.0018	-3.2883	3.3562	1.4021	-0.5760	0.0483
145	245	YES	5	5 0.5893 0.9995	13 0.0005	-3.3339	3.0352	2.7664	-0.7531	-0.7580
146	246	YES	5	5 0.1035 0.4368	11 0.2585	-0.0203	2.2857	1.0298	-2.0997	-0.2704
147	247	YES	5	5 0.6599 0.9997	13 0.0003	-3.0535	3.3160	1.9057	-1.7746	0.1456
148	248	YES	5	5 0.9306 0.9130	13 0.0815	-3.1121	1.7403	1.6021	0.2911	0.1675
149	249	YES	UNGRPD	5 0.6513 0.5377	13 0.2817	-2.0219	1.3281	1.3532	0.1948	-1.2963

GROUP 3 1 5 13 7 11

FABRIC TYPE III IV MA IA MA IB L I UNASSIGNED

APPENDIX III

THIRD DISCRIMINANT ANALYSIS: CLASSIFICATION RESULTS

CASE SEQNUM	SMP NUM	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP P(D/G)	P(G/D)	2ND HIGHEST GROUP P(G/D)	DISCRIMINANT SCORES...				
SAMPLES FROM LOCUS 1N 17											
150	250	YES	4	4	0.9983 0.7213	11 0.1966	0.3914	0.8888	-1.5820	-0.0465	0.1228
151	251	YES	11	11	0.9511 0.5013	3 0.4463	0.2436	-0.5649	-0.2263	0.9758	0.1186
152	252	YES	3	3	0.9923 0.6004	11 0.3524	-0.3786	-0.5320	0.0132	0.0687	0.5190
153	253	YES	3	3	0.9682 0.6660	11 0.3212	-0.1279	-1.2572	-0.5659	-0.0346	-0.4682
154	255	YES	3	3	0.9803 0.8375	11 0.1543	-0.6287	-1.5156	0.3381	-0.5161	0.6226
155	256	NO	UNGRPD	3	0.8708 0.6636	11 0.2974	-0.6787	-0.8079	-1.0884	-0.7187	-0.2991
156	357	YES	3	3	0.7538 0.5649	11 0.3511	0.1142	-0.2285	-0.6727	-1.2449	0.0788
157	358	YES	11	11	0.4444 0.4714	3 0.4109	-0.4932	-0.3632	-1.4284	-0.5940	-1.6575
158	359	YES	3	3	0.5869 0.3511	13 0.3189	-1.8931	0.1981	0.3194	0.3375	0.1511
159	362	YES	3	3	0.6864 0.6987	11 0.2048	-1.4071	-0.5187	1.1537	-0.4400	0.9654
160	363	YES	3	3	0.1447 0.8301	11 0.1557	0.6782	-1.0765	-0.4360	-2.7457	0.2312
161	364	YES	3	3	0.7279 0.6231	11 0.2255	-1.7009	-0.7169	0.2756	0.5352	0.9361
162	365	YES	11 **	4	0.8202 0.8363	11 0.0899	-0.3262	1.3234	-1.5204	-0.8470	1.2773
163	366	YES	3	3	0.7965 0.7667	11 0.2287	-0.3173	-1.2379	0.1499	-1.3664	-0.8505
164	367	YES	4	4	0.9590 0.9755	11 0.9186	0.0241	1.9160	-2.2366	-0.6246	0.1552
165	368	YES	3	3	0.8512 0.7699	11 0.2190	-0.3308	-1.4110	-0.9609	-0.9075	-0.3798
166	370	YES	UNGRPD	4	0.3966 0.6439	11 0.2251	0.1508	0.6098	-1.6510	-1.7703	-1.3554
167	371	YES	3	3	0.8160 0.6766	11 0.2994	-1.3239	-1.0386	0.4211	-0.2539	-1.1040
168	372	YES	3	3	0.3948 0.9338	11 0.0658	0.0236	-3.0735	0.6638	-0.6924	-0.0553
169	373	YES	3	3	0.9378 0.8104	11 0.1860	0.2679	-1.7859	0.0447	-0.3024	0.3441
170	374	YES	11 **	3	0.9156 0.6182	11 0.3577	-0.1487	-1.0093	-0.8711	-0.2385	-0.6031
171	375	YES	4	4	0.7527 0.9521	11 0.0260	-1.1919	1.9260	-2.3266	-0.1233	0.3102
172	376	YES	11	11	0.7874 0.4491	3 0.3545	-1.0787	0.5865	-0.4754	-0.7075	-0.4326

GROUP	3	4	5	13	7	11
FABRIC TYPE	III	IV	MA IA	MA IB	L I	UNASSIGNED

THIRD DISCRIMINANT ANALYSIS: CLASSIFICATION RESULTS

CASE SEQNUM	SMP NUM	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP P(D/G) P(G/D)	2ND HIGHEST GROUP P(G/D)	DISCRIMINANT SCORES...				
SAMPLES FROM LOCUS 1N 17										
173	377	YES	4	4 0.6855 0.9680	11 0.0230	1.1328	0.9020	-2.7479	-0.8697	0.2129
174	378	YES	7	7 0.5327 1.0000	4 0.0000	11.1123	0.8801	0.0714	-1.0820	-0.1507
175	379	YES	7	7 0.0000 1.0000	4 0.0000	12.9429	1.3115	2.5038	0.1313	4.6316
176	380	YES	4	4 0.9190 0.8933	11 0.0770	-0.0703	1.0902	-2.3651	0.7575	0.1798
177	381	NO	UNGRPD	4 0.9812 0.9048	11 0.0687	-0.4334	1.3828	-2.1325	-0.2463	-0.3268
178	382	YES	11 **	4 0.7740 0.4251	11 0.2748	-0.8080	1.2995	-0.6732	-0.4877	0.8831
179	383	YES	11 **	3 0.7474 0.6596	11 0.3255	-0.6965	-0.6241	0.0990	-1.2819	-1.0539
180	385	NO	UNGRPD	3 0.1106 0.7236	11 0.2248	0.2118	-1.3578	-1.6034	0.8949	2.1800
181	386	YES	3	3 0.8783 0.6570	11 0.2824	-0.5359	-0.9173	0.4197	0.6876	1.0284
182	387	YES	4	4 0.9411 0.6248	11 0.2672	0.1015	0.5942	-1.8435	0.6616	-0.2025
183	388	YES	4	4 0.8440 0.9324	11 0.0454	0.6139	0.7563	-2.5728	-0.8699	0.0494
184	389	NO	UNGRPD	5 0.5293 0.8482	13 0.1266	-1.9473	2.1444	1.9012	0.6207	-1.5245
185	390	YES	11	11 0.6157 0.5176	13 0.3098	0.0535	1.2881	0.4000	1.2591	-0.0872
186	391	YES	3 **	13 0.7661 0.3838	3 0.3725	-1.4220	-0.0758	0.1990	1.0169	1.6519
187	392	YES	UNGRPD	5 0.5528 0.6952	13 0.1875	-2.3210	1.9399	-0.1257	-0.8152	1.1833
188	393	YES	4	4 0.9041 0.9206	11 0.0526	-0.6807	1.5829	-1.9655	-0.9890	-0.0442
189	394	YES	4	4 0.8563 0.9353	11 0.0405	0.4215	0.8975	-2.4242	-0.8648	0.7441
190	395	YES	4	4 0.9883 0.8907	11 0.0743	-0.0431	1.0941	-2.1634	0.0283	0.4980
191	396	YES	3	3 0.9372 0.5069	11 0.4417	-0.5351	-0.2530	0.6493	-0.1712	-0.5199
192	398	YES	3	3 0.4023 0.8873	11 0.1080	-0.4735	-1.4464	1.7260	-1.5260	0.6907
193	399	YES	4	4 0.6273 0.7344	11 0.1316	-0.6741	1.9755	-0.7044	-1.2388	0.6556

GROUP	3	4	5	13	7	11
FABRIC TYPE	III	IV	MA IA	MA IB	L I	UNASSIGNED

APPENDIX III

THIRD DISCRIMINANT ANALYSIS: CLASSIFICATION RESULTS

CASE SEQNUM	SMP NUM	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP P(D/G)	P(G/D)	2ND HIGHEST GROUP P(G/D)	DISCRIMINANT SCORES...				
SAMPLES OF ARS LAMPS											
197	471	YES	3	3 0.0000	0.8748	11 0.1071	0.5010	-0.0623	2.7598	-5.3622	0.1182
198	472	YES	7	7 0.0915	1.0000	11 0.0000	9.6996	-1.6291	-0.5426	-0.5858	-1.6509
199	475	YES	7	7 0.0040	1.0000	11 0.0000	10.1617	0.7152	0.3245	1.7853	-3.6129
200	476	YES	11	11 0.3287	0.6062	3 0.3227	1.2358	-0.3567	0.2523	1.7969	0.7662
201	477	YES	11	11 0.7923	0.4192	4 0.2681	-0.2588	0.8453	-0.7067	0.5596	0.5890
202	478	YES	11	11 0.2027	0.4347	13 0.4009	-0.3376	0.0779	1.8232	2.1639	-0.3827
203	479	YES	7 **	11 0.0000	0.4619	7 0.3550	4.6760	0.0584	1.2134	1.6323	2.6866
204	482	YES	7	7 0.0046	1.0000	4 0.0000	7.2831	0.8842	-0.8816	-2.2028	-2.1722
205	455	YES	3 **	11 0.6537	0.6955	3 0.2474	1.2166	0.2978	0.8878	0.6391	-0.3473
206	477	YES	11	11 0.0204	0.6596	3 0.3188	1.2168	-1.1597	2.2604	1.9053	-1.7751
207	488	YES	7	7 0.9300	1.0000	11 0.0000	9.4028	0.7913	0.9906	0.1420	-1.0194
208	492	YES	3	3 0.2498	0.7773	11 0.2122	1.0137	-1.5910	-0.4828	0.4527	1.9026

GROUP	3	4	5	13	7	11
FABRIC TYPE	III	IV	MA IA	MA IB	L I	UNASSIGNED

FINAL DISCRIMINANT ANALYSIS OF ARS POTTERY
FABRIC TYPES III & IV

CASE SEQNUM	SMP NUM	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP P(D/G) P(G/D)	2ND HIGHEST GROUP P(G/D)	DISCRIMINANT SCORES...		
SAMPLES FROM LOCUS 2F32-36								
54	126	YES	3	3 0.6052 0.9977	4 0.0013	-1.7338	0.5811	-0.1837
55	127	YES	3	3 0.4972 0.9999	4 0.0001	-1.7430	1.5719	-0.9430
56	128	YES	3	3 0.5715 0.9999	5 0.0000	-1.7954	1.6964	-0.2549
57	129	YES	UNGRPD	3 0.3927 1.0000	5 0.0000	-1.1732	2.6598	0.3442
58	130	YES	3	3 0.5903 0.9999	4 0.0001	-1.5374	1.7815	-0.7918
59	132	YES	3	3 0.1744 1.0000	4 0.0000	-0.0080	3.0858	-1.1134
60	133	YES	3	3 0.1921 1.0000	4 0.0000	-0.2685	2.7866	-1.5471
61	134	YES	3	3 0.2650 1.0000	4 0.0000	-0.5479	3.1038	-0.4837
62	135	YES	3	3 0.9593 0.9993	4 0.0007	-1.0020	0.9564	-0.2615
63	136	YES	3	3 0.2393 1.0000	4 0.0000	-0.5217	2.5389	-1.6438
64	138	YES	UNGRPD	3 0.8318 0.9977	4 0.0016	-0.9350	0.4897	0.3666
65	139	YES	3	3 0.6840 1.0000	5 0.0000	-1.5173	1.7898	0.0438
66	140	YES	3	3 0.3397 0.8637	4 0.1324	-0.7331	-0.6728	-0.0523
67	141	YES	3	3 0.4821 0.9867	4 0.0133	-1.3691	0.3122	-1.1466
68	142	NO	UNGRPD	4 0.0704 0.9057	3 0.0546	-2.4680	-1.9670	-1.2859
69	143	YES	UNGRPD	3 0.2261 0.6612	4 0.3387	-0.4534	-0.4750	-1.4556
70	144	YES	3	3 0.5706 0.9613	4 0.0387	-0.7790	0.0525	-1.0010
71	145	YES	UNGRPD	3 0.0077 0.9230	4 0.0770	2.7571	0.5891	-1.1408
72	146	YES	3	3 0.6641 0.9998	4 0.0002	-0.5287	1.7906	-1.2157

GROUP	3	4	5	13	7	11
FABRIC TYPE	III	IV	MA IA	MA IB	L I	UNASSIGNED

APPENDIX IV

FINAL DISCRIMINANT ANALYSIS OF ARS POTTERY
FABRIC TYPES III & IV

CASE SEQNUM LOCI 2F32-36	SMP NUM	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP P(D/G)	P(G/D)	2ND HIGHEST GROUP P(G/D)	DISCRIMINANT SCORES...		
73	147	NO	UNGRPD	3 0.1851	0.9900	4 0.0100	-0.4550	1.0012	-2.3313
74	148	YES	3	3 0.2224	0.9970	5 0.0025	-0.1009	0.4855	1.8096
75	150	YES	3	3 0.6941	0.9989	4 0.0011	-0.8164	1.0502	-0.8468
76	151	YES	3	3 0.4775	0.9879	4 0.0116	-1.5724	0.1832	-0.7823
77	152	YES	UNGRPD	3 0.8620	0.9989	4 0.0010	-1.2765	0.7881	-0.2628
78	153	YES	UNGRPD	3 0.9555	0.9994	4 0.0006	-0.7511	1.1875	-0.6470
79	155	YES	3	3 0.1240	0.6950	4 0.3050	0.8139	-0.0770	-1.7370
80	157	YES	3	3 0.6229	1.0000	4 0.0000	-0.5575	2.4442	0.1161
81	158	YES	3 **	4 0.3505	0.5189	3 0.4811	0.8694	-0.5941	-1.0023
82	159	YES	3	3 0.7647	0.9990	4 0.0010	-0.6740	1.2500	-1.1927
83	160	NO	3	3 0.4391	0.9656	4 0.0285	-1.2746	-0.3030	-0.0226
84	161	YES	UNGRPD	3 0.9262	0.9987	4 0.0013	-0.1902	1.0948	-0.7475
85	162	YES	3	3 0.2808	0.8618	4 0.1370	0.1040	-0.6564	0.3393
86	163	YES	UNGRPD	3 0.8185	0.9979	4 0.0020	-1.1225	0.7926	-0.7844
87	164	YES	UNGRPD	4 0.9615	0.9938	3 0.0062	-0.2032	-2.0492	-1.6836
88	167	YES	3	3 0.8371	0.9989	4 0.0010	-1.3232	0.8203	-0.3973
89	168	YES	3	3 0.4008	0.9449	4 0.0550	-1.0507	-0.0108	-1.2822
90	169	YES	4 **	3 0.9656	0.9993	4 0.0007	-0.9507	1.0040	-0.3522
91	170	YES	UNGRPD	3 0.0000	0.8532	4 0.1468	0.5378	1.2515	-4.8424
92	171	YES	UNGRPD	3 0.3154	0.9991	4 0.0009	1.1739	0.9568	0.7050
93	172	YES	UNGRPD	3 0.4614	0.9999	5 0.0001	-1.2847	1.8702	1.0555
94	175	YES	UNGRPD	3 0.3726	0.9999	5 0.0001	-0.3162	1.7026	1.5275
95	176	YES	3	3 0.1406	0.9854	5 0.0146	-1.6565	1.2358	1.8891

GROUP	3	4	5	13	7	11
FABRIC TYPE	III	IV	MA IA	MA IB	L I	UNASSIGNED

APPENDIX IV.

FINAL DISCRIMINANT ANALYSIS OF ARS POTTERY. FABRIC TYPES III & IV

CASE SEQNUM LOCI 2F32-36	SMP NUM	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP P(D/G) P(G/D)	2ND HIGHEST GROUP P(G/D)	DISCRIMINANT SCORES...		
73	147	NO	UNGRPD	3 0.1851 0.9900	4 0.0100	-0.4550	1.0012	-2.3313
74	148	YES	3	3 0.2224 0.9970	5 0.0025	-0.1009	0.4855	1.8096
75	150	YES	3	3 0.8941 0.9989	4 0.0011	-0.8164	1.0502	-0.8468
76	151	YES	3	3 0.4775 0.9879	4 0.0116	-1.5724	0.1832	-0.7823
77	152	YES	UNGRPD	3 0.8620 0.9989	4 0.0010	-1.2765	0.7881	-0.2628
78	153	YES	UNGRPD	3 0.9555 0.9994	4 0.0006	-0.7511	1.1875	-0.6470
79	155	YES	3	3 0.1240 0.6950	4 0.3050	0.8139	-0.0770	-1.7370
80	157	YES	3	3 0.6229 1.0000	4 0.0000	-0.5575	2.4442	0.1161
81	158	YES	3 **	4 0.3505 0.5189	3 0.4811	0.8694	-0.5941	-1.0023
82	159	YES	3	3 0.7647 0.9990	4 0.0010	-0.6740	1.2500	-1.1927
83	160	NO	3	3 0.4391 0.9656	4 0.0285	-1.2746	-0.3030	-0.0226
84	161	YES	UNGRPD	3 0.9262 0.9987	4 0.0013	-0.1902	1.0948	-0.7475
85	162	YES	3	3 0.2808 0.8618	4 0.1370	0.1040	-0.6564	0.3393
86	163	YES	UNGRPD	3 0.8185 0.9979	4 0.0020	-1.1225	0.7926	-0.7844
87	164	YES	UNGRPD	4 0.9615 0.9938	3 0.0062	-0.2032	-2.0492	-1.6836
88	167	YES	3	3 0.8371 0.9989	4 0.0010	-1.3232	0.8203	-0.3973
89	168	YES	3	3 0.4008 0.9449	4 0.0550	-1.0507	-0.0108	-1.2822
90	169	YES	4 **	3 0.9656 0.9993	4 0.0007	-0.9507	1.0040	-0.3522
91	170	YES	UNGRPD	3 0.0000 0.8532	4 0.1468	0.5378	1.2515	-4.8424
92	171	YES	UNGRPD	3 0.3154 0.9991	4 0.0009	1.1739	0.9568	0.7050
93	172	YES	UNGRPD	3 0.4614 0.9999	5 0.0001	-1.2847	1.8702	1.0555
94	175	YES	UNGRPD	3 0.3726 0.9999	5 0.0001	-0.3162	1.7026	1.5275
95	176	YES	3	3 0.1406 0.9854	5 0.0146	-1.6565	1.2358	1.8891

GROUP CODE 3 4 5 13 7 11

FABRIC TYPE III IV MA IA MA IB L I UNASSIGNED

APPENDIX IV

FINAL DISCRIMINANT ANALYSIS OF ARS POTTERY

FABRIC TYPES III & IV

CASE SEQNUM	SMP NUM	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP	P(D/G)	P(G/D)	2ND HIGHEST GROUP	P(G/D)	DISCRIMINANT SCORES...		
SAMPLES FROM LOCUS1M 7											
115	201	YES	3	3	0.9913	0.9988	4	0.0012	-0.3110	0.6781	-0.1297
116	202	YES	UNGRPD	3	0.1324	0.9414	4	0.0444	0.0495	-0.6512	1.3064
117	203	YES	4	4	0.1585	0.9979	3	0.0020	1.7235	-2.6880	0.2641
118	204	YES	UNGRPD	3	0.5059	0.9930	4	0.0070	0.9401	0.6305	-0.2160
119	207	YES	3	3	0.5002	0.9998	4	0.0002	0.7427	1.3015	0.7554
120	210	YES	4	4	0.6618	0.9999	3	0.0001	1.0444	-3.1352	-1.4561
121	211	YES	UNGRPD	4	0.2248	0.6587	3	0.3413	1.2647	-0.4710	-1.6118
122	212	NO	UNGRPD	4	0.2175	0.9800	3	0.0200	-1.7738	-1.1327	-2.1613
123	213	YES	UNGRPD	3	0.3007	0.9707	4	0.0251	-0.1043	-0.3781	0.9523
124	215	YES	3	3	0.7782	0.9835	4	0.0164	-0.3872	0.1029	-0.1894
125	216	YES	4	4	0.3792	0.9958	5	0.0036	-0.6935	-3.3152	-0.2658

GROUP CODE	3	4	5	13	7	11
FABRIC TYPE	III	IV	MA IA	MA IB	L I	UNASSIGNED

FINAL DISCRIMINANT ANALYSIS OF ARS POTTERY. FABRIC TYPES III & IV

CASE SEQNUM SAMPLES	SMP NUM FROM MAHRINE	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP P(D/G) P(G/D)	2ND HIGHEST GROUP P(G/D)	DISCRIMINANT SCORES...		
126	226	YES	UNGRPD	3 0.3640 0.9252	4 0.0729	-1.2878	-0.3861	-0.6130
127	227	YES	UNGRPD	3 0.8368 0.9999	5 0.0000	-0.8501	1.6330	0.5588
128	228	YES	UNGRPD	3 0.1562 0.8065	4 0.1225	-0.9626	-0.9585	0.6297
129	229	YES	UNGRPD	3 0.2661 0.6580	4 0.3413	-0.4855	-0.7986	-0.5752
130	230	YES	UNGRPD	4 0.0037 0.9999	5 0.0001	-1.1507	-5.6556	-1.2795
131	231	YES	5	5 0.4391 0.9702	4 0.0243	-2.4619	-2.2729	0.6899
132	232	YES	5	5 0.3572 0.6004	3 0.3865	-1.9279	-0.8404	1.0085
133	233	YES	UNGRPD	3 0.1458 0.7720	5 0.2230	-1.9832	-0.3181	0.8819
134	234	YES	UNGRPD	5 0.5666 0.9315	3 0.0683	-2.3170	-0.4966	1.9573
135	235	YES	UNGRPD	3 0.4151 0.9636	4 0.0307	-1.3670	-0.3053	-0.1303
136	236	YES	UNGRPD	3 0.0014 0.9995	5 0.0005	0.4823	2.0032	3.5812
137	237	YES	UNGRPD	5 0.3675 0.6223	3 0.3693	-1.6885	-0.7960	1.3473
138	238	YES	UNGRPD	3 0.2579 0.9408	5 0.0579	-1.4881	0.1141	1.2726
139	239	YES	UNGRPD	3 0.1096 0.9898	5 0.0102	-1.8726	1.5177	1.8628
140	240	YES	5	5 0.4232 0.9863	3 0.0137	-2.7036	-0.1821	2.6747
141	241	YES	5	5 0.9716 1.0000	3 0.0000	-3.2879	-1.8979	2.4723
142	242	YES	5	5 0.6791 0.9709	3 0.0289	-2.8013	-0.6937	1.6052
143	243	YES	5	5 0.5759 1.0000	4 0.0000	-3.5242	-3.0389	2.2270
144	244	YES	5	5 0.6580 1.0000	3 0.0000	-3.7109	-2.7043	2.5041
145	245	YES	5	5 0.4340 1.0000	3 0.0000	-3.6708	-1.9716	3.6470
146	246	YES	5	5 0.1740 0.9237	4 0.0511	-0.7295	-2.1551	-1.9643
147	247	YES	5	5 0.6055 1.0000	3 0.0000	-3.7096	-2.5662	2.9495
148	248	YES	5	5 0.8537 0.9998	3 0.0002	-3.5254	-1.1504	2.3454

GROUP CODE 3 4 5 13 7 11

FABRIC TYPE III IV MA IA MA IB L I UNASSIGNED

APPENDIX IV

FINAL DISCRIMINANT ANALYSIS OF ARS POTTERY

FABRIC TYPES III & IV

CASE SEQNUM	SMP NUM	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP P(D/B)	P(G/D)	2ND HIGHEST GROUP P(G/D)	DISCRIMINANT SCORES...		
SAMPLES FROM LOCUS 1N 17									
150	250	YES	4	4	0.9897 0.9941	3 0.0058	0.3705	-2.0112	-1.5132
151	251	YES	UNGRPD	3	0.9259 0.9970	4 0.0030	-0.0639	0.6218	-0.0454
152	252	YES	3	3	0.8463 0.9919	4 0.0081	0.0477	0.4940	-0.4482
153	253	YES	3	3	0.8230 0.9981	4 0.0019	-0.0897	1.0872	-1.0002
154	255	YES	3	3	0.8837 1.0000	4 0.0000	-0.8396	1.8435	0.0760
155	256	NO	UNGRPD	3	0.2491 0.8879	4 0.1121	-0.3461	0.1133	-1.8817
156	357	YES	3	3	0.3499 0.7787	4 0.2212	0.0031	-0.3713	-1.0012
157	368	YES	UNGRPD	4	0.3026 0.6921	3 0.3079	-0.1972	-0.5854	-2.2338
158	369	YES	3	3	0.3850 0.9825	5 0.0127	-1.8197	0.0490	0.1759
159	362	YES	3	3	0.3874 0.9971	5 0.0028	-1.6918	1.2202	1.1234
160	363	YES	3	3	0.5006 0.8966	4 0.1034	-0.1028	-0.2252	-0.7200
161	364	YES	3	3	0.5782 0.9989	5 0.0009	-1.8695	0.9567	0.0960
162	365	YES	UNGRPD	4	0.8018 0.9943	3 0.0052	-0.7524	-2.4396	-1.0282
163	366	YES	3	3	0.9773 0.9996	4 0.0004	-0.2085	1.3584	-0.4067
164	367	YES	4	4	0.7140 0.9999	3 0.0001	0.3714	-3.1504	-2.0338
165	368	YES	3	3	0.5047 0.9961	4 0.0039	-0.2823	1.0740	-1.6530
166	370	YES	UNGRPD	4	0.6103 0.9987	3 0.0013	0.8759	-2.0086	-2.4714
167	371	YES	3	3	0.9753 0.9994	4 0.0005	-0.8533	1.1087	-0.4340
168	372	YES	3	3	0.0596 1.0000	4 0.0000	0.1442	3.7901	-0.1484
169	373	YES	3	3	0.3006 0.9996	4 0.0004	1.1371	1.7762	-0.9050
170	374	YES	UNGRPD	3	0.6111 0.9897	4 0.0103	0.0360	0.7241	-1.3050
171	375	YES	4	4	0.5493 0.9993	3 0.0006	-1.0163	-2.7931	-1.9593
172	376	YES	UNGRPD	4	0.5956 0.6755	3 0.3242	-0.4468	-1.0561	-0.9881

GROUP CODE 3 4 5 13 7 11

FABRIC TYPE III IV MA IA MA IB L I UNASSIGNED

APPENDIX IV

FINAL DISCRIMINANT ANALYSIS OF ARS POTTERY

FABRIC TYPES III & IV

CASE SEQNUM	SMP NUM	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP P(D/G)	P(G/D)	2ND HIGHEST GROUP P(G/D)	DISCRIMINANT SCORES...		
SAMPLES FROM LOCUS 1N 17									
173	377	YES	4	4	0.5467 0.9993	3 0.0007	1.0590	-2.1499	-2.4962
174	378	YES	UNGRPD	7	0.0000 1.0000	4 0.0000	20.9065	-3.7053	-4.8850
175	379	YES	UNGRPD	7	0.0000 1.0000	4 0.0000	23.0908	-2.7112	-1.5306
176	380	YES	4	4	0.8172 0.9993	3 0.0007	0.0574	-2.4245	-2.2809
177	38	NO	UNGRPD	4	0.7691 0.9995	3 0.0005	-0.4164	-2.7278	-2.0752
178	382	YES	UNGRPD	4	0.2430 0.6387	3 0.2956	-1.2441	-1.5678	-0.0264
179	383	YES	UNGRPD	3	0.9395 0.9981	4 0.0018	-0.8877	0.6410	-0.1281
180	385	NO	UNGRPD	3	0.4648 0.9857	4 0.0143	-0.2858	0.6858	-1.6579
181	386	YES	3	3	0.8867 0.9998	5 0.0001	-0.9352	1.2948	0.5161
182	387	YES	4	4	0.9054 0.9836	3 0.0164	0.1433	-1.6443	-1.8049
183	388	YES	4	4	0.4702 0.9990	3 0.0010	1.0083	-1.9856	-2.6715
184	389	NO	UNGRPD	5	0.7910 0.9999	3 0.0001	-2.5951	-1.5330	3.1302
185	390	YES	UNGRPD	3	0.0552 0.6566	4 0.3009	-0.0051	-1.2653	1.1070
186	391	YES	3	3	0.3195 0.9784	5 0.0211	-2.0238	0.4760	0.7184
187	392	YES	UNGRPD	5	0.4076 0.9873	4 0.0087	-2.9664	-2.1059	0.5217
188	393	YES	4	4	0.8688 0.9969	3 0.0029	-1.0336	-2.5039	-1.5088
189	394	YES	4	4	0.8329 0.9989	3 0.0011	0.0097	-2.3194	-2.2546
190	395	YES	4	4	0.9210 0.9973	3 0.0027	-0.3813	-2.3077	-1.7620
191	396	YES	3	3	0.8101 0.9964	4 0.0032	-0.5193	0.3437	0.4304
192	398	YES	3	3	0.1924 1.0000	5 0.0000	-0.2539	2.6637	1.3966
193	399	YES	4	4	0.7573 0.9908	3 0.0080	-0.3954	-2.4505	-0.4404

GROUP CODE	3	4	5	13	7	11
FABRIC TYPE	III	IV	MA IA	MA IB	L I	UNASSIGNED

APPENDIX IV

FINAL DISCRIMINANT ANALYSIS OF ARS POTTERY

FABRIC TYPES III & IV

CASE SEQNUM	SMP NUM	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP	P(D/G)	P(G/D)	2ND HIGHEST GROUP	P(G/D)	DISCRIMINANT SCORES...		
SAMPLES OF ARS LAMPS											
196	471	YES	7	7	0.0052	1.0000	4	0.0000	12.5490	-1.2549	2.4434
197	472	YES	3	3	0.0240	0.9919	5	0.0081	-0.1812	1.0371	2.9150
198	475	YES	7	7	0.2586	1.0000	3	0.0000	8.8415	1.3401	0.2727
199	476	YES	7	7	0.6942	1.0000	4	0.0000	10.3291	-0.2096	1.8775
200	477	YES	UNGRPD	3	0.3775	0.9992	4	0.0008	0.8628	0.8550	0.9373
201	478	YES	UNGRPD	3	0.1841	0.5754	4	0.4206	-0.6263	-1.0514	-0.2294
202	479	YES	UNGRPD	3	0.0735	0.9785	5	0.0214	-0.8269	0.8719	2.4619
203	482	YES	7	7	0.1803	1.0000	4	0.0000	7.1739	-0.1920	0.6842
204	485	YES	7	7	0.0767	1.0000	4	0.0000	7.0486	-1.1762	0.2267
205	487	YES	3	3	0.1018	0.9988	5	0.0009	0.4300	0.6324	2.1165
206	488	YES	UNGRPD	3	0.0080	1.0000	4	0.0000	1.4149	2.4744	2.3901
207	489	YES	7	7	0.7912	1.0000	4	0.0000	9.8662	-0.5579	2.0875
208	492	YES	3	3	0.5786	0.9999	4	0.0001	0.5929	2.0196	-0.2465

GROUP CODE	3	4	5	13	7	11
FABRIC TYPE	III	IV	MA IA	MA IB	L I	UNASSIGNED

COARSE WARE CLASSIFICATION ANALYSIS.

CASE SEQNUM	SMP NUM	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP P(D/G) P(G/D)	2ND HIGHEST GROUP P(G/D)	DISCRIMINANT SCORES...			
HAMILCAR CLAY									
1	7	NO	UNGRPD	80 0.0001 1.0000	91 0.0000	-2.4852	-4.3487	2.9273	-2.1504
2	8	NO	UNGRPD	80 0.0004 1.0000	81 0.0000	-5.2443	-3.7853	2.8147	-1.8713
3	9	NO	UNGRPD	80 0.0000 0.9984	91 0.0016	-1.7624	-4.5601	3.3571	-2.0432
LA MALGA CLAY									
4	25	NO	UNGRPD	92 0.0000 1.0000	93 0.0000	8.1773	-0.2478	-2.5983	2.6757
5	27	NO	UNGRPD	92 0.2604 0.9678	91 0.0289	4.7454	-0.7292	0.0636	-0.1128
6	29	NO	UNGRPD	92 0.0000 1.0000	93 0.0000	9.0706	1.7206	-2.7088	3.3898
7	30	NO	UNGRPD	92 0.0929 0.9999	91 0.0001	6.3235	-0.9325	-0.6997	2.3055
BYRSA CLAY									
8	32	NO	UNGRPD	92 0.0000 0.9966	91 0.0034	5.1289	-0.5469	-4.2292	2.6277
9	34	NO	UNGRPD	80 0.0000 1.0000	81 0.0000	-8.0700	-5.2272	1.2027	-2.1709
10	35	NO	UNGRPD	80 0.0000 1.0000	81 0.0000	-8.5717	-5.3258	1.6419	-1.8803
11	37	NO	UNGRPD	80 0.0000 1.0000	81 0.0000	-9.6997	-7.3854	3.3961	0.3670
12	40	NO	UNGRPD	80 0.0000 1.0000	91 0.0000	-4.4855	-8.0627	1.0851	-1.7872
13	41	NO	UNGRPD	80 0.0006 1.0000	81 0.0000	-5.5683	-4.0841	-0.2096	-1.6184
14	42	NO	UNGRPD	80 0.0000 1.0000	91 0.0000	-5.9541	-7.1085	3.0952	-0.0804
15	43	NO	UNGRPD	80 0.0000 1.0000	81 0.0000	-6.4843	-6.2270	2.3530	-0.6868
GAMART CLAY									
16	45	NO	UNGRPD	80 0.0000 1.0000	91 0.0000	-5.2309	-6.0736	2.0841	-1.1877
17	48	NO	UNGRPD	81 0.0804 0.9986	92 0.0014	1.0850	1.7632	-2.1921	1.1031
18	49	NO	UNGRPD	92 0.0174 0.9987	81 0.0013	3.0789	1.0619	-2.5917	2.1299
19	50	NO	UNGRPD	81 0.1772 0.9990	92 0.0010	0.9054	1.5240	-1.7035	0.9081

GROUP CODE	80	81	91	92	93
FABRIC	CW IA	CW IB	LMP I	LMP II	LMP III

APPENDIX V

COARSE MARE CLASSIFICATION ANALYSIS.

CASE SEQNUM	SMP NUM	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP	P(D/G)	P(G/D)	2ND HIGHEST GROUP	P(G/D)	DISCRIMINANT SCORES...			
NABEUL CLAY												
20	53	NO	UNGRPD	92	0.0072	0.9989	81	0.0011	2.9089	0.9206	-2.6720	2.8533
21	54	NO	UNGRPD	80	0.0013	0.9996	91	0.0002	-2.1734	-3.1684	0.3074	-3.0116
22	55	NO	UNGRPD	80	0.0009	1.0000	81	0.0000	-6.5560	-2.1833	2.5758	-2.1048
23	56	NO	UNGRPD	80	0.0074	0.9967	91	0.0032	-1.7840	-3.5849	0.4833	-1.3022
24	57	NO	UNGRPD	91	0.0000	1.0000	92	0.0000	12.1905	-17.9826	-9.4032	-0.4966
25	58	NO	UNGRPD	80	0.0028	1.0000	81	0.0000	-3.9229	-3.7413	2.2843	-2.0197
26	59	NO	UNGRPD	80	0.0288	0.9976	91	0.0018	-1.6245	-3.1115	0.3909	-0.6630
27	60	NO	UNGRPD	80	0.3211	1.0000	81	0.0000	-5.6594	-1.0152	0.5528	0.4512
28	61	NO	UNGRPD	80	0.0003	1.0000	81	0.0000	-4.8510	-4.0388	-0.7118	-2.4358
29	62	NO	UNGRPD	91	0.0006	0.9984	81	0.0010	-0.4773	-3.7676	-3.1042	0.9314
30	63	NO	UNGRPD	80	0.0000	1.0000	81	0.0000	-8.6483	-1.8273	0.8788	-1.8914
31	65	NO	UNGRPD	80	0.0000	1.0000	81	0.0000	-7.1145	-4.3644	0.3147	-1.0301
THUBURBO MAIUS CLAY												
32	75	NO	UNGRPD	92	0.0004	0.7589	91	0.2343	3.0685	-0.3303	-3.6487	1.2009
33	76	NO	UNGRPD	92	0.0030	0.8485	81	0.1166	2.3597	0.0425	-2.8539	1.4502
34	77	NO	UNGRPD	92	0.0378	0.9033	81	0.0801	2.5057	2.4058	-1.0600	0.8278
35	78	NO	UNGRPD	92	0.0462	0.8874	93	0.1085	3.1092	2.7311	-0.9747	0.6100
36	79	NO	UNGRPD	92	0.0099	0.7109	81	0.2613	2.4959	2.6349	-1.5866	0.6842

GROUP CODE	80	81	91	92	93
FABRIC	CW IA	CW IB	LMP I	LMP II	LMP III

APPENDIX V

COARSE MARE CLASSIFICATION ANALYSIS.

CASE SEQNUM	SMP NUM	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP P(D/G) P(G/D)	2ND HIGHEST GROUP P(G/D)	DISCRIMINANT SCORES...			
KILN GROUP: CRM I AND II									
54	402	YES	81	81 0.9506 0.9998	80 0.0002	-1.3042	1.7843	-1.9498	0.2518
55	403	YES	80	80 0.9719 0.9975	81 0.0025	-3.8204	-0.4260	0.2386	0.3316
56	404	NO	UNGRPD	80 0.0068 0.9943	81 0.0057	-5.6238	0.7911	-0.9243	-2.2974
57	405	YES	81	81 0.7717 0.9990	80 0.0010	-2.0646	1.5347	-2.1311	0.6641
58	406	YES	80	80 0.1502 0.7544	81 0.2456	-3.3303	-0.2705	-1.5508	-1.0396
59	407	YES	81	81 0.7577 1.0000	80 0.0000	-1.2065	2.3501	-2.2962	-0.0964
60	408	YES	81	81 0.6270 0.9937	80 0.0063	-2.7270	1.9169	-1.5380	-0.7128
61	409	YES	81	81 0.6161 1.0000	80 0.0000	-0.0660	1.5314	-1.9111	-0.5449
62	410	YES	81	81 0.9620 0.9993	80 0.0007	-1.6365	1.5033	-1.8826	0.1291
63	411	YES	81	81 0.4067 1.0000	80 0.0000	-0.7066	2.1351	-1.5585	-1.7220
64	412	YES	81	81 0.9412 0.9917	80 0.0083	-1.2867	1.2985	-0.4249	0.3999
65	413	YES	80	80 0.3970 0.9995	81 0.0005	-3.9101	-0.6108	0.7815	-0.2777
66	414	YES	80	80 0.4873 0.5538	81 0.4462	-2.2984	0.3147	-0.1490	-0.0533
67	415	YES	80	80 0.5635 0.9993	81 0.0007	-2.8262	-0.2142	2.2543	0.2902
68	416	YES	80	80 0.4332 1.0000	81 0.0000	-4.6174	-0.9359	2.4101	-0.2830
69	417	YES	80	80 0.9740 0.9994	81 0.0006	-3.3626	-1.2114	0.5570	0.0324
70	418	YES	UNGRPD	80 0.5177 0.9969	81 0.0031	-4.0887	-0.5868	-0.3086	1.3125
71	419	YES	81	81 0.1065 0.9666	80 0.0334	-1.2441	0.8760	-0.0676	2.4612
72	420	YES	81	81 0.4987 0.9878	80 0.0122	-1.0895	0.8321	-0.4954	1.5300
73	421	YES	81	81 0.0096 0.9756	80 0.0244	-2.0384	2.6121	0.6640	-2.8984
74	422	YES	81	81 0.0275 0.9285	92 0.0464	0.7201	-0.4803	-0.1936	1.1075

GROUP CODE	80	81	91	92	93
FABRIC	CM IA	CM IB	LMP I	LMP II	LMP III

APPENDIX V

COARSE WARE CLASSIFICATION ANALYSIS.

CASE SEQNUM	SMP NUM	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP	P(D/G)	P(G/D)	2ND HIGHEST GROUP	P(G/D)	DISCRIMINANT SCORES...			
KILN GROUP: CRW I AND II												
75	423	YES	81	81	0.7299	0.9839	80	0.0161	-1.2612	1.0664	-0.2995	1.0274
76	424	NO	UNGRPD	80	0.0000	1.0000	81	0.0000	-8.6835	-3.7864	1.7398	-1.3883
77	426	YES	80	80	0.5226	1.0000	81	0.0000	-4.6987	-1.7373	0.1497	-0.5674
78	427	YES	80	80	0.6584	0.7932	81	0.2068	-2.8727	0.3418	-0.1956	-0.1419
79	428	YES	80	80	0.6928	1.0000	81	0.0000	-3.8570	-0.9448	2.0100	0.7426
80	429	YES	80	80	0.5112	0.9988	81	0.0012	-2.3970	-0.4959	2.1285	-0.2526
81	430	YES	80	80	0.8424	0.9995	81	0.0005	-4.2716	-0.2451	0.7254	-0.9349
82	431	YES	80	80	0.4011	1.0000	81	0.0000	-5.3811	-1.3354	1.2400	0.3523
83	433	YES	80	80	0.5631	0.9915	81	0.0085	-2.8041	-0.6180	0.5919	1.4898

GROUP CODE	80	81	91	92	93
FABRIC	CW IA	CW IB	LMP I	LMP II	LMP III

APPENDIX V

COARSE WARE CLASSIFICATION ANALYSIS.

CASE SEQNUM	SMP NUM	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP P(D/G) P(G/D)	2ND HIGHEST GROUP P(G/D)	DISCRIMINANT SCORES...			
THIRD CENTURY LAMPS									
84	434	YES	91	91 0.2105 1.0000	92 0.0000	3.0961	-5.9344	-1.4580	-0.6269
85	438	YES	92	92 0.4133 0.9953	93 0.0047	5.7600	1.9140	1.0953	1.8298
86	439	YES	91	91 0.3157 1.0000	92 0.0000	1.7254	-3.6372	0.9101	-1.4273
87	440	YES	93	93 0.8802 1.0000	92 0.0000	5.8235	3.1197	0.9815	-2.4210
88	445	YES	92	92 0.1350 0.9998	81 0.0002	2.6028	0.8986	-0.7574	3.0921
89	446	YES	92	92 0.1351 0.9029	91 0.4571	3.4462	-1.7749	-0.0322	1.1911
90	449	YES	91	91 0.7121 1.0000	92 0.0000	3.9130	-4.6516	-1.0473	-0.3581
91	451	YES	92	92 0.9167 0.9931	93 0.0069	4.5169	1.0266	0.8628	0.8699
92	452	YES	93	93 0.8408 0.9760	92 0.0240	5.1636	2.1691	0.3981	-0.8836
93	453	YES	91	91 0.8950 0.9999	92 0.0001	3.5805	-2.9011	-0.6452	-0.7389
94	454	YES	92	92 0.1220 0.9996	93 0.0004	6.2927	0.1018	2.3975	1.6495
95	455	YES	91	91 0.2633 0.9969	92 0.0031	4.6647	-2.7564	-1.3784	0.4293
96	458	YES	UNGRPD	92 0.0045 0.9904	93 0.0096	4.1472	3.9437	-1.3050	2.3002
97	461	YES	92	92 0.7701 0.9991	93 0.0009	3.7633	1.3639	-0.3175	1.4035
98	457	YES	91	91 0.3630 1.0000	92 0.0000	2.7471	-5.3297	-0.6585	-1.7195
99	463	YES	93	93 0.9464 0.9999	92 0.0001	4.5235	3.3912	1.1753	-1.9040
100	467	YES	93	93 0.9843 0.9992	92 0.0008	4.7392	2.4287	1.3665	-1.6732

GROUP CODE	80	81	91	92	93
FABRIC	CW IA	CW IB	LMP I	LMP II	LMP III

APPENDIX VI
COMPOSITION OF POTTERY SAMPLES

AFRICAN RED SLIP

Samples from Loci 1F32 to 36

SMP	FB	ORG GRP	FIN GRP	Si*	Al*	Ca*	Fe*	Mg*	Na*	Ti*	Mn+	Cr+	PCTOT	LOSS	RAT
126	5	43	#	56.8	18.8	.72	4.63	1.24	.038	1.11	118	224	83.32	.47	3.0
127	5	43	49	62.4	16.4	.72	3.70	1.17	.018	1.09	30	114	85.46	.43	3.8
128	5	43	#	59.3	17.7	.82	4.07	1.06	.024	1.15	ND	162	83.96	.48	3.4
129	5	43	99	66:0	18.0	.13	3.81	.94	.211	1.14	13	184	90.19	.29	3.7
130	5	43	#	63.3	18.5	.61	4.30	1.09	.050	1.14	ND	149	88.94	.51	3.4
132	5	43	#	67.1	23.8	.62	5.33	1.29	.080	1.30	85	157	99.58	.55	2.8
133	5	43	#	62.0	19.3	.58	4.19	.92	.078	1.15	194	123	88.23	.51	3.2
134	5	43	#	60.4	19.6	.62	4.20	.87	.053	1.21	235	150	86.96	.38	3.1
135	5	43	#	55.4	19.1	.35	5.05	1.14	.176	1.18	200	197	82.37	.88	2.9
136	5	43	#	57.0	18.3	.75	4.14	.91	.095	1.16	46	112	82.27	.97	3.1
138	5	41	43	57.6	20.5	.51	5.84	1.50	.076	1.29	523	166	87.30	.56	2.8
139	5	42	43	64.2	18.7	.75	4.28	1.08	.049	1.15	40	186	90.24	.64	3.4
140	5	43	#	54.7	19.0	.70	5.60	1.51	.146	1.15	451	205	82.75	.52	2.9
141	5	43	#	62.9	19.4	.75	5.14	1.25	.043	1.10	117	176	90.54	.57	3.2
142	4			60.1	20.1	.66	6.89	1.34	.042	1.14	48	179	90.29	.48	3.0
143	5	42	43	56.6	20.7	.74	6.03	1.61	.111	1.17	338	166	86.97	.57	2.7
144	5	42	43	54.1	19.5	.70	5.32	1.46	.106	1.15	277	182	82.28	.66	2.8

* % Wt. of oxide. + ppm oxide. PCTOT = Total wt %. LOSS = %Loss on ignition.
RAT = Ratio of silica to alumina
FB: 5 = Pottery. 4 = Slip. 0 = Other
ORG GRP = ORIGINAL FABRIC ASSIGNMENT. 41 = FABRIC N I 42 = FABRIC N II
FIN GRP = FINAL FABRIC ASSIGNMENT 43 = FABRIC N III 49 = FABRIC N IX
(# = UNCHANGED) 99 = UNASSIGNED
ND = NONE DETECTED

APPENDIX VI.

Samples from Loci 1F32 to 36

APPENDIX VI.

SMP	FB	ORG GRP	FIN GRP	Si*	Al*	Ca*	Fe*	Mg*	Na*	Ti*	Mn+	Cr+	PCTOT	LOSS	RAT
145	5	41	#	55.9	18.7	2.02	4.28	1.61	.169	1.04	747	189	83.73	.53	3.0
146	5	43	#	63.7	20.0	.88	4.37	1.06	.049	1.08	118	195	91.06	.74	3.2
147	4			68.8	21.5	.93	5.46	1.09	.038	1.09	67	154	98.83	2.48	3.2
148	5	42	99	66.4	17.6	1.97	4.66	1.27	.185	1.16	123	229	93.23	.42	3.8
150	5	42	43	65.4	18.3	1.46	4.54	1.13	.029	1.11	22	150	91.97	.77	3.6
151	5	43	#	58.5	18.0	.69	4.73	1.14	.066	1.06	136	198	84.22	.66	3.2
152	5	42	43	58.4	19.6	.58	4.94	1.26	.133	1.15	54	222	86.08	.53	3.0
153	5	43	#	64.2	18.5	.83	4.63	1.20	.106	1.13	157	150	90.65	.42	3.5
155	5	43	41	59.0	21.0	.59	5.84	1.66	.232	1.13	464	166	89.46	.56	2.8
157	5	43	#	64.4	19.4	.58	4.20	1.14	.074	1.18	338	171	90.96	.65	3.3
158	5	41	99	58.0	19.2	.96	5.91	1.16	.396	1.07	166	219	86.68	2.71	3.0
159	5	43	#	62.6	17.4	.86	4.02	1.03	.067	1.03	216	158	87.01	.57	3.6
160	4			65.1	19.6	1.04	5.15	1.33	.067	1.04	142	253	93.38	3.72	3.3
161	5	43	#	65.3	18.0	1.20	4.09	1.15	.097	1.02	200	187	90.86	.65	3.6
162	5	43	99	65.5	17.2	.86	4.77	1.59	.234	1.03	538	198	91.17	.68	3.8
163	5	43	#	63.0	17.1	1.01	3.88	1.14	.064	1.00	72	195	87.21	.70	3.7
164	5	42	99	60.5	16.2	.78	5.25	1.44	.311	.91	216	182	85.33	1.07	3.7
167	5	49	43	64.7	16.8	.82	4.03	1.14	.045	1.04	226	166	88.59	.49	3.8
168	5	49	43	60.7	17.8	1.38	4.66	1.20	.045	1.03	16	179	86.75	.98	3.4
169	5	49	43	56.1	18.4	.93	4.42	1.15	.084	1.11	150	211	82.19	.63	3.0
170	5	49	#	60.1	17.7	.83	4.35	1.24	.071	1.00	202	ND	85.22	.61	3.4
171	5	49	#	62.4	15.9	3.25	3.79	1.03	.063	1.08	179	189	87.50	1.70	3.9
172	5	49	43	59.9	18.3	1.06	4.12	1.23	.088	1.21	29	210	85.87	.61	3.3
175	5	43	99	64.9	17.1	1.23	4.12	1.17	.200	1.19	186	189	89.93	.70	3.8
176	5	43		58.8	19.2	.72	4.61	1.20	.046	1.21	330	262	85.78	.77	3.1

* % Wt. of oxide. + ppm oxide. PCTOT = Total wt %. LOSS = %Loss on ignition.
RAT = Ratio of silica to alumina

FB: 5 = Pottery. 4 = Slip. 0 = Other

ORG GRP = ORIGINAL FABRIC ASSIGNMENT.

FIN GRP = FINAL FABRIC ASSIGNMENT
(# = UNCHANGED)

41 = FABRIC N I 42 = FABRIC N II
43 = FABRIC N III 49 = FABRIC N IX
99 = UNASSIGNED

ND = NONE DETECTED

SAMPLES FROM LOCUS 1M 7

APPENDIX VI.

SMP	FB	ORG GRP	FIN GRP	Si*	Al*	Ca*	Fe*	Mg*	Na*	Ti*	Mn+	Cr+	PCTOT	LOSS	RAT
179	5	53	99	60.27	15.99	1.07	5.29	2.025	.245	.965	227	237	85.86	.59	3.8
181	5	53	63	65.52	15.89	.61	3.93	1.180	.217	1.147	43	224	88.50	.42	4.1
182	5	54	53	62.68	16.65	.59	4.33	1.363	.298	1.097	222	240	87.01	.19	3.8
183	5	54	#	60.27	14.42	1.86	5.08	1.539	.426	.987	322	216	84.58	.77	4.2
184	4			61.95	15.54	1.66	5.78	1.414	.228	.994	266	210	87.57	.91	4.0
185	5	53	#	56.07	16.78	1.23	3.61	1.872	.325	1.047	302	277	80.94	.85	3.3
186	4			56.70	18.56	2.62	6.27	1.871	.412	1.394	306	298	87.77	1.18	3.1
187	5	54	53	62.79	17.03	.66	4.90	1.373	.308	1.111	165	203	88.17	.42	3.7
188	5	54	64	66.78	16.16	1.39	5.63	1.595	.350	.954	190	163	92.86	.35	4.1
189	5	54	#	60.06	17.52	1.30	4.14	1.092	.140	1.222	616	194	85.48	.16	3.4
191	5	53	#	59.11	17.84	1.02	4.77	1.253	.325	1.121	442	114	85.45	.45	3.3
193	5	53	63	59.30	18.24	.64	4.66	1.316	.291	1.226	222	166	85.68	.42	3.3
194	5	54	#	61.32	14.91	2.02	5.11	1.436	.262	.898	826	136	85.95	.54	4.1
195	4			67.87	15.21	1.42	5.43	1.531	.258	.902	1051	125	92.63	.99	4.5
196	5	53	#	63.48	14.78	.90	3.54	1.081	.312	1.029	70	218	85.12	.35	4.3
197	5	54	53	66.25	17.50	1.26	3.43	1.044	.270	1.124	42	218	90.89	.58	3.8
198	5	53	54	66.40	14.53	.75	4.65	1.071	.241	.880	586	226	88.53	.32	4.6
199	5	53	#	67.35	19.41	.83	4.38	.906	.267	1.197	2	195	94.34	.33	3.5
200	5	53	63	64.60	16.99	.83	3.63	1.009	.153	1.176	162	162	88.38	.48	3.8
201	5	54	99	72.66	13.36	1.58	3.36	.863	.081	.955	358	93	92.87	.51	5.4
202	5	54	#	64.47	13.06	1.06	4.26	.963	.347	.977	512	178	85.13	.45	4.9
203	5	54	#	63.84	16.08	3.07	5.60	1.529	.291	.977	288	222	91.39	1.22	4.0
204	5	53	#	69.09	16.80	.72	4.41	1.384	.412	1.040	253	158	93.86	.36	4.1
207	5	53	#	62.24	18.39	.91	5.01	1.333	.259	1.237	542	142	89.39	.34	3.4
210	5	53	64	61.80	15.33	1.87	5.78	1.519	.356	.910	301	162	87.57	1.10	4.0
211	5	53	54	61.13	16.61	1.34	5.01	1.092	.252	.977	517	136	86.42	.42	3.7
212	4			62.41	18.52	1.38	6.09	1.220	.308	1.017	507	131	90.95	1.26	3.4
213	5	54	53	59.37	18.22	.72	5.18	1.433	.304	1.109	384	248	86.33	2.48	3.3
215	5	53	99	65.41	15.52	1.34	3.63	1.509	.214	.972	8	194	88.60	.76	4.2
216	5	54	64	63.38	15.37	1.28	6.06	1.647	.276	1.002	315	158	89.01	.60	4.1

* % Wt. of oxide. + ppm oxide. PCTOT = Total wt %. LOSS = %Loss on ignition. ND = NONE DETECTED.
FB: 5 = Pottery. 4 = Slip. 0 = Other RAT = Ratio of silica to alumina
ORG GRP = ORIGINAL FABRIC ASSIGNMENT. 53 = FABRIC M III 63 = FABRIC N III
FIN GRP = FINAL FABRIC ASSIGNMENT 54 = FABRIC M IV 64 = FABRIC N IV
(# = UNCHANGED) 99 = UNASSIGNED

Samples from Mahrine

APPENDIX VI.

SMP	FB	ORG GRP	FIN GRP	Si*	Al*	Ca*	Fe*	Mg*	Na*	Ti*	Mn+	Cr+	PCTOT	LOSS	RAT
226	5	30	99	66.6	16.3	.64	4.89	1.32	.189	1.05	130	130	90.99	.53	4.1
227	5	30	99	63.4	18.0	1.30	4.05	1.21	.081	1.15	64	195	89.22	.80	3.5
228	5	30	99	65.5	16.7	.83	4.87	1.58	.154	1.05	451	192	90.75	.43	3.9
229	5	30	99	63.8	16.1	.77	4.86	1.52	.241	1.03	299	141	88.36	.61	4.0
230	5	99	99	79.5	7.0	3.15	4.55	.60	.031	.50	376	102	95.37	5.16	11.2
231	5	30	30	67.3	15.9	.93	5.18	1.57	.056	1.00	280	205	91.91	.31	4.2
232	5	30	30	65.5	15.6	1.07	4.52	1.37	.094	1.04	205	198	89.11	.41	4.2
233	5	30	99	65.2	15.5	.80	4.37	1.21	.122	1.04	170	194	88.25	.59	4.2
234	5	30	99	64.9	16.5	.80	4.62	1.48	.143	1.10	83	250	89.45	.37	3.9
235	5	30	99	68.3	16.1	.96	4.40	1.53	.106	1.04	174	144	92.49	.38	4.2
236	5	30	99	63.6	19.9	.96	4.41	1.85	.213	1.34	688	248	92.29	.60	3.2
237	5	30	99	62.2	16.2	.93	4.73	1.32	.137	1.07	283	230	86.58	.82	3.8
238	5	30	99	69.5	17.3	.98	4.77	1.43	.120	1.14	200	184	95.22	.70	4.0
239	5	30	99	68.7	16.6	.96	3.61	1.01	.098	1.09	16	242	92.05	.92	4.1
240	5	30	30	62.7	16.6	.98	4.54	1.17	.052	1.13	173	275	87.18	1.39	3.8
241	5	30	3	64.0	12.2	1.01	4.23	1.17	.112	.99	162	222	83.65	.43	5.3
242	5	30	3	60.5	14.4	.62	4.20	1.17	.109	1.04	173	221	82.03	.65	4.2
243	5	30	3	65.7	13.2	.80	5.24	1.30	.125	1.00	232	218	87.30	2.03	5.0
244	5	30	3	62.8	12.7	.70	4.73	1.45	.115	1.02	219	224	83.50	.57	5.0
245	5	30	3	65.6	10.6	.90	3.85	1.14	.143	.99	226	232	83.19	.56	6.2
246	5	30	3	60.6	12.9	1.22	5.03	1.33	.465	1.04	117	211	82.53	.97	4.7
247	5	30	3	62.9	11.1	.50	4.69	1.24	.202	1.04	253	192	81.65	.68	5.7
248	5	30	30	68.7	14.1	1.02	4.21	1.13	.049	1.01	ND	245	90.15	.68	4.9
249	0	99	99	64.7	14.1	.82	3.95	1.20	.174	.98	110	254	85.90	1.10	4.6

* % Wt. of oxide. + ppm oxide. PCTOT = Total wt %. LOSS = %Loss on ignition.
RAT = Ratio of silica to alumina

FB: 5 = Pottery. 4 = Slip. 0 = Other

ORG GRP = ORIGINAL FABRIC ASSIGNMENT.

FIN GRP = FINAL FABRIC ASSIGNMENT
(# = UNCHANGED)

ND = NONE DETECTED

53 = FABRIC M III
54 = FABRIC M IV
99 = UNASSIGNED

63 = FABRIC N III
64 = FABRIC N IV
67 = FABRIC N VII
70 = FABRIC L I

Samples from locus 1N 17

APPENDIX VI.

SMP	FB	ORG GRP	FIN GRP	Si*	Al*	Ca*	Fe*	Mg*	Na*	Ti*	Mn+	Cr+	PCTOT	LOSS	RAT
250	5	64	#	65.1	14.4	1.68	4.94	1.45	.349	1.92	2	136	88.86	3.37	4.5
251	5	63	#	68.7	16.3	.74	4.26	1.38	.321	1.06	136	147	92.74	.63	4.2
252	5	64	63	66.4	14.9	1.50	4.07	1.22	.206	1.05	160	102	89.31	1.04	4.5
253	5	63	#	62.0	16.6	.85	4.00	1.32	.256	1.06	32	141	86.12	.49	3.7
255	5	63	#	64.2	17.4	.74	4.19	1.12	.197	1.17	ND	147	88.91	.63	3.7
356	4	64	63	61.5	15.0	.98	4.26	1.13	.183	.99	176	86	84.04	.99	4.1
357	5	64	#	63.5	14.1	1.04	4.55	1.14	.336	1.01	126	96	85.65	.57	4.5
358	5	64	#	59.5	13.2	.99	3.70	1.35	.293	.89	ND	104	79.91	.72	4.5
359	5	63	#	67.3	13.9	.64	3.89	1.24	.132	1.02	214	112	88.09	.38	4.9
362	5	63	#	68.4	14.5	.70	3.84	1.13	.209	1.14	ND	123	89.91	.40	4.7
363	5	63	#	66.4	16.0	1.07	5.61	.18	.294	1.00	227	152	90.48	.50	4.2
364	5	63	#	71.2	15.1	.54	3.99	1.07	.115	1.07	112	106	93.09	.32	4.7
365	5	64	63	64.4	16.4	1.26	6.12	1.21	.230	1.00	184	155	90.63	.47	3.9
366	5	63	#	56.6	16.4	.80	4.00	1.19	.249	1.12	120	152	80.37	.69	3.5
367	5	64	#	56.0	16.1	1.60	5.94	1.70	.248	.96	339	144	82.55	.83	3.5
368	5	63	#	59.5	16.2	.32	4.27	1.21	.238	1.08	238	85	82.83	.34	3.7
370	5	64	#	54.7	13.3	1.79	4.73	1.23	.277	.88	293	104	76.98	.32	4.1
371	5	63	#	62.9	13.9	1.20	3.11	1.11	.158	1.00	ND	133	83.28	.50	4.5
372	5	63	#	59.9	18.6	.69	3.53	1.14	.220	1.25	ND	141	85.33	.29	3.2
373	5	63	99	61.3	17.1	2.18	3.89	1.20	.174	1.12	5	133	87.05	1.47	3.6

* % Wt. of oxide. + ppm oxide. PCTOT = Total wt %. LOSS = %Loss on ignition.
FB: 5 = Pottery. 4 = Slip. 0 = Other RAT = Ratio of silica to alumina
ORG GRP = ORIGINAL FABRIC ASSIGNMENT. 53 = FABRIC M III 63 = FABRIC N III
FIN GRP = FINAL FABRIC ASSIGNMENT 54 = FABRIC M IV 64 = FABRIC N IV
(# = UNCHANGED) 99 = UNASSIGNED 67 = FABRIC N VII
ND = NONE DETECTED

APPENDIX VI.

Samples from locus 1N 17

SMP	FB	ORG GRP	FIN GRP	Si*	Al*	Ca*	Fe*	Mg*	Na*	Ti*	Mn+	Cr+	PCTOT	LOSS	RAT
374	5	63	#	59.1	17.5	.51	4.63	1.24	.190	1.08	429	128	84.29	.70	3.4
375	5	63	#	55.1	17.2	.66	5.99	1.83	.132	1.01	466	138	81.98	.89	3.2
376	5	63	#	60.1	13.9	1.44	4.41	1.24	.148	.97	330	112	82.18	.94	4.3
377	5	64	#	54.6	18.0	.91	6.22	1.75	.364	1.04	384	128	82.85	4.01	3.0
378	5	67	#	41.7	10.8	17.10	3.77	1.68	.375	.71	446	88	76.15	.65	3.8
379	5	67	#	55.9	13.4	19.12	4.89	1.67	.386	1.00	608	86	96.37	9.96	4.2
380	5	64	#	64.9	15.5	1.34	5.29	1.56	.248	.89	205	122	89.69	.85	4.2
381	4	64	#	61.3	14.6	1.17	5.28	1.47	.258	.89	198	131	85.03	2.23	4.2
382	5	63	#	62.4	16.5	.77	5.54	1.46	.232	1.07	216	168	87.93	.51	3.8
383	5	63	#	57.4	16.2	.50	4.28	1.15	.237	1.08	174	176	80.89	.49	3.5
385	4	63	#	74.3	17.5	.62	5.07	1.17	.246	1.08	62	67	99.96	2.42	4.2
386	5	63	#	72.1	16.0	.59	4.16	1.15	.238	1.11	112	123	95.29	.48	4.5
387	5	64	#	64.7	15.7	1.15	5.01	1.46	.270	.92	232	133	89.22	.92	4.1
388	5	63	64	52.8	17.9	1.44	5.88	1.73	.267	1.03	299	138	81.01	.93	2.9
389	4	63	99	65.4	15.2	1.07	4.35	1.20	.169	.98	112	346	88.34	.89	4.3
390	5	63	54	68.8	15.6	1.68	4.75	1.39	.272	.99	261	222	93.53	.30	4.4
391	5	63	#	72.7	16.6	.34	4.66	1.27	.155	1.12	130	139	96.83	.55	4.4
392	5	63	99	67.3	13.6	.21	5.33	1.16	.151	1.02	333	118	88.73	.47	5.0
393	5	63	64	56.0	16.5	.43	5.87	1.61	.255	1.01	318	152	81.70	.66	3.4
394	5	64	#	63.3	15.0	.34	5.67	1.45	.375	.95	106	93	87.73	.62	4.2
395	5	64	#	63.4	16.5	1.01	5.73	1.49	.276	.96	158	149	89.42	1.00	3.8
396	5	63	#	67.0	13.8	1.09	3.82	1.05	.259	1.01	187	141	87.95	.86	4.9
398	5	63	#	58.2	17.7	.86	4.23	1.11	.178	1.31	334	146	83.65	1.07	3.3
399	5	64	#	57.9	14.9	1.52	5.60	1.49	.214	1.03	381	138	82.73	.71	3.9

* % Wt. of oxide. + ppm oxide. PCTOT = Total wt %. LOSS = %Loss on ignition.
RAT = Ratio of silica to alumina

FB: 5 = Pottery. 4 = Slip. 0 = Other

ORG GRP = ORIGINAL FABRIC ASSIGNMENT.

FIN GRP = FINAL FABRIC ASSIGNMENT
(# = UNCHANGED)

ND = NONE DETECTED

53 = FABRIC M III
54 = FABRIC M IV
99 = UNASSIGNED
63 = FABRIC N III
64 = FABRIC N IV
67 = FABRIC N VII

Samples of ARS Lamps. APPENDIX VI.

SMP	FB	ORG GRP	FIN GRP	Si*	Al*	Ca*	Fe*	Mg*	Na*	Ti*	Mn+	Cr+	PCTOT	LOSS	RAT
471	5	70	#	52.4	14.4	.99	4.84	.73	.475	1.30	186	184	75.06	.37	3.6
472	5	70	63	59.5	21.1	2.50	6.76	1.49	.610	1.74	189	171	93.74	.51	2.8
475	5	70	#	62.6	18.2	1.17	5.74	1.57	1.270	1.19	933	141	91.75	.65	3.4
476	5	70	#	58.0	20.0	.67	6.89	1.74	1.105	1.18	2602	184	89.63	.38	2.9
477	5	70	99	71.7	17.8	.77	4.79	1.47	.367	1.14	426	162	98.00	.51	4.0
478	5	70	99	68.0	15.1	.48	5.00	1.45	.301	1.03	373	114	91.32	.31	4.5
479	5	70	99	77.7	13.9	.66	3.44	1.16	.318	1.02	286	184	98.14	.45	5.6
482	5	70	99	73.4	16.6	6.40	5.03	1.26	.344	1.09	429	149	104.11	.62	4.4
485	5	70	#	42.8	20.0	1.82	6.59	2.15	1.018	1.22	778	258	75.56	1.45	2.1
487	5	70	53	62.2	19.3	.27	5.18	1.60	.420	1.22	491	254	90.18	.47	3.2
488	5	70	#	69.9	16.3	.53	3.56	1.01	.316	1.12	966	182	92.69	.64	4.3
489	5	70	#	61.3	16.9	3.89	5.63	1.95	1.161	1.16	805	227	91.92	3.18	3.6
492	5	70	63	66.4	19.8	.34	5.12	1.48	.321	1.27	288	106	94.74	.50	3.4

* % Wt. of oxide. + ppm oxide. PCTOT = Total wt %. LOSS = %Loss on ignition.
FB: 5 = Pottery. 4 = Slip. 0 = Other RAT = Ratio of silica to alumina
ORG GRP = ORIGINAL FABRIC ASSIGNMENT. 53 = FABRIC M III 63 = FABRIC N III
FIN GRP = FINAL FABRIC ASSIGNMENT 54 = FABRIC M IV 64 = FABRIC N IV
(# = UNCHANGED) 99 = UNASSIGNED 67 = FABRIC N VII
ND = NONE DETECTED 70 = FABRIC L I

APPENDIX VI. (CONT)

COMPOSITION OF COARSE WARE FROM KILN

SMP NUM	Si*	Al*	Ca*	Fe*	Mg*	Na*	Ti*	Mn#	Cr#	PCTOT	LOSS	RAT
402	50.9	11.9	18.8	4.38	1.78	.477	.72	445	45	88.93	4.85	4.3
403	59.7	11.1	12.4	4.12	1.70	.452	.75	365	112	90.19	2.62	5.4
404	58.1	12.0	10.9	3.82	1.37	.514	.67	390	11	87.34	2.14	4.8
405	51.0	11.8	18.7	4.24	1.75	.400	.70	165	50	88.61	4.03	4.3
406	60.9	7.7	13.9	4.31	2.15	1.215	.67	485	34	90.73	5.90	7.9
407	50.4	11.3	19.2	4.21	1.65	.447	.70	547	18	87.81	5.47	4.5
408	58.0	12.0	18.0	4.23	1.96	.984	.72	406	26	95.83	3.97	4.8
409	53.1	11.4	16.8	4.35	.41	.517	.72	347	11	87.25	7.47	4.7
410	55.6	12.3	18.2	4.62	2.08	.517	.77	318	32	94.08	4.71	4.5
411	48.4	11.9	19.2	4.35	1.74	2.094	.70	277	40	88.31	13.26	4.1
412	50.4	11.9	17.6	4.34	1.95	.519	.74	1019	114	87.43	6.81	4.2
413	54.3	10.6	10.5	3.91	1.43	.358	.71	770	134	81.76	1.05	5.1
414	48.3	11.6	14.9	4.33	1.89	.444	.70	1085	134	82.17	3.69	4.1
415	57.2	11.7	11.0	4.79	4.47	.767	1.03	853	162	90.92	4.73	4.9
416	57.2	12.8	9.2	3.96	1.52	.356	.76	1072	194	85.77	.08	4.5
417	42.4	12.5	10.9	4.79	3.55	.711	.84	294	173	75.55	3.01	3.4
418	50.3	11.7	14.3	4.03	1.90	.440	.69	ND	154	83.38	2.85	4.3
419	48.5	13.0	19.7	4.20	1.83	.570	.75	301	181	88.43	4.35	3.7
420	48.7	12.2	19.0	4.47	2.12	.459	.73	859	154	87.67	4.13	4.0
421	54.3	11.8	17.2	3.99	1.96	1.925	.68	1893	88	91.85	3.49	4.6
422	43.1	14.1	16.4	5.36	1.81	.477	.85	518	157	87.06	1.93	3.4
423	49.1	13.3	19.5	4.47	2.18	1.194	.76	342	147	91.25	5.39	3.8
424	75.7	8.6	1.6	3.71	.90	.319	.66	346	117	91.48	.81	8.8
426	57.4	10.7	9.1	4.41	2.00	.529	.73	304	114	84.89	4.65	5.3
427	62.4	9.7	17.7	4.19	2.19	1.918	.68	590	115	98.80	5.50	6.4
428	53.5	14.5	11.4	4.23	1.68	.503	.80	376	211	86.59	4.26	3.7
429	63.1	13.4	8.9	4.49	1.49	.314	.95	438	122	92.74	.75	4.7
430	57.8	14.0	10.9	4.42	1.82	.424	.79	566	110	90.25	1.34	4.1
431	57.3	10.8	10.0	3.72	1.46	.409	.68	547	173	84.32	.68	5.3
433	52.2	12.2	14.5	4.27	1.79	.357	.74	546	186	86.04	14.09	4.3

* WT. OF OXIDE LOSS = LOSS ON IGNITION RAT = RATIO OF Si/Al

\# PPM OF OXIDE PCTOT = TOTAL WT %

APPENDIX VI. (CONT).

COMPOSITION OF THIRD CENTURY LAMPS

SMP NUM	Si*	Al*	Ca*	Fe*	Mg*	Na*	Ti*	Mn#	Cr#	PCTOT	LOSS	RAT
434	46.6	6.0	5.5	6.69	1.60	.732	.83	318	110	68.02	5.92	7.8
438	41.1	17.2	21.1	5.68	1.51	.489	1.04	1046	189	88.16	5.12	2.4
439	52.7	7.1	5.3	5.98	2.49	.743	.94	1285	122	75.24	5.98	7.4
440	45.8	14.3	20.0	5.77	1.46	.612	.88	3778	115	88.90	6.25	3.2
445	42.2	13.8	22.8	5.14	1.99	.668	.84	333	187	87.49	8.40	3.0
446	41.5	16.1	17.2	6.66	2.26	.421	.90	1184	221	85.01	10.07	2.6
449	46.3	16.3	12.6	7.84	1.62	.672	.89	701	179	86.16	5.29	2.9
451	46.5	17.9	19.2	6.16	2.00	.561	1.05	1058	166	93.28	6.06	2.6
452	44.1	16.0	21.1	5.84	2.01	1.94	.98	1099	125	92.02	6.11	2.8
453	49.0	16.8	13.3	7.34	1.57	.557	.94	840	142	89.43	3.66	2.9
454	46.5	19.5	18.2	6.59	1.61	.489	1.15	1190	240	94.10	3.89	2.4
455	44.2	16.5	17.4	7.46	1.65	.598	.87	1000	178	88.69	7.45	2.7
458	44.7	17.3	27.5	5.15	1.37	.342	.89	838	112	97.24	8.36	2.6
461	45.2	16.5	21.6	5.71	1.51	.421	.90	1054	155	91.81	7.77	2.7
457	70.1	18.5	10.8	8.61	1.51	.798	.99	822	117	111.26	3.91	3.8
463	49.2	18.6	19.6	5.57	1.45	1.72	1.06	1035	82	97.16	6.35	2.7
467	58.7	19.7	18.3	6.38	1.62	.773	1.12	1779	82	106.55	3.85	3.0

* WT. OF OXIDE LOSS = LOSS ON IGNITION RAT = RATIO OF Si/Al.

APPENDIX VII

FINAL GROUP MEANS

NUMBER CASES	FABRIC	Si*	Al*	Ca*	Fe*	Mg*	Na*	Ti*	Mn#	Cr#
11	MAR I	64.2	13.6	0.89	4.58	1.28	0.138	1.03	185	222
26	F III	60.5	18.8	0.91	4.55	1.15	0.086	1.13	146	184
1	F IX	55.9	18.7	2.02	4.28	1.61	0.169	1.04	747	188
5	M III	62.7	16.8	1.00	3.87	1.42	0.308	1.08	183	232
3	M IV	63.9	15.2	1.95	5.11	1.35	0.265	0.92	566	194
23	N III	63.1	16.2	0.93	4.24	1.19	0.239	1.11	170	128
14	N IV	60.5	15.7	1.26	5.60	1.56	0.285	0.96	264	137
2	N VII	48.8	12.1	18.11	4.32	1.67	0.381	0.85	527	87
6	L I	60.0	18.3	3.35	6.12	1.76	0.995	1.19	772	195
TOTAL	91									

GROUP STANDARD DEVIATIONS

NUMBER CASES	FABRIC	Si*	Al*	Ca*	Fe*	Mg*	Na*	Ti*	Mn#	Cr#
11	MAR I	2.6	2.0	0.21	0.44	0.14	0.117	0.04	76	23
26	F III	3.6	1.4	0.54	0.55	0.15	0.073	0.07	115	33
1	F IX	INSUFICIENT DATA FOR STANDARD DEVIATION								
5	M III	4.0	1.8	0.44	0.73	0.35	0.076	0.10	208	33
3	M IV	2.5	0.8	1.16	0.47	0.24	0.025	0.05	269	50
23	N III	5.9	1.9	0.44	0.62	0.20	0.083	0.11	153	24
14	N IV	4.5	1.2	0.43	0.44	0.15	0.068	0.05	123	20
2	N VII	10.1	1.8	1.43	0.79	0.01	0.008	0.20	114	1
6	L I	9.9	1.5	2.52	0.76	0.31	0.330	0.06	269	45
TOTAL	91									

(* %wt. of oxide)
(# ppm oxide)

FINAL ARS FABRIC TYPE MEANS

GROUP MEANS

NUMBER CASES	FABRIC	Si*	Al*	Ca*	Fe*	Mg*	Na*	Ti*	Mn#	Cr#
73	TYPE III	63.0	17.4	0.89	4.29	1.19	0.181	1.12	199	169
22	TYPE IV	60.6	15.9	1.38	5.54	1.54	0.285	0.96	299	151
11	MA I	64.2	13.6	0.86	4.58	1.29	0.143	1.03	174	226
6	L I (ARS)	60.0	18.3	3.35	6.12	1.76	0.995	1.19	771	190

GROUP STANDARD DEVIATIONS

DEVIATIONS		Si	Al	Ca	Fe	Mg	Na	Ti	Mn	Cr
73	TYPE III	4.9	1.9	0.48	0.54	0.19	0.112	0.08	188	41
22	TYPE IV	4.1	1.1	0.54	0.43	0.21	0.065	0.05	164	35
11	MA I	2.6	2.1	0.20	0.44	0.15	0.116	0.05	82	23
6	L I	9.9	1.5	2.52	0.76	0.31	0.330	0.06	269	45

APPENDIX VII. (CONT)

GROUP MEANS FOR COARSE WARE (KILN GROUP) AND THIRD CENTURY LAMPS

GROUP	Si*	Al*	Ca*	Fe*	Mg*	Na*	Ti*	Mn#	Cr#
CW IA	56.0	11.7	11.8	4.28	2.08	0.626	0.77	592	140
CW IB	51.6	12.1	18.5	4.32	1.78	0.842	0.73	576	75
LMP I	51.0	13.6	11.6	7.04	1.75	0.654	0.90	783	143
LMP II	43.8	16.8	20.0	5.99	1.81	0.508	0.98	977	193
LMP III	49.5	17.1	19.8	5.89	1.64	1.259	1.01	1922	100

GROUP STANDARD DEVIATIONS

	N								
CW IA	14	5.6	1.8	2.6	0.30	0.87	0.441	0.11	260	45
CW IB	12	3.0	0.6	0.9	0.16	0.46	0.595	0.03	482	59
LMP I	7	8.8	5.0	4.8	1.11	0.34	0.114	0.06	315	28
LMP II	6	2.5	1.9	2.2	0.59	0.31	0.093	0.12	322	32
LMP III	4	6.5	2.4	1.2	0.34	0.26	0.664	0.11	1281	22

* %Wt OXIDE
# PPM OXIDE

APPENDIX VIII

COMPOSITION OF CLAY SAMPLES

CARTHAGE: HAMILCAR

SMP	Si *	Al *	Ca *	Fe *	Mg *	Na *	Ti *	Mn #	Cr #	PCTOT	LOSS	RAT
1	72.1	2.0	.02	.98	.21	.041	.14	147	16	75.50	0.94	35.3
2	68.4	4.4	12.27	1.65	.59	.018	.24	803	22	87.53	9.39	15.7
3	68.5	5.2	16.74	1.93	.68	.036	.26	774	22	93.33	11.47	13.1
4	88.9	1.6	.02	.74	.16	.014	.10	80	19	91.52	0.40	55.3
5	82.8	6.2	.14	2.66	.55	.014	.47	413	56	92.75	1.85	13.4
6	59.2	9.9	1.86	3.89	.69	1.526	.57	282	93	77.70	2.74	6.0
7	66.4	15.5	1.71	6.10	1.50	.176	.98	1050	168	92.41	6.44	4.3
C 8	71.5	12.1	1.42	4.89	1.24	.144	.84	1018	149	92.14	4.87	5.9
F 9	65.3	16.5	1.94	6.40	1.60	.203	1.01	1210	195	92.93	5.44	4.0

CARTHAGE: CANADIAN SITE

SMP	Si *	Al *	Ca *	Fe *	Mg *	Na *	Ti *	Mn #	Cr #	PCTOT	LOSS	RAT
10	37.3	6.4	24.1	3.15	1.41	.399	.44	1275	67	73.20	24.37	5.8
C 11	47.6	5.5	21.3	2.51	1.27	.288	.36	1126	77	78.85	22.41	8.6
F 12	37.5	6.9	25.0	3.23	1.56	.423	.44	1278	75	75.05	26.20	5.4
13	45.7	3.0	25.7	1.54	.78	.084	.20	405	ND	77.01	25.31	15.1
14	52.4	4.6	5.63	2.04	.52	.034	.45	397	54	65.65	15.60	11.5
15	62.3	6.0	.61	2.14	.76	1.526	.37	464	154	73.68	2.48	10.4
16	79.4	5.8	8.08	2.62	.71	.022	.40	491	69	97.01	7.33	13.7
17	70.5	3.1	13.6	1.44	.65	.014	.25	339	32	89.56	10.38	22.6
18	88.6	3.8	7.23	1.57	.47	.007	.27	240	18	101.88	6.30	23.6
19	57.6	3.5	32.3	1.55	.83	.007	.19	253	35	95.91	19.85	16.6
20	72.7	3.7	4.22	1.67	.55	.007	.30	299	35	83.13	4.61	19.6
21	77.1	4.2	8.26	1.89	.66	.007	.28	315	37	92.46	7.50	18.2
22	82.2	5.9	.24	2.49	.67	.014	.36	338	43	91.91	2.63	13.8
23	64.5	4.9	.59	1.79	.45	1.848	.27	24	24	74.29	2.89	13.3
24	36.1	1.2	51.9	5.04	1.34	.014	.00	195	ND	95.59	38.21	31.3

SMP = SAMPLE NUMBER
* WT. PERCENT OF OXIDE
\# PARTS PER MILLION OF OXIDE
C = COARSE FRACTION
F = FINE FRACTION

LOSS = LOSS ON IGNITION (WT. PERCENT)
RAT = RATIO OF SILICA TO ALUMINA
PCTOT = SAMPLE NUMBER
ND = NONE DETECTED

APPENDIX VIII (cont)

CARTHAGE: LA MALGA

SMP	Si *	Al *	Ca *	Fe *	Mg *	Na *	Ti *	Mn #	Cr #	PCTOT	LOSS	RAT
25	19.5	17.3	23.4	7.10	1.85	.129	.925	355	187	70.20	19.08	1.1
26	26.1	23.3	14.9	6.92	1.89	.143	.999	277	237	74.21	15.19	1.1
27	23.5	16.7	29.2	6.72	1.67	.007	.858	1338	190	78.67	21.66	1.4
28	19.5	5.7	40.4	3.44	.83	.014	.245	534	46	70.07	33.88	3.4
29	43.5	17.6	23.0	7.34	1.93	.192	.937	1618	216	94.50	19.30	2.5
30	36.9	15.4	25.6	7.03	2.13	.123	.772	538	126	87.91	19.81	2.4

CARTHAGE: COLLINE DE JUNON

SMP	Si *	Al *	Ca *	Fe *	Mg *	Na *	Ti *	Mn #	Cr #	PCTOT	LOSS	RAT
31	50.8	8.5	.26	3.79	.945	.112	.506	462	88	64.94	3.60	6.0

CARTHAGE: BYRSA

SMP	Si *	Al *	Ca *	Fe *	Mg *	Na *	Ti *	Mn #	Cr #	PCTOT	LOSS	RAT
32	78.2	13.9	.14	5.43	1.64	.027	.803	101	101	100.10	5.93	5.6
33	66.4	8.4	11.8	3.60	1.13	.007	.526	349	80	91.90	10.78	7.9
34	75.7	14.3	.30	5.60	2.83	.168	.858	134	133	99.78	5.60	5.3
35	76.8	14.6	.42	5.54	2.89	.097	.795	382	293	101.09	5.91	5.3
36	20.4	4.2	47.1	1.44	1.25	.014	.145	1690	38	74.51	36.60	4.9
37	69.5	15.9	.13	7.66	3.16	.136	.932	554	187	97.38	6.40	4.4
38	76.6	8.6	.08	4.06	1.47	.094	.514	275	106	91.39	3.45	8.9
39	34.5	7.8	54.0	2.73	1.49	.014	.342	480	77	100.90	28.59	4.4
40	47.2	11.6	3.36	5.08	2.22	.129	.705	147	133	70.29	6.85	4.1
41	64.8	14.9	.29	6.05	2.55	.260	.890	197	197	89.77	5.66	4.3
C 42	65.5	13.4	.26	5.63	2.44	.239	.855	123	216	88.29	5.35	4.9
F 43	64.2	14.1	.30	6.05	2.52	.280	.912	142	192	88.34	5.52	4.5
44	28.5	6.9	36.1	2.79	1.65	.007	.346	373	88	76.22	31.35	4.1

APPENDIX VIII (cont)

CARTHAGE: GAMART

SMP	Si *	Al *	Ca *	Fe *	Mg *	Na *	Ti *	Mn #	Cr #	PCTOT	LOSS	RAT
45	40.1	13.1	23.1	4.96	1.65	.045	.633	1622	126	83.55	24.59	3.1
46	43.3	4.2	29.6	4.56	.72	.007	.197	234	37	82.56	18.50	10.2
47	60.6	4.1	15.6	2.25	.62	.007	.187	365	27	83.33	12.22	14.7
48	37.0	13.8	24.0	5.53	1.81	.384	.740	558	134	83.27	26.26	2.7
C 49	38.0	13.2	20.0	4.75	1.73	.447	.746	502	107	78.91	24.86	2.9
F 50	36.3	14.2	24.4	5.57	2.01	.167	.757	470	147	83.47	27.20	2.6
51	16.5	3.7	46.0	1.26	1.10	.084	.129	ND	33	68.72	37.68	4.4

NABEUL: SITE A

SMP	Si *	Al *	Ca *	Fe *	Mg *	Na *	Ti *	Mn #	Cr #	PCTOT	LOSS	RAT
52	73.8	5.3	8.56	2.30	.583	.064	.401	118	75	91.01	8.31	14.0
53	63.3	13.6	9.41	6.20	2.11	1.54	.770	1210	122	96.97	11.27	4.7
54	68.4	15.7	7.14	4.79	1.75	1.55	.857	141	133	100.11	9.30	4.4
55	56.4	16.7	8.69	6.48	2.29	.829	.902	248	155	92.36	11.74	3.4
56	55.8	14.6	9.95	15.3	1.98	.622	.800	26	125	98.94	11.08	3.8
57	65.4	18.0	6.40	6.13	2.43	1.48	.949	66	182	100.86	10.38	3.6
58	55.5	15.5	9.74	6.01	1.88	.766	.862	176	157	90.22	11.02	3.6

NABEUL: SITE B

SMP	Si *	Al *	Ca *	Fe *	Mg *	Na *	Ti *	Mn #	Cr #	PCTOT	LOSS	RAT
59	61.3	10.8	10.4	3.74	1.49	.328	.709	130	126	88.86	9.01	5.7
60	68.6	14.8	8.9	5.50	1.39	1.92	.631	18	99	98.80	9.64	5.8
61	56.7	11.1	15.1	6.44	1.85	.234	.670	384	105	92.11	13.93	5.1
62	74.2	1.3	1.18	.69	.184	.025	.119	ND	ND	77.75	1.67	55.3
63	61.2	11.4	3.92	3.56	1.49	.305	.673	ND	90	82.55	6.60	5.4
64	73.1	5.6	1.58	3.85	.85	.311	.372	ND	58	85.74	3.50	13.0
65	66.4	10.9	4.18	4.72	1.43	.294	.661	107	128	88.57	6.58	6.1

OUDNA

SMP	Si *	Al *	Ca *	Fe *	Mg *	Na *	Ti *	Mn #	Cr #	PCTOT	LOSS	RAT
66	72.5	7.64	12.4	2.95	.91	.015	.386	710	74	96.77	10.90	9.5
67	72.3	7.41	8.91	3.08	.92	.007	1.10	312	74	93.71	9.67	9.8
68	64.8	6.61	6.56	3.21	.99	.014	.394	821	59	82.58	7.67	9.8
69	66.4	7.50	12.5	3.02	1.09	.081	.421	197	74	90.96	11.80	8.8
70	65.1	6.05	15.0	2.44	1.02	.077	.399	362	66	90.05	11.31	10.8
71	62.5	6.65	16.7	2.91	1.02	.105	.327	517	90	90.24	13.30	9.4
72	22.3	5.16	10.7	2.49	.88	.046	.334	334	45	41.88	9.67	4.3
73	68.5	3.57	4.37	1.48	.42	.007	.284	59	19	78.66	4.96	19.2
74	74.9	6.67	6.67	2.28	.75	.524	.381	373	43	92.21	7.19	11.2

APPENDIX VIII (cont)

THUBURBO MAIUS

SMP	Si *	Al *	Ca *	Fe *	Mg *	Na *	Ti *	Mn #	Cr #	PCTOT	LOSS	RAT
75	44.9	14.1	24.9	6.65	2.04	.169	.641	1770	126	93.32	19.53	3.2
76	44.1	14.7	23.3	6.26	2.18	.157	.721	1238	130	91.42	18.97	3.0
77	38.9	13.3	21.1	4.84	1.68	.328	.807	1200	96	80.97	23.90	2.9
C 78	37.0	13.1	20.9	4.77	1.59	.314	.817	1283	104	78.38	24.28	2.8
F 79	37.6	13.0	21.7	4.76	1.62	.400	.770	1094	94	79.76	24.35	2.9

MAHRINE

SMP	Si *	Al *	Ca *	Fe *	Mg *	Na *	Ti *	Mn #	Cr #	PCTOT	LOSS	RAT
80	69.1	12.4	3.33	3.47	.867	.007	.696	278	182	89.84	6.85	5.6
81	70.2	13.3	2.75	3.18	.876	.015	.822	202	126	91.05	6.28	5.3
82	51.6	17.0	8.80	7.14	1.30	.031	.939	494	150	86.74	9.20	3.0
83	83.1	5.1	1.60	2.11	.380	.007	.394	296	43	92.70	3.24	16.4
84	79.9	9.0	1.66	3.46	.624	.007	.675	445	86	95.29	4.41	8.9
85	83.4	7.4	2.14	3.43	.678	.112	.548	432	128	97.52	4.40	11.3
C 86	86.3	4.1	.70	2.48	.641	.059	.484	349	102	94.75	2.72	20.9
F 87	72.2	9.3	3.53	3.92	.848	.164	.688	514	174	88.93	5.89	7.7
88	29.1	9.1	.99	3.56	.583	.018	.513	413	75	43.86	4.26	3.2

SIDI THABET

SMP	Si *	Al *	Ca *	Fe *	Mg *	Na *	Ti *	Mn #	Cr #	PCTOT	LOSS	RAT
89	24.7	7.5	33.3	3.65	.976	.095	.486	1067	70	70.70	31.90	3.3
90	28.3	9.1	28.5	4.09	.954	.210	.519	1296	85	71.64	29.53	3.1

OUED MEDJERDA

SMP	Si *	Al *	Ca *	Fe *	Mg *	Na *	Ti *	Mn #	Cr #	PCTOT	LOSS	RAT
91	48.5	16.0	17.6	4.90	1.57	1.08	.730	1018	74	80.28	23.33	8.1
92	36.1	13.8	18.6	5.32	1.80	.379	.765	1050	123	76.70	41.19	2.6

APPENDIX VIII (cont)

UTICA

SMP	Si *	Al *	Ca *	Fe *	Mg *	Na *	Ti *	Mn #	Cr #	PCTOT	LOSS	RAT
93	46.9	2.9	22.1	1.96	.511	.143	.240	398	19	74.74	23.80	16.2
94	53.8	9.1	18.3	4.10	1.16	.535	.643	509	90	87.59	19.68	5.9

TIDOIS

SMP	Si *	Al *	Ca *	Fe *	Mg *	Na *	Ti *	Mn #	Cr #	PCTOT	LOSS	RAT
95	39.3	9.1	40.0	4.03	1.24	.007	.538	744	85	94.16	26.62	4.3
96	44.0	12.5	37.3	4.77	.734	.007	.685	1098	110	99.98	24.80	3.5
97	41.3	10.6	37.5	4.19	1.68	.007	.595	1174	118	95.85	25.74	3.9
98	34.1	11.0	46.0	3.61	2.71	.007	.486	1030	107	98.01	28.76	3.1
99	49.1	15.7	24.9	6.13	2.14	.007	.845	1189	176	98.75	20.39	3.1

APPENDIX IX

FREQUENCIES: Si OXIDE CONCENTRATION. CARTHAGE CLAYS.

	COUNT	MIDPOINT	ONE SYMBOL EQUALS APPROXIMATELY .20 OCCURRENCES
Si	0	13	
	1	17	*****
	3	21	**********
	2	25	**********
	1	29	*****
	1	33	*****
	8	37	**********
	1	41	*****
	3	45	**********
	3	49	**********
	1	53	*****
	1	57	*****
	7	61	**********
	7	65	**********
	5	69	**********
	3	73	**********
	7	77	**********
	4	81	**********
	0	85	
	2	89	**********
	0	93	

I....+....I....+....I....+....I....+....I....+....I

0 2 4 6 8 10

HISTOGRAM FREQUENCY

MEAN 56.570 STD DEV 19.524 MINIMUM 16.464
MAXIMUM 88.872

FREQUENCIES: Si OXIDE CONCENTRATIONS. CLAYS FROM OTHER SITES.

COUNT	MIDPOINT	ONE SYMBOL EQUALS APPROXIMATELY .20 OCCURRENCES
1	21.00	*****
1	24.33	*****
2	27.67	**********
0	31.00	
1	34.33	*****
5	37.67	**********
1	41.00	*****
3	44.33	**********
3	47.67	**********
1	51.00	*****
3	54.33	**********
2	57.67	**********
3	61.00	**********
4	64.33	**********
6	67.67	**********
4	71.00	**********
4	74.33	**********
0	77.67	
1	81.00	*****
2	84.33	**********
1	87.67	*****

I....+....I....+....I....+....I....+....I....+....I....+....I

0 2 4 6 8 10

HISTOGRAM FREQUENCY

MEAN 57.139 STD DEV 16.672 MINIMUM 22.302
MAXIMUM 86.268

APPENDIX IX

FREQUENCIES. Al OXIDE CONCENTRATIONS..CARTHAGE CLAYS.

COUNT	MIDPOINT	ONE SYMBOL EQUALS APPROXIMATELY .40 OCCURRENCES
0	-3.0	
0	-1.5	
0	.0	
3	1.5	********
10	3.0	**************************
11	4.5	*****************************
9	6.0	************************
3	7.5	********
3	9.0	********
1	10.5	***
2	12.0	*****
7	13.5	******************
5	15.0	**************
3	16.5	********
2	18.0	*****
0	19.5	
0	21.0	
0	22.5	
1	24.0	***
0	25.5	
0	27.0	

I....+....I....+....I....+....I....+....I....+....I
0 4 8 12 16 20
HISTOGRAM FREQUENCY

MEAN 8.288 STD DEV 5.291 MINIMUM 1.153
MAXIMUM 23.266

FREQUENCIES: Al OXIDE CONCENTRATIONS. CLAYS FROM OTHER SITES.

COUNT	MIDPOINT	ONE SYMBOL EQUALS APPROXIMATELY .20 OCCURRENCES
0	0	
1	1	*****
0	2	
1	3	*****
2	4	**********
3	5	***************
3	6	***************
5	7	*************************
3	8	***************
6	9	******************************
0	10	
6	11	******************************
3	12	***************
4	13	********************
3	14	***************
3	15	***************
2	16	**********
2	17	**********
1	18	*****
0	19	
0	20	

I....+....I....+....I....+....I....+....I....+....I
0 2 4 6 8 10
HISTOGRAM FREQUENCY

MEAN 10.034 STD DEV 4.108 MINIMUM 1.342
MAXIMUM 18.031

APPENDIX IX

FREQUENCIES. Ca OXIDE CONCENTRATIONS. CARTHAGE CLAYS.

COUNT	MIDPOINT	ONE SYMBOL EQUALS APPROXIMATELY .40 OCCURRENCES
0	-3	
16	0	**********
5	3	**********
2	6	*****
3	9	********
8	12	**********
3	15	********
1	18	***
3	21	********
7	24	**********
2	27	*****
2	30	*****
2	33	*****
1	36	***
1	39	***
0	42	
1	45	***
1	48	***
1	51	***
1	54	***
0	57	

I....+....I....+....I....+....I....+....I....+....I....+....I
0 4 8 12 16 20
HISTOGRAM FREQUENCY

MEAN 14.910 STD DEV 14.549 MINIMUM .016
MAXIMUM 54.032

FREQUENCIES: Ca OXIDE CONCENTRATIONS. CLAYS FROM OTHER SITES.

COUNT	MIDPOINT	ONE SYMBOL EQUALS APPROXIMATELY .20 OCCURRENCES
0	-1.5	
8	1.0	**********
5	3.5	**********
4	6.0	**********
7	8.5	**********
3	11.0	**********
2	13.5	**********
3	16.0	**********
3	18.5	**********
4	21.0	**********
1	23.5	*****
2	26.0	**********
1	28.5	*****
0	31.0	
1	33.5	*****
0	36.0	
2	38.5	**********
1	41.0	*****
0	43.5	
1	46.0	*****
0	48.5	

I....+....I....+....I....+....I....+....I....+....I....+....I
0 2 4 6 8 10
HISTOGRAM FREQUENCY

MEAN 13.720 STD DEV 11.491 MINIMUM .704
MAXIMUM 46.032

APPENDIX IX

FREQUENCIES. Fe OXIDE CONCENTRATIONS. CARTHAGE CLAYS.

COUNT	MIDPOINT	ONE SYMBOL EQUALS APPROXIMATELY .40 OCCURRENCES
0	-.50	
0	.25	
4	1.00	**********
16	1.75	**
9	2.50	************************
4	3.25	**********
3	4.00	********
6	4.75	***************
7	5.50	******************
4	6.25	**********
5	7.00	*************
1	7.75	***
0	8.50	
0	9.25	
0	10.00	
0	10.75	
0	11.50	
0	12.25	
0	13.00	
1	13.75	***
0	14.50	

I....+....I....+....I....+....I....+....I....+....I....+....I
0 4 8 12 16 20
HISTOGRAM FREQUENCY

MEAN 3.787 STD DEV 2.366 MINIMUM .742
MAXIMUM 13.468

FREQUENCIES: Fe OXIDE CONCENTRATIONS. CLAYS FROM OTHER SITES.

COUNT	MIDPOINT	ONE SYMBOL EQUALS APPROXIMATELY .40 OCCURRENCES
1	.50	***
1	1.25	***
4	2.00	**********
7	2.75	******************
11	3.50	*****************************
5	4.25	*************
8	5.00	*********************
2	5.75	*****
7	6.50	******************
1	7.25	***
0	8.00	
0	8.75	
0	9.50	
0	10.25	
0	11.00	
0	11.75	
0	12.50	
0	13.25	
0	14.00	
0	14.75	
1	15.50	***

I....+....I....+....I....+....I....+....I....+....I....+....I
0 4 8 12 16 20
HISTOGRAM FREQUENCY

MEAN 4.299 STD DEV 2.204 MINIMUM .686
MAXIMUM 15.274

APPENDIX IX

FREQUENCIES. Mg OXIDE CONCENTRATION. CARTHAGE CLAYS.

COUNT	MIDPOINT	ONE SYMBOL EQUALS APPROXIMATELY .40 OCCURRENCES
2	.15	*****
0	.30	
4	.45	**********
12	.60	**********
7	.75	**********
3	.90	********
2	1.05	*****
5	1.20	**********
2	1.35	*****
4	1.50	**********
5	1.65	**********
3	1.80	********
3	1.95	********
1	2.10	***
1	2.25	***
1	2.40	***
2	2.55	*****
0	2.70	
2	2.85	*****
0	3.00	
1	3.15	***

I....+....I....+....I....+....I....+....I....+....I....+....I
0 4 8 12 16 20
HISTOGRAM FREQUENCY

MEAN	1.244	STD DEV	.719	MINIMUM	.163
MAXIMUM	3.157				

FREQUENCIES: Mg OXIDE CONCENTRATIONS. CLAYS FROM OTHER SITES

COUNT	MIDPOINT	ONE SYMBOL EQUALS APPROXIMATELY .20 OCCURRENCES
0	-.05	
0	.10	
1	.25	*****
2	.40	**********
5	.55	**********
3	.70	**********
7	.85	**********
5	1.00	**********
2	1.15	**********
2	1.30	**********
4	1.45	**********
3	1.60	**********
4	1.75	**********
2	1.90	**********
3	2.05	**********
2	2.20	**********
1	2.35	*****
1	2.50	*****
1	2.65	*****
0	2.80	
0	2.95	

I....+....I....+....I....+....I....+....I....+....I....+....I
0 2 4 6 8 10
HISTOGRAM FREQUENCY

MEAN	1.270	STD DEV	.608	MINIMUM	.184
MAXIMUM	2.714				

APPENDIX IX

FREQUENCIES: Na OXIDE CONCENTRATIONS. CARTHAGE CLAYS.

COUNT	MIDPOINT	ONE SYMBOL EQUALS APPROXIMATELY .50 OCCURRENCES
0	-.1	
26	.0	**********
11	.1	**********
7	.2	**********
4	.3	*******
5	.4	********
0	.5	
1	.6	**
0	.7	
1	.8	**
0	.9	
0	1.0	
1	1.1	**
0	1.2	
1	1.3	**
0	1.4	
2	1.5	***
0	1.6	
0	1.7	
1	1.8	**
0	1.9	

I....+....I....+....I....+....I....+....I....+....I....+....I

0 6 12 18 24 30

HISTOGRAM FREQUENCY

MEAN .250 STD DEV .410 MINIMUM .007
MAXIMUM 1.848

FREQUENCIES: Na OXIDE. CLAYS FROM OTHER SITES

COUNT	MIDPOINT	ONE SYMBOL EQUALS APPROXIMATELY .40 OCCURRENCES
18	.0	**********
7	.1	**********
5	.2	**********
6	.3	**********
2	.4	*****
2	.5	*****
1	.6	***
0	.7	
2	.8	*****
0	.9	
0	1.0	
1	1.1	***
0	1.2	
0	1.3	
0	1.4	
2	1.5	*****
1	1.6	***
0	1.7	
0	1.8	
1	1.9	***
0	2.0	

I....+....I....+....I....+....I....+....I....+....I....+....I

0 4 8 12 16 20

HISTOGRAM FREQUENCY

MEAN .319 STD DEV .468 MINIMUM .007
MAXIMUM 1.918

FREQUENCIES: Ti OXIDE CONCENTRATIONS. CARTHAGE CLAYS.

COUNT	MIDPOINT	ONE SYMBOL EQUALS APPROXIMATELY .20 OCCURRENCES
1	.01	*****
0	.06	
2	.11	**********
2	.16	**********
6	.21	******************************
10	.26	**
3	.31	***************
6	.36	******************************
2	.41	**********
4	.46	********************
3	.51	***************
1	.56	*****
1	.61	*****
0	.66	
1	.71	*****
4	.76	********************
2	.81	**********
4	.86	********************
4	.91	********************
2	.96	**********
2	1.01	**********

I....+....I....+....I....+....I....+....I....+....I

0 2 4 6 8 10

HISTOGRAM FREQUENCY

MEAN .484 STD DEV .285 MINIMUM .002
MAXIMUM 1.012

FREQUENCIES: Ti OXIDE CONCENTRATIONS. CLAYS FROM OTHER SITES.

COUNT	MIDPOINT	ONE SYMBOL EQUALS APPROXIMATELY .20 OCCURRENCES
1	.11	*****
0	.16	
0	.21	
2	.26	**********
2	.31	**********
2	.36	**********
6	.41	******************************
1	.46	*****
5	.51	**************************
1	.56	*****
2	.61	**********
7	.66	**********************************
5	.71	**************************
3	.76	***************
4	.81	********************
3	.86	***************
1	.91	*****
2	.96	**********
0	1.01	
0	1.06	
1	1.11	*****

I....+....I....+....I....+....I....+....I....+....I

0 2 4 6 8 10

HISTOGRAM FREQUENCY

MEAN .613 STD DEV .213 MINIMUM .119
MAXIMUM 1.102

APPENDIX IX

FREQUENCIES: Mn OXIDE CONCENTRATIONS. CARTHAGE CLAYS.

COUNT	MIDPOINT	ONE SYMBOL EQUALS APPROXIMATELY .20 OCCURRENCES
2	36	**********
7	117	**********************************
4	198	********************
9	279	***
8	360	**
6	441	******************************
8	522	**
2	603	**********
2	684	**********
2	765	**********
0	846	
0	927	
1	1008	*****
2	1089	**********
1	1170	*****
2	1251	**********
1	1332	*****
0	1413	
0	1494	
0	1575	
3	1656	***************

I....+....I....+....I....+....I....+....I....+....I....+....I
0 2 4 6 8 10
HISTOGRAM FREQUENCY

MEAN 525.547 STD DEV 411.157 MINIMUM 1.600
MAXIMUM 1689.600

FREQUENCIES: MN OXIDE CONCENTRATIONS. CLAYS FROM OTHER SITES.

COUNT	MIDPOINT	ONE SYMBOL EQUALS APPROXIMATELY .20 OCCURRENCES
7	36	**********************************
4	121	********************
5	206	************************
3	291	***************
6	376	******************************
3	461	***************
3	546	***************
0	631	
2	716	**********
1	801	*****
0	886	
0	971	
6	1056	******************************
1	1141	*****
4	1226	********************
2	1311	**********
0	1396	
0	1481	
0	1566	
0	1651	
1	1736	*****

I....+....I....+....I....+....I....+....I....+....I....+....I
0 2 4 6 8 10
HISTOGRAM FREQUENCY

MEAN 556.933 STD DEV 463.299 MINIMUM 1.600
MAXIMUM 1769.600

APPENDIX IX

FREQUENCIES: Cr OXIDE CONCENTRATION. CARTHAGE CLAYS.

COUNT	MIDPOINT	ONE SYMBOL EQUALS APPROXIMATELY .40 OCCURRENCES
11	7	**********
8	21	********
6	35	******
4	49	****
2	63	**
4	77	****
3	91	***
3	105	***
0	119	
5	133	*****
3	147	***
1	161	*
0	175	
5	189	*****
1	203	*
2	217	**
1	231	*
0	245	
0	259	
0	273	
1	287	*

I....+....I....+....I....+....I....+....I....+....I....+....I

0 4 8 12 16 20

HISTOGRAM FREQUENCY

MEAN 83.813 STD DEV 74.374 MINIMUM 1.600
MAXIMUM 292.800

FREQUENCIES: Cr OXIDE CONCENTRATIONS. CLAYS FROM OTHER SITES.

COUNT	MIDPOINT	ONE SYMBOL EQUALS APPROXIMATELY .20 OCCURRENCES
1	2	**
0	11	
2	20	**********
0	29	
0	38	
3	47	***
2	56	**********
1	65	**
8	74	**********
3	83	***
5	92	*****
3	101	***
3	110	***
3	119	***
6	128	******
1	137	**
1	146	**
2	155	**********
0	164	
2	173	**********
2	182	**********

I....+....I....+....I....+....I....+....I....+....I....+....I

0 2 4 6 8 10

HISTOGRAM FREQUENCY

MEAN 98.367 STD DEV 42.293 MINIMUM 1.600
MAXIMUM 182.400

APPENDIX X.
DIRECT CURRENT PLASMA EMISSION PARAMETERS AND ACCURACY.

TABLE X.3 ANALYSIS OF U.S.G.S. STANDARDS

ELEMENT STANDARD	Si*	Al*	Ca*	Fe*	Mg*	Na*	Ti*	Mn*	Cr**
MGO-1									
	22.5	7.52	1.11	5.41	1.83	3.00	0.51	589	107
	22.7	7.92	0.98	4.81	1.84	2.99	0.44	579	86
	23.8	8.58	1.13	4.91	2.03	3.13	0.39	617	120
	23.5	8.26	1.11	4.97	1.93	3.21	0.51	633	148
	24.5	8.35	1.03	4.82	1.86	3.08	0.35	609	92
$\bar{X}$	23.4	8.13	1.07	4.98	1.90	3.08	0.42	605	110
Std Dev	.5	.37	.13	.22	.17	.08	.08	19	22
REPORTED VALUE	23.9	8.71	0.986	4.88	1.89	2.90	0.45	1000	105
QLO-1									
	30.7	8.90	2.22	2.89	0.627	3.15	0.25	605	48
	32.1	8.65	2.47	3.00	0.696	3.55	0.27	617	54
	30.6	8.42	2.35	3.01	0.665	3.34	0.27	594	66
	30.8	9.18	2.53	3.13	0.690	3.49	0.35	660	70
	30.6	8.79	2.42	2.88	0.648	3.30	0.27	582	37
$\bar{X}$	31.0	8.79	2.40	2.98	0.665	3.37	0.30	612	55
Std Dev	.5	.36	.10	.09	.058	.14	.04	27	12
REPORTED VALUE	30.8	8.71	2.32	3.00	0.627	3.14	0.37	900	4
SCO-1									
	26.4	7.42	1.84	3.58	1.70	0.713	0.39	289	76
	30.0	7.54	1.98	3.54	1.81	0.739	0.42	301	91
	30.2	7.42	2.01	3.71	1.81	0.726	0.31	310	108
	29.3	6.63	1.76	3.66	1.73	0.691	0.35	282	135
	29.9	7.32	1.98	3.53	1.65	0.740	0.33	286	94
$\bar{X}$	29.2	7.21	1.91	3.60	1.74	.722	0.36	294	101
Std Dev	1.3	.32	.10	.16	.06	.040	0.04	10	23
REPORTED VALUE	29.6	7.25	1.89	3.60	1.66	.705	0.37	500	71

* WT. PERCENT ** PPM

APPENDIX X.
DIRECT CURRENT PLASMA EMISSION PARAMETERS AND ACCURACY.

TABLE X.2: WAVELENGTHS USED FOR DCP ANALYSIS

ELEMENT	WAVELENGTH (nm)
Si	288.158
Al	396.156
Ca	317.933
Fe	259.940
Mg	280.270
Na	589.592
Ti	337.28C
Mn	257.610
Cr	357.869

APPENDIX X.
DIRECT CURRENT PLASMA EMISSION PARAMETERS AND ACCURACY.

TABLE X.3: DRILL CONTAMINATION CORRECTION FOR CHROMIUM

SAMPLE NO.		CHROMINM (PPM)	INCREASE IN Cr CONCENTRATION
145	Drilled	136	
145	Not Drilled	126	10
141	Drilled	135	
141	Not Drilled	105	30
181	Drilled	171	
181	Not Drilled	126	45
202	Drilled	124	
202	Not Drilled	102	22
380	Drilled	124	
380	Not Drilled	108	12
		MEAN =	24

APPENDIX XI.

ESTIMATE OF STANDARD DEVIATION

SUMMARY:

ELEMENT	Si*	Al*	Ca*	Fe*	Mg*	Na*	Ti*	Mn*	Cr**
Ave. (N = 84)	28.4	8.76	1.08	3.46	.739	.795	.568	279	99
$\underline{s}$	1.33 (4.7%)	.33 (3.8%)	.11 (10.2%)	.12 (3.5%)	.06 (8.1%)	.068 (8.6%)	.05 (8.8%)	25 (9.0%)	23 (23.4%)

ABUNDANCES OF PAIRED SAMPLES

USGS STANDARD MGO-1

ELEMENT REPLICATION	Si*	Al*	Ca*	Fe*	Mg*	Na*	Ti*	Mn**	Cr**
1	22.5	7.52	1.11	5.41	1.83	3.00	0.51	589	107
2	22.7	7.92	0.98	4.81	1.84	2.99	0.44	579	86
D++	.05	.16	.17	.31	.00	.00	.01	100	441
1	22.5	7.52	1.11	5.41	1.83	3.00	0.51	589	107
3	23.8	8.58	1.13	4.91	2.03	3.13	0.39	617	120
D	1.74	1.12	.000	.25	.04	.02	.01	784	169
1	22.5	7.52	1.11	5.41	1.83	3.00	0.51	589	107
4	23.4	8.26	1.11	4.97	1.93	3.21	0.51	633	148
D	.77	.55	0	.19	.01	.04	0	1936	1681
1	22.5	7.52	1.11	5.41	1.83	3.00	0.51	589	107
5	24.5	8.35	1.03	4.82	1.86	3.08	0.35	609	92
D	4.08	.69	.01	.35	.00	.01	.03	400	225
2	22.7	7.92	0.98	4.81	1.84	2.99	0.44	579	86
3	23.8	8.58	1.13	4.91	2.03	3.13	0.39	617	120
D	1.19	.44	.02	.01	.04	.02	.00	1444	1156

++ $D = d^2 = (x_1 - x_2)^2$ $\quad \underline{s}^2 = \sum d^2 / 2N$ *WT %. **ppm

USGS STANDARD MGO-1

ELEMENT REPLICATION	Si*	Al*	Ca*	Fe*	Mg*	Na*	Ti*	Mn*	Cr**
2	22.7	7.92	0.98	4.81	1.84	2.99	0.44	579	86
4	23.4	8.26	1.11	4.97	1.93	3.21	0.51	633	148
D	.42	.12	.02	.03	.01	.05	.01	2916	3844
2	22.7	7.92	0.98	4.81	1.84	2.99	0.44	579	86
5	24.5	8.35	1.03	4.82	1.86	3.08	0.35	609	92
D	3.20	.19	.00	.00	.01	.01	.01	900	36
3	23.8	8.58	1.13	4.91	2.03	3.13	0.39	617	120
4	23.4	8.26	1.11	4.97	1.93	3.21	0.51	633	148
D	.19	.10	.00	.00	.01	.01	.01	256	784
3	23.8	8.58	1.13	4.91	2.03	3.13	0.39	617	120
5	24.5	8.35	1.03	4.82	1.86	3.08	0.35	609	92
D	.49	.05	.01	.01	.03	.00	.00	64	784
4	23.4	8.26	1.11	4.97	1.93	3.21	0.51	633	148
5	24.5	8.35	1.03	4.82	1.86	3.08	0.35	609	92
D	1.30	.01	.01	.02	.01	.02	.03	576	3136

USGS STANDARD SCO-1

ELEMENT REPLICATION	Si*	Al*	Ca*	Fe*	Mg*	Na*	Ti*	Mn*	Cr**
1	26.4	7.42	1.84	3.58	1.70	0.713	0.39	289	76
2	30.0	7.54	1.98	3.54	1.81	0.739	0.42	301	91
D	12.5	.01	.02	.00	.01	.0007	.001	144	225
1	26.4	7.42	1.84	3.58	1.70	0.713	0.39	289	76
3	30.2	7.42	2.01	3.71	1.81	0.726	0.31	310	108
D	14.14	0	.03	.02	.01	.0002	.006	441	
1	26.4	7.42	1.84	3.58	1.70	0.713	0.39	289	76
4	29.3	6.63	1.76	3.66	1.73	0.691	0.35	282	135
D	8.41	.62	.01	.01	.001	.0005	.002	49	3481
1	26.4	7.42	1.84	3.58	1.70	0.713	0.39	289	76
5	30.0	7.32	1.98	3.53	1.65	0.740	0.33	286	94
D	12.25	.01	.02	.00	.00	.0007	.004	9	324

USGS STANDARD SCO-1

ELEMENT REPLICATION	Si*	Al*	Ca*	Fe*	Mg*	Na*	Ti*	Mn*	Cr**
2	30.0	7.54	1.98	3.54	1.81	0.739	0.42	301	91
3	30.2	7.42	2.01	3.71	1.81	0.726	0.31	310	108
D	.05	.01	.00	.03	0	.0002	.012	81	289
2	30.0	7.54	1.98	3.54	1.81	0.739	0.42	301	91
4	29.3	6.63	1.76	3.66	1.73	0.691	0.35	282	135
D	.41	.83	.05	.01	.01	.0023	.005	361	1936
2	30.0	7.54	1.98	3.54	1.81	0.739	0.42	301	91
5	29.9	7.32	1.98	3.53	1.65	0.740	0.33	286	94
D	.00	.05	0	.00	.03	.000	.008	225	9
3	30.2	7.42	2.01	3.71	1.81	0.726	0.31	310	108
4	29.3	6.63	1.76	3.66	1.73	0.691	0.35	282	135
D	.74	.62	.06	.00	.01	.0012	.002	784	729
3	30.2	7.42	2.01	3.71	1.81	0.726	0.31	310	108
5	29.9	7.32	1.98	3.53	1.65	0.740	0.33	286	94
D	.07	.01	.00	.03	.03	.0002	.00	576	196
4	29.3	6.63	1.76	3.66	1.73	0.691	0.35	282	135
5	30.0	7.32	1.98	3.53	1.65	0.740	0.33	286	94
D	.36	.48	.05	.02	.01	.0024	.000	16	1681

USGS STANDARD QLO-1

ELEMENT REPLICATION	Si*	Al*	Ca*	Fe*	Mg*	Na*	Ti*	Mn*	Cr**
1	30.7	8.90	2.22	2.89	0.627	3.15	0.25	605	48
2	32.1	8.65	2.47	3.00	0.696	3.55	0.27	617	54
D	2.16	.06	.06	.01	.0048	.160	.0004	144	36
1	30.7	8.90	2.22	2.89	0.627	3.15	0.25	605	48
3	30.6	8.42	2.35	3.01	0.665	3.34	0.27	594	66
D	.01	.23	.02	.01	.0014	.036	.0004	121	324
1	30.7	8.90	2.22	2.89	0.627	3.15	0.25	605	48
4	30.8	9.18	2.53	3.13	0.690	3.49	0.35	660	70
D	.03	.08	.10	.06	.004	.116	.01	3025	484
1	30.7	8.90	2.22	2.89	0.627	3.15	0.25	605	48
5	30.6	8.79	2.42	2.88	0.648	3.30	0.27	582	37
D	.00	.01	.04	.00	.0004	.023	.0004	529	121

USGS STANDARD QLO-1

ELEMENT REPLICATION	Si*	Al*	Ca*	Fe*	Mg*	Na*	Ti*	Mn*	Cr**
2	32.1	8.65	2.47	3.00	0.696	3.55	0.27	617	54
3	30.6	8.42	2.35	3.01	0.665	3.34	0.27	594	66
D	2.37	.05	.01	.00	.0001	.044	0	529	144
2	32.1	8.65	2.47	3.00	0.696	3.55	0.27	617	54
4	30.8	9.18	2.53	3.13	0.690	3.49	0.35	660	70
D	1.66	.28	.00	.02	.0000	.004	.0064	1849	256
2	32.1	8.65	2.47	3.00	0.696	3.55	0.27	617	54
5	30.6	8.79	2.42	2.88	0.648	3.30	0.27	582	37
D	2.22	.02	.00	.01	.0023	.063	.0	1225	289
3	30.6	8.42	2.35	3.01	0.665	3.34	0.27	594	66
4	30.8	9.18	2.53	3.13	0.690	3.49	0.35	660	70
D	.06	.58	.03	.01	.0006	.023	.0064	4356	16
3	30.6	8.42	2.35	3.01	0.665	3.34	0.27	594	66
5	30.6	8.79	2.42	2.88	0.648	3.30	0.27	582	37
D	.00	.14	.00	.02	.003	.002	0	144	841
4	30.8	9.18	2.53	3.13	0.690	3.49	0.35	660	70
5	30.6	8.79	2.42	2.88	0.648	3.30	0.27	582	37
D	.04	.15	.01	.06	.0018	.000	.0064	6084	1089

ELEMENT smp.no.	Si*	Al*	Ca*	Fe*	Mg*	Na *	Ti*	Mn **	Cr **
128 (1)	28.7	9.35	.49	2.92	.635	.011	.678	0	113
(2)	27.9	9.22	.53	2.90	.638	.024	.701	0	89
D	.69	.02	.002	.000	.0000	.0000	.0005	0	576
129 (1)	30.0	9.06	.07	2.60	.565	.141	.684	5	73
(2)	32.8	9.95	.09	2.83	.571	.161	.681	10	157
D	7.57	.79	.000	.053	.0000	.0004	.0000	25	7056
134 (1)	28.5	10.52	.39	2.91	.531	.042	.704	149	94
(2)	29.0	10.22	.39	3.09	.519	.034	.748	145	94
D	.25	.09	.000	.032	.0001	.0001	.0019	16	0
140 (1)	24.8	9.96	.43	4.01	.950	.106	.702	238	124
(2)	27.3	10.09	.44	3.98	.875	.101	.673	326	132
D	6.66	.06	.000	.001	.0056	.0000	.0000	7744	64
141 (1)	30.7	9.89	.44	3.67	.713	.030	.659	60	105
(2)	27.6	10.65	.49	3.67	.791	.031	.653	86	115
D	9.18	.58	.003	.000	.0060	.0000	.0000	676	100

smp.no	Si	Al	Ca	Fe	Mg	Na	Ti	Mn	Cr
143 (1)	29.2	11.36	.45	4.47	1.027	.075	.706	190	93
(2)	24.5	10.58	.46	4.14	.916	.080	.680	227	113
D	21.81	.61	.000	.109	.0123	.0000	.0007	1369	400
144 (1)	23.7	10.01	.44	3.78	.858	.083	.682	154	117
(2)	27.7	10.58	.44	3.82	.897	.067	.680	187	111
D	18.49	.32	.000	.002	.0015	.0003	.0000	1089	36
150 (1)	31.3	9.54	.83	3.38	.635	.031	.633	23	75
(2)	31.0	9.80	.97	3.10	.729	.011	.677	5	110
D	.06	.07	.002	.078	.0088	.0004	.0019	324	1225
155 (1)	27.4	10.94	.38	4.14	.968	.159	.659	279	121
(2)	28.2	11.30	.36	4.19	1.039	.168	.681	295	85
D	.66	.13	.000	.003	.0050	.0001	.0005	256	1296
157 (1)	30.3	9.93	.36	2.88	.640	.056	.693	202	103
(2)	31.0	10.58	.36	3.13	.732	.048	.705	215	108
D	.48	.42	.000	.063	.0085	.0064	.0001	169	25
167 (1)	31.2	9.01	.54	2.96	.693	.038	.610	118	104
(2)	30.0	8.81	.48	2.82	.681	.026	.630	163	103
D	1.10	.04	.004	020	.0001	.0001	.0004	2025	1
172 (1)	27.1	9.82	.59	2.91	.718	.063	.731	15	134
(2)	29.3	9.56	.73	2.97	.763	.063	.725	20	188
D	4.84	.07	.002	.004	.0020	.0000	.0000	25	2916
176 (1)	27.7	10.14	.39	3.28	.690	.050	.706	211	178
(2)	27.7	9.98	.42	3.22	.722	.028	.726	198	128
D	.00	.03	.001	.004	.0010	.0005	.0004	169	2500
176 (1)	27.7	10.14	.39	3.28	.690	.050	.706	211	178
(3)	28.1	10.36	.47	3.36	.749	.022	.721	203	179
D	.16	.05	.006	.006	.0035	.0008	.0002	64	1
176 (2)	27.7	9.98	.42	3.22	.722	.028	.726	198	128
(3)	28.1	10.36	.47	3.36	.749	.022	.721	203	179
D	.16	.14	.003	.020	.0007	.0036	.0000	25	2601
182 (1)	28.6	8.68	.368	3.02	.794	.101	.679	34	151
(2)	31.1	8.94	.375	3.16	.847	.206	.664	20	126
D	26.25	.068	.000	.012	.0096	.0110	.0002	196	625
191 (1)	28.8	9.44	.669	3.36	.743	.222	.667	287	36
(2)	27.5	9.43	.607	3.46	.766	.241	.675	265	106
	1.69	.00	.004	.010	.0005	.0004	.0001	484	4900

smp.no	Si	Al	Ca	Fe	Mg	Na	Ti	Mn	Cr
193 (1)	28.2	9.47	.236	3.29	.858	.159	.652	138	72
(2)	27.9	9.36	.310	3.13	.815	.261	.684	145	95
D	.06	.012	.005	.026	.0018	.0104	.0010	49	529
193 (1)	28.2	9.47	.236	3.29	.858	.159	.652	138	72
(3)	28.3	9.97	.561	3.34	.706	.205	.923	114	147
D	.01	.250	.106	.003	.0231	.0021	.0734	576	5625
193 (2)	27.9	9.36	.310	3.13	.815	.261	.684	145	95
(3)	28.3	9.97	.561	3.34	.706	.205	.923	114	147
D	.12	.372	.063	.044	.0119	.0031	.0571	961	2704
197 (1)	29.2	9.16	.754	2.39	.598	.205	.693	23	133
(2)	33.9	9.36	.811	2.52	.660	.178	.638	29	137
D	21.07	.040	.003	.017	.0038	.0007	.0030	36	16
211 (1)	28.6	8.59	.898	3.56	.642	.154	.563	289	73
(2)	29.7	8.95	.761	3.60	.673	.202	.594	351	91
D	1.25	.130	.019	.002	.0010	.0023	.0010	3844	324
226 (1)	30.9	8.49	.288	3.47	.757	.143	.626	75	52
(2)	32.0	8.98	.425	3.55	.769	.123	.647	88	121
D	1.25	.240	.0188	.006	.0001	.0004	.0004	169	4761
226 (1)	30.9	8.49	.288	3.47	.757	.143	.626	75	52
(3)	32.3	8.40	.471	3.46	.853	.138	.619	80	69
D	2.16	.000	.0355	.000	.0092	.0000	.0000	225	289
226 (2)	32.0	8.98	.425	3.55	.769	.123	.647	88	121
(3)	32.3	8.40	.471	3.46	.853	.138	.619	80	69
D	.12	.336	.0021	.008	.0070	.0002	.0008	64	2704
227 (1)	31.0	9.90	.772	2.90	.744	.093	.707	19	101
(2)	29.6	9.33	.867	2.88	.722	.078	.670	33	130
D	2.10	.323	.0090	.000	.0005	.0002	.0014	196	841
227 (1)	31.0	9.90	.772	2.90	.744	.093	.707	19	101
(3)	30.1	9.32	.837	2.75	.696	.046	.716	68	134
D	.24	.000	.0009	.017	.0023	.0022	.0001	2401	1089
227 (2)	29.6	9.33	.867	2.88	.722	.078	.670	33	130
(3)	30.1	9.32	.837	2.75	.696	.046	.716	68	134
D	.92	.336	.0042	.023	.0007	.0010	.0021	1225	16
228 (1)	30.5	8.67	.459	3.41	.918	.112	.613	328	126
(2)	32.0	9.02	.584	3.54	.982	.108	.641	235	113
D	2.25	.123	.0156	.017	.0041	.0000	.0008	8649	169

smp.no	Si	Al	Ca	Fe	Mg	Na	Ti	Mn	Cr
230 (1)	36.8	3.73	2.034	3.06	.322	.023	.295	225	47
(2)	36.4	3.71	1.990	2.99	.317	.008	.292	260	67
D	.18	.000	.0019	.005	.0000	.0002	.0000	1225	400
230 (1)	36.8	3.73	2.034	3.06	.322	.023	.295	225	47
(3)	40.5	3.65	2.051	3.05	.323	.009	.315	196	60
D	13.84	.006	.0003	.000	.0000	.0002	.0004	841	169
230 (1)	36.8	3.73	2.034	3.06	.322	.023	.295	225	47
(4)	37.8	3.89	1.915	3.17	.337	.045	.304	208	69
D	1.00	.026	.0142	.012	.0002	.0005	.0001	169	484
230 (2)	36.4	3.71	1.990	2.99	.317	.008	.292	260	67
(3)	40.5	3.65	2.051	3.05	.323	.009	.315	196	60
D	17.14	.004	.0037	.004	.0000	.0000	.0005	4096	49
230 (2)	36.4	3.71	1.990	2.99	.317	.008	.292	260	67
(4)	37.8	3.89	1.915	3.17	.337	.045	.304	208	69
D	1.96	.032	.0056	.032	.0004	.0014	.0001	2704	4
230 (3)	40.5	3.65	2.051	3.05	.323	.009	.315	196	60
(4)	37.8	3.89	1.915	3.17	.337	.045	.304	208	69
D	7.51	.109	.0185	.014	.0003	.0013	.0001	144	81
231 (1)	31.9	8.23	.556	3.71	.933	.068	.610	157	120
(2)	32.2	8.61	.603	3.68	.961	.012	.582	194	135
D	.06	.144	.0022	.001	.0008	.0031	.0008	1369	225
233 (1)	31.6	8.27	.569	3.11	.719	.069	.650	114	129
(2)	30.5	8.13	.435	3.03	.726	.102	.600	97	111
D	1.02	.020	.0179	.006	.0001	.0011	.0025	289	324
234 (1)	30.9	8.75	.475	3.23	.889	.080	.662	53	105
(2)	31.3	8.73	.531	3.22	.894	.123	.656	51	207
D	.15	.000	.0031	.000	.0000	.0018	.0004	4	10404
235 (1)	32.6	8.56	.564	3.08	.914	.060	.622	80	98
(2)	32.4	8.50	.629	3.19	.932	.092	.625	139	81
D	.04	.004	.0042	.012	.0003	.0010	.0000	3481	121
238 (1)	34.6	9.86	.690	3.59	.876	.099	.693	112	91
(2)	31.5	8.48	.655	3.29	.833	.071	.658	136	137
D	9.54	1.904	.0012	.0900	.0018	.0008	.0012	576	2116
252 (1)	33.2	8.65	.379	3.10	.905	.218	.663	103	89
(2)	32.3	8.54	.542	2.98	.763	.225	.607	63	89
D	.90	.012	.0267	.014	.0202	.0001	.0031	1600	0

smp.no	Si	Al	Ca	Fe	Mg	Na	Ti	Mn	Cr
373 (1)	30.3	9.12	1.290	2.79	.736	.132	.697	5	82
(2)	28.2	9.01	1.410	2.76	.713	.116	.643	5	82
D	4.37	.C12	.0144	.001	.0005	.0003	.0029	0	0
382 (1)	28.2	8.57	.455	3.85	.862	.148	.571	126	106
(2)	31.2	8.87	.513	4.06	.898	.182	.613	143	102
D	9.18	.090	.0034	.044	.0013	.0012	.0018	289	16
386 (1)	32.1	8.55	1.690	3.80	.987	.219	.576	84	163
(2)	32.8	8.92	1.880	3.84	.977	.195	.583	83	175
D	.48	.137	.0361	.002	.0001	.0006	.0000	1	144
386 (1)	32.1	8.55	1.690	3.80	.987	.219	.576	84	163
(3)	32.4	8.56	1.220	3.63	.902	.386	.532	75	151
D	.11	.000	.2209	.029	.0072	.0279	.0019	81	144
386 (2)	32.8	8.92	1.880	3.84	.977	.195	.583	83	175
(3)	32.4	8.56	1.220	3.63	.902	.386	.532	75	151
D	.13	.13	.436	.044	.0056	.0365	.0026	64	576
396 (1)	30.7	7.25	.694	2.77	.646	.193	.611	128	99
(2)	33.1	7.31	.574	2.68	.636	.176	.595	105	77
D	5.15	.004	.0144	.008	.0001	.0003	.0003	529	484
399 (1)	27.4	8.22	.887	4.03	.867	.144	.635	279	85
(2)	27.8	7.59	1.020	3.97	.925	.162	.604	193	86
D	.18	.397	.0177	.004	.0034	.0003	.0010	7396	1
476 (1)	28.2	11.22	.442	5.26	1.108	.776	.737	1703	108
(2)	27.1	9.94	.398	4.58	.991	.801	.678	1550	121
D	1.30	1.638	.0019	.102	.0137	.0006	.0035	23409	169
480 (1)	31.9	8.10	5.820	4.21	1.356	.479	.562	232	72
(2)	28.3	8.01	5.930	4.34	1.345	.455	.555	240	136
D	15.29	.001	.0100	.017	.0001	.0006	.000	64	4096
482 (1)	35.1	8.54	.516	3.60	.803	.254	.651	280	79
(2)	34.8	9.06	.357	3.58	.720	.233	.650	249	105
D	.06	.270	.025	.000	.0069	.0004	.000	961	676

smp.no	Si	Al	Ca	Fe	Mg	Na	Ti	Mn.	Cr
484 (1)	35.9	8.19	.458	3.46	.820	.228	.754	177	97
(2)	33.5	8.02	.412	3.43	.953	.206	.620	153	116
D	5.81	.029	.0021	.001	.0177	.0005	.0180	576	361
484 (1)	35.9	8.19	.458	3.46	.820	.228	.754	177	97
(3)	32.0	7.83	.440	3.37	.783	.208	.620	141	113
D	15.60	.129	.0003	.008	.0014	.0004	.0180	1296	256
484 (1)	33.5	8.02	.412	3.43	.953	.206	.620	153	116
(2)	32.0	7.83	.440	3.37	.783	.208	.620	141	113
D	2.37	.036	.0001	.0004	.0289	.0000	.000	144	9
TOTAL	298.26	18.29	1.92	2.56	.515	.774	.389	108195	90446
x (N=84)	28.4	8.76	1.08	3.46	.739	.795	.568	279	99
s	1.33 (4.7%)	.33 (3.8%)	.11 (10.2%)	.12 (3.5%)	.06 (8.1%)	.068 (8.6%)	.05 (8.8%)	25 (9.0%)	23 (23%)

ABBREVIATIONS**	BIBLIOGRAPHY
Abascal (1974)	Abascal, M.R., Harbottle, G. and Sayre, E.V. "Correlation Between Terra Cotta Figurines and Pottery from the Valley of Mexico and Source Clays by Activation Analysis". in Beck, C.W. (ed.) Archaeological Chemistry. Washington, D.C. Am. American Chemical Society (1984) 81-100.
Actes CCC (1982)	"Actes du Colloque sur la céramique de Carthage". 23-24 juin 1980, CEDAC Dossier 1. Tunis: Institut national d'archéologie et d'art de Tunisie. (1982).
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ABSTRACT

CHEMICAL ANALYSIS OF POTTERY AND CLAY FROM CARTHAGE

Ph.D. Thesis presented to the School of Graduate Studies, University of Ottawa by James B. Gallagher. April 1, 1987.

This study utilized Direct Current Emission Spectrometry to determine elemental abundances for seven major and two minor elements in ceramics and clay minerals from the vicinity of Carthage, Tunisia. The Roman pottery from Carthage has not been studied previously with laboratory techniques. The pottery samples included two groups of red-gloss table ware of the African Red Slip variety, utilitarian pottery and two types of lamps. These objects were recovered by archaeological excavations conducted in the Northern Sector of the Roman city by a team under the directorship of Professor C.M. Wells of the University of Ottawa. Clay deposits were located by prospection at Carthage and at other sites in the region where pottery manufacture is attested.

The analysis established that the table ware was made with siliceous clays. This fact, considered in conjunction with certain physical characteristics, shows the pottery was made using techniques which were significantly different from those employed elsewhere by Roman craftsmen manufacturing red-gloss pottery. Conversely, other ceramics from Carthage were made from calcareous clays. The significance of this difference implies that manufacturing methods were, in some instances, introduced by craftsmen trained in the Italic tradition.

The possibility of using chemical composition to establish the exact provenience of manufacture was also explored. Groups of African Red Slip and

lamps could be distinguished by comparing their elemental abundances with discriminant analysis, a multivariate statistical technique. The composition of the groups was then compared with the data obtained from the local clays to identify the potential sources of the raw material used in pottery manufacture. Although no definitive sources of manufacture could be identified the data establishes a basis for further research. The analyses also identified specific problems which must be considered in designing future provenience studies with North Africa pottery.