

REGIONAL CERAMIC TRADE IN EARLY BRONZE AGE GREECE:
EVIDENCE FROM NEUTRON ACTIVATION ANALYSIS OF
EARLY HELLADIC POTTERY FROM ARGOLIS AND KORINTHIA

by

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ABSTRACT

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REGIONAL CERAMIC TRADE IN EARLY BRONZE AGE GREECE:
EVIDENCE FROM NEUTRON ACTIVATION ANALYSIS OF
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Ceramic production and exchange in Early Bronze Age Greece have been studied through provenance determination by neutron activation analysis. The concentrations of Na, K, Rb, Cs, Ca, Al, Sc, La, Ce, Eu, Yb, Th, Ti, Hf, V, Cr, Mn, Fe, and Co were determined, with respect to Perlman-Asaro standard pottery, in 255 objects of the Early Helladic (or EH) II and III periods found at Keramidhaki, Korakou, Phlious, Zygouriés, Tiryns, and Asine in Korinthia and Argolis. Multivariate treatment of these data, merged with 162 analyses from the author's earlier work with samples from Lerna (Argolis) and Lake Vouliagméni (Korinthia), yielded 11 compositional reference groups. Many of these could be attributed to centres of production on distributional or other grounds, thereby allowing the sources of more than half the sampled objects to be determined.

The following conclusions were reached: All 8 sites (except possibly Phlious) were sources of common EH II

ware (sauceboats and small bowls), which had limited distributions. Many unusual EH-II fine wares had other sources and broader distributions. The attribution of coarse wares was complicated by the presence of tempering material. The changes in pottery acquisition patterns which accompanied the beginning of EH III were probably more drastic at Tiryns than at Lerna or Korákou.

RESUME

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LE COMMERCE REGIONAL DES CERAMIQUES EN GRECE A L'AGE DU BRONZE ANCIEN: ANALYSES PAR ACTIVATION NEUTRONIQUE DE POTERIES DE L'HELLADIQUE ANCIEN EN PROVENANCE DE L'ARGOLIDE ET DE LA CORINTHIE

Nous avons étudié la fabrication et les échanges de céramiques en Grèce pendant l'Age du Bronze Ancien. Nous avons dosé, par activation neutronique relative à l'étalon de Perlman et Asaro, les teneurs des éléments Na, K, Rb, Cs, Ca, Al, Sc, La, Ce, Eu, Yb, Th, Ti, Hf, V, Cr, Mn, Fe, et Co dans 255 objets des phases Helladique Ancien (ou HA) II et III trouvés à Keramidhaki, Korákou, Phlonte, Zygouriès, Tirynthe, et Asinè en Argolide et Corinthie. Le traitement multivariable de ces données, ainsi que de 162 analyses antérieures d'objets de Lerne (Argolide) et du Lac Vouliagmeni (Corinthie), a produit 11 groupes de composition. Nous avons pu attribuer plusieurs de ces groupes à des centres de fabrication, et avons déterminé l'origine de plus de la moitié des objets.

Nos conclusions sont les suivantes:

- des potiers à chacun des 8 sites (à l'exception possible de Phlonte) fabriquaient de la céramique commune

(saucières et petits bols) dont la distribution était limitée;

- la plupart des types de céramique fine provenaient d'autres sources et leur distribution était plus répandue;

- les attributions de la céramique grossière ont été embrouillées par la présence des dégraissants (inclusions dans la pâte);

- il semble que les habitudes de production ont changé, avec le début de l'HA III, beaucoup plus à Tirynthe qu'à Lerne ou à Korâkou.

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NOTE ON TRANSLITERATION

All renderings of Greek names into English tread a path between complete arbitrariness and rigid, pedantic consistency. The aim in this thesis is to use familiar transliterations where they exist and systematic versions otherwise. Modern Greek place-names have generally been transliterated phonetically, with an accent to mark the stressed syllable, following the system of the Blue Guide to Greece (Rossiter 1973). Ancient names have usually been rendered into Latin characters on a traditional, letter-by-letter basis. Exceptions have been made for common names with conventional English spellings, such as Mycenae and Crete. This allows a distinction to be made between the ancient city here called "Corinth" and the modern town, "Kórinthos", nearby. Some inconsistencies no doubt remain but it is hoped that at least ambiguity has been avoided.

1. INTRODUCTION

1.1 The study of Greek prehistory

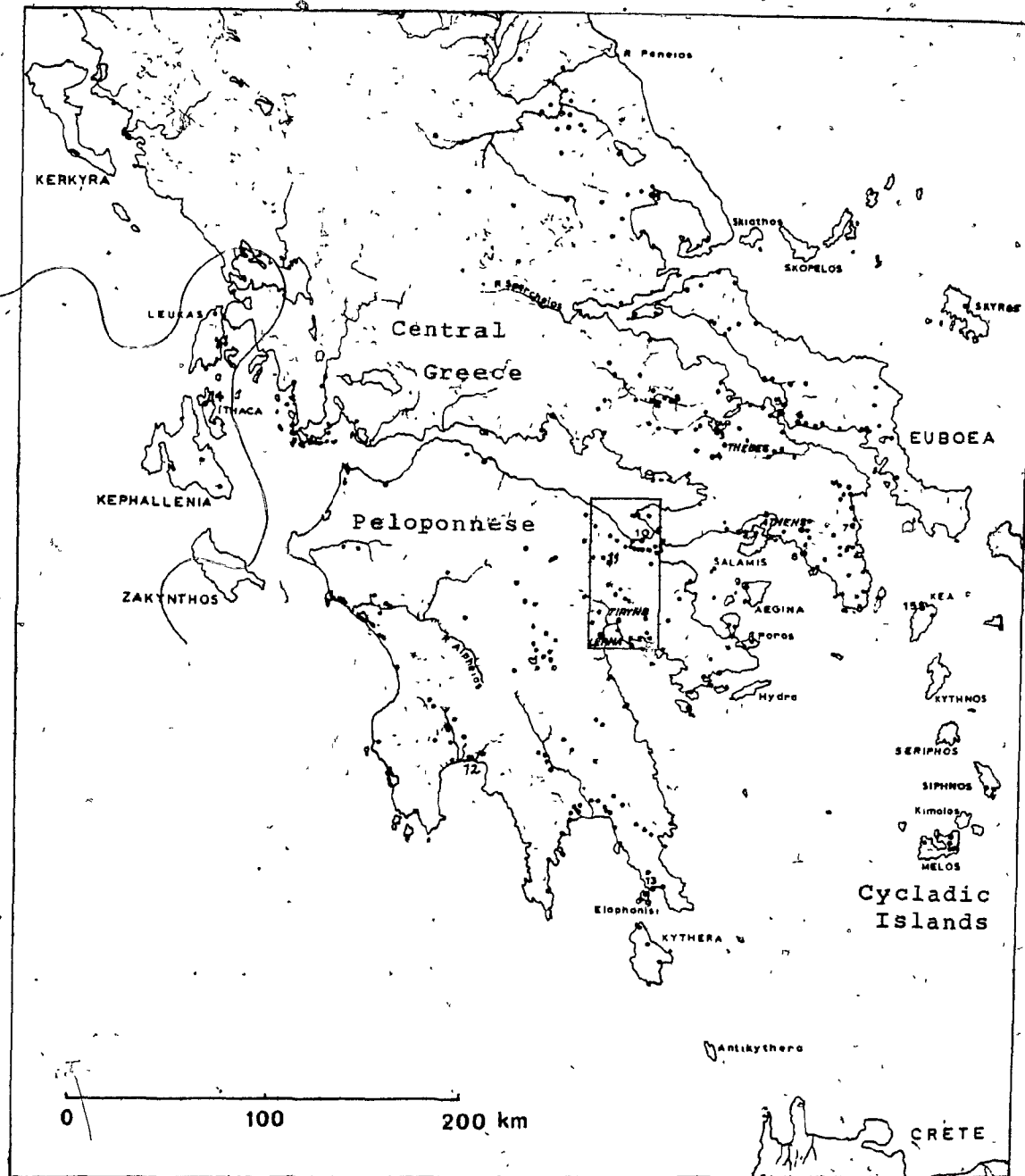
The study of man's prehistory is in part an investigation of his gradual rise to civilization. Raw material for this investigation is the archaeological record, sparse for the earlier stages but growing more abundant as man left more concrete and complex traces of his activities. One area where this progression has been particularly well studied is Greece (Fig. 1-i). From the time of Schliemann's spectacular discovery of the shaft graves at Mycenae in 1876, research has steadily enlarged our knowledge of the Minoan and Mycenaean civilizations and their antecedents. Today the continuous habitation of Greece can be traced back to Neolithic times, and at a few sites even further.

The steps in the modern discovery of prehistoric Greece have been described by McDonald (1967), Stubbings (1972), and Warren (1975). The following summary is based on their accounts.

The last quarter of the nineteenth century saw Schliemann's and Dörpfeld's excavation of the palace at Tiryns (1884-1885), and the continuation of their work at Troy (1882, 1890). In the Cycladic islands hundreds of primitive graves were excavated by Tsountas during the 1890's, and three successive settlements were discovered at Phylakopí on Mélos by a British team (1896-1899).

FIGURE 1-i: Partial distribution of Early Bronze I and II sites in Greece (after Hope Simpson and Dickinson 1979, Map 1). Stippled areas denote land above 200 metres. The area in the rectangle is shown enlarged in Figure 3-i. Key to numbered sites:

1. Pevkákia
2. Orkhomenos
3. Litharés
4. Eufresis
5. Mánika
6. Lefkandí
7. Askitarió
8. Áyios Kosmás
9. Kolónna
10. Korákou
11. Zygouriés
12. Akovítika
13. Pavlopétrí
14. Pelikáta
15. Ayía Iríni (Kéa)



Sir Arthur Evans' excavations of the palace at Knossos on Crete beginning at the turn of the century revealed the glories of the Minoan civilization, and established its priority over that of Mycenae. The Knossos stratigraphy enabled Evans to classify the remains into four periods, namely the Neolithic followed by the Early, Middle, and Late Bronze Ages. For the Bronze Age, this paralleled the sequence of settlements at Phylakopi, and was itself paralleled by evidence from sites of the Peloponnese.

During and after the First World War, Blegen excavated at Korákou, Zygouries, and Gonia in the Korinthia. In collaboration with Wace, he divided the mainland Bronze Age into three periods which were named Early, Middle, and Late Helladic, to correspond with the designations "Minoan" for Crete and "Cycladic" for the island group of that name (Table 1-I). The Late Helladic period is synonymous with the Mycenaean Age.

Subsequent work by specialists in Greek prehistory has clarified the cultural sequence in Crete, in the Cycladic islands, and on the mainland. At the same time, the geographical range and the variety of characteristic features of these cultures have been explored. Highlights of these advances include excavation of the Late Minoan palaces at Phaistos, Mallia, Kato Zakro, and Khania; the Mycenaean one at Pylos; and the Cycladic town or palace at Akrotiri on Thera. Funerary practices have been studied through excavation

TABLE 1-I: Chronological Chart for the Greek Bronze Age
(after Hope Simpson and Dickinson 1979)

All dates are approximate, the earlier ones very much so.

Abbreviations used:

E, M, L	Early, Middle, Late
M	Minoan
H	Helladic
B	Bronze
GP	Grotta-Pelos (Early Cycladic I)
KS	Keros-Syros (Early Cycladic II)
PG	Protogeometric
DA	Dark Age

BC	CRETE	MAINLAND	CYCLADES
3000			
2900			
2800	EM I	EH I (+EB I in Thessaly)	GP
2700			
2600			
2500			
2400	EM II	EH II (+EB II in Thessaly)	KS (+GP overlap ?)
2300			
2200			
2100	EM III (mainly in E.)	EH III (EB III in Thessaly, Lefkandi 1-2)	Phylakopi I (+KS survival ?)
2000			
1900	MM I A		
1800	MM I B - II	MH	MB (Phylakopi II:a-b)
1700			
1600	MM III A - B		
1500	LM I A	LH I	LB I - II
	LM I B	LH II A	(Phylakopi III:1-2)
	LM II	LH II B	
1400	LM III A 1	LH III A 1	
	LM III A 2	LH III A 2	
1300	LM III B	LH III B 1	
		LH III B 2	
1200			
	LM III C	LH III C	
1100			
	Sub-Minoan	Sub-Mycenaean + later	LH-III C
1000	(+PG after 1000)	PG + local DA	styles

of the Early Minoan tombs of the Mesara plain, a large number of Early Cycladic cemeteries, and the Mycenaean cemeteries at Prosymna in the Argolid and Perati in Attike. Unexpected discoveries of Late Bronze Age temples at Mycenae, Tiryns, Kéa, and Phylakopi have led to a fuller understanding of Mycenaean religion. A view of Mycenaean life from a different angle was provided by the decipherment of the syllabic script ("Linear B") of the Late Bronze Age palaces. Research has also resulted in the systematic study of all types of pre-historic artifacts, and in more synthetic studies of pre-historic "history", religion, trade, technology and culture processes. The state of Bronze Age studies in the 1970's has been described by Hood (1971), Vermeule (1972), Renfrew (1972), Christopoulos and Bastias (1974), Warren (1975), Chadwick (1976), Schachermeyr (1976), Dickinson (1977), and Thimme (1977). These works give full references to the discoveries mentioned above. They also serve as sources for the synopsis of the Early Bronze Age which follows.

1.2 Salient features of the Greek Early Bronze Age

If any one word can be used to characterize Early Bronze Age life in the Aegean, it is "diversified". The work of Treuil (1979) has shown that development from the preceding Neolithic period was not abrupt, nor was it characterized by any single dramatic technical advance. Rather, a slow process of differentiation was taking place in many aspects of society,

leading to a more complex organization of culture. Of course, the archaeological record does not allow us to view society directly, but the material remains themselves testify to diversification in various fields of endeavour, and their interpretation leads to an understanding of more abstract changes.

Relatively little is known about the last phase of the Late Stone Age, the "Final Neolithic" (Renfrew 1972, pp. 68-80). Farming was based on grain crops such as emmer wheat, and on pulses and fruits, with domesticated sheep/goats, cattle, and pigs providing meat. Decoration on pottery was limited to pattern-burnish and crusted-paint. There are some indications of copper smelting, particularly at Kephála on Kéa (Coleman 1977, p. 4). The earliest Greek cemetery with built graves was also found at Kephála. Finally, the little evidence that exists for village plans shows them to have been agglomerated at Knossos but open (i.e., with individual single-roomed houses) in central and northern Greece (Renfrew 1972, p. 80).

The most notable changes which mark the beginning of the Early Bronze Age in the late fourth millennium BC are a general displacement of settlements towards seacoasts (Treuil 1979, p. 530), and a variety of changes in pottery styles. Painted pottery appeared in Crete (Renfrew 1972, p. 84), incision and red slip were used as decorative techniques on the Greek mainland and the Cyclades (Renfrew 1972, p. 100), and bowls

with rolled rims became common in the Cyclades and the Troad (Renfrew 1972, p. 153). Otherwise, during the first phase of the Early Bronze Age, at least, most aspects of material culture remained unchanged (Treuil 1979, p. 799).

The second phase of the Early Bronze Age (mid-third-millennium BC and perhaps earlier) was characterized by an apparent quickening in the pulse of life, in the words of Renfrew (1972, p. 451) transforming:

what were hitherto essentially independent cultures in different regions of the Aegean into a complex of related units whose individuality although at first distinct became gradually less marked as the bronze age continued. Indications of contact became suddenly very much more numerous: an international spirit was abroad; and forms and conventions in one region were very much more readily adopted in others.

Renfrew's book The Emergence of Civilisation (1972) is a study of the processes that led to this development. He attributed it to the workings of the "multiplier effect", a positive feedback among the several sub-systems of the Early Bronze Age cultural system: subsistence, metallurgy, craft technology, social systems, projective systems, and trade and communication. In this section we are less concerned with determining the origins of the Early Bronze Age cultures than with describing their various aspects. Renfrew's categories nevertheless provide a convenient outline for discussion, with consideration of the last of them, trade in the Early Bronze Age, being reserved for the following section.

The mode of subsistence characteristic of the Early Bronze Age Aegean was, according to Renfrew (1972, p. 280), Mediterranean polyculture. To the range of crops cultivated during the Neolithic were added the olive and the vine. The introduction of both of these must have had considerable effect on everyday life: cooking, personal hygiene, lighting, and ceremonies would all have been transformed. Moreover their cultivation did not compete with that of the already-established crops, since the olive and the vine can thrive on marginal land, such as hill slopes, and require relatively little attention. The total productivity was thus increased and diversified.

Among those for which we have evidence, metallurgy is the craft which showed the most development during the Early Bronze Age (Renfrew 1972, pp. 308-338). Both the number and the variety of metal artifacts recovered from contexts of that period are much greater than those from earlier ones. Known metals included gold, silver, lead, and copper, the last often alloyed with arsenic or with tin to make bronze. Bronze was used for tools and weapons; lead for repairs to pottery, for bracelets, and for figurines; silver and gold for jewelry and vessels. The availability of luxury goods both reflected and encouraged social changes, such as the evolution of wealth, wealth disparities, and social hierarchies (see below).

The availability of metal tools was no doubt an advantage to craftsmen in many disciplines. Carpentry,

boatbuilding, masonry, jewelry, sculpture, and gem, seal, and stone-vase carving would all have benefited. There is direct evidence for technical progress in a number of these areas (Renfrew 1972, pp. 339-361). Although some marble vases were made in the Neolithic period, it is only in the third millennium that they became popular (Renfrew 1972, p. 347). The use of a tubular drill greatly facilitated their manufacture, and allowed harder stones to be carved as well. Enlargement of the selection of tool types at the disposition of the craftsman thus led to an extension of the range of raw materials workable by him, and resulted in a diversification of objects produced, some of which appear in the archaeological record. It should be emphasized that the old tool types continued to be used as well. This is true at least for obsidian blades, still very common on Early Bronze Age sites (Torrence 1979). It would seem reasonable, from the sophistication and diversity of artifacts produced during the Early Bronze Age, to assume the existence of specialized craftsmen, either full or part time.

The social systems of the Early Bronze Age are more difficult to discern. Renfrew (1972, pp. 370-399) indicated three aspects where evolution from the Neolithic is evident. These are the emergence of wealth and hierarchy; the development of ownership and redistribution; and hostility and the inception of warfare.

Disparities in the wealth of individuals are most clearly seen from the contents of their graves, especially those excavated in the Cyclades (Doumas 1977). During the third millennium BC the difference between the richer and poorer graves of individual cemeteries grew ever greater. Whereas the poor ones contained a few pottery vessels, or nothing at all, the rich ones had marble vessels and other stone objects. By the end of the Early Bronze Age the richest graves contained personal adornments of silver as well as metal tools and weapons. There is even an indication that simple pots were shunned by the rich, as they do not often appear in association with metal objects. These disparities do not seem to be related to the sex of the deceased; instead a conscious concept of wealth and status is in evidence (Renfrew 1972, p. 374). Similar conclusions can be drawn from the variations in the size of buildings, which range from single-room huts to the monumental structure at Lerna known as the House of the Tiles: a large, two-storey building dating to the end of the second, or middle, phase of the Early Helladic period.

The development of an economy which included a system of storage and redistribution of goods can also be deduced from the archaeological record. The existence of seals and sealings in the third-millennium-BC Aegean indicates that in many instances, an owner or producer of certain goods took pains to identify them as his, most likely while they

were somewhere not under his control. In other words, there was at that time a "distinction between ownership and immediate possession" (Renfrew 1972, p. 388). The Early Bronze Age occupation levels at Lerna, in the Argolid, provide more concrete evidence. The House of the Tiles contained a deposit of 124 clay sealing fragments in one of its small rooms (Heath 1958). Imprints on their reverse sides show that they had been used to secure wooden chests and storage jars. It is likely, then, that the House of the Tiles itself was a focus for the storage and redistribution of goods (Renfrew 1972, p. 390). Some sort of central authority is implied by the mere presence of such an imposing structure, as well as by the presence of a double fortification wall belonging to a slightly earlier phase.

The appearance of defensive works, together with weapons, is the main indication of a third social development, that of warfare (Renfrew 1972, pp. 392-398). This was no doubt linked to the emergence of wealth disparities, and also to the use of oar-powered long ships (for which there is pictorial evidence) for piracy.

The most abstract of Renfrew's sub-systems, the symbolic and projective sub-systems, will not be treated here in detail. These include language, mensuration, notation, play, art, and religion. Suffice it to say that these are the aspects of a culture which are most evocative to our imaginations and which most strikingly characterize a people.

Unfortunately, the evidence is often difficult to interpret (or, what is worse, open to a large number of alternative interpretations). The only features of these sub-systems which are of direct relevance to trade (discussed in the next section) are the weights and records. With respect to these, Renfrew (1972, p. 409) notes that silversmiths of Early Bronze Age Troy (Troy II) were capable of precise weight measurements, though there is no direct evidence for a system of weight standards. The only recording systems that have survived are abstract seals and their sealings on clay, and simple strokes incised on the lower parts of vases ("potters' marks").

1.3 Trade in the Early Bronze Age

Evidence for ancient trade, or more generally for the movement of objects in prehistory (precise definitions follow), appears in two forms. The presence of a type of raw material or an object made of that material at a distance from its known source is proof that either the raw material or the finished object has travelled. Alternatively, an artifact whose form is very unusual for the region in which it was found, but common in another region, has a high probability of being an import. The possibility always exists that it was made at the place where it was found, as an imitation of the common form of another region, but even this is evidence of contact of some type.

In the Aegean area, evidence of both kinds exists for the Neolithic and Early Bronze Ages. Of course, it is limited to objects which have survived thousands of years of burial; primarily those made of stone, bone, shell, fired clay, and metal. By studying artifacts of these materials, it is possible to note an intensification of external trading activity in the Aegean from the Neolithic to the Early Bronze Age. By external trade is meant a series of exchanges between different cultures, adjacent or widely-separated. Internal trade, between villages of a single culture, is more difficult to study (see section 1.5).

At least two types of object are known to have been traded in the Late Stone Age. Fragments of the natural volcanic glass known as obsidian were used as cutting tools from very early times (Taylor 1976). The Aegean is blessed with a prolific obsidian source on the Cycladic island of Mélos, and two minor ones, on nearby Antíparos and on Yiali to the east. These can be distinguished chemically both one from the other, and from more distant sources in the Balkans, Anatolia, and the Western Mediterranean (Renfrew et al. 1965; Durrani et al. 1971; Aspinall et al. 1972). Mélos is the source of almost all the obsidian at Neolithic sites in the Aegean, from Crete to Thessaly. It seems from the dearth of permanent Neolithic settlements on Mélos (Cherry 1979) that any seafarer who wanted obsidian visited the island to collect some. Inhabitants of inland villages would most likely have obtained

their supply, either directly or through intermediaries, from their coastal neighbours. In any case, the finding of Melian obsidian in the Frankthi cave on the Argolic peninsula, in levels about 9000 radiocarbon years old, provides one of the earliest known indications that man was voyaging by sea (Dixon and Renfrew 1973).

The Aegean Sea was the source of another product traded during the Neolithic period, this one of decorative rather than technical importance. This is the shell known as spondylus, found carved into bracelets at sites in the Balkans and particularly along the Danube. Oxygen-isotope analyses by Schackleton and Renfrew (1970) showed these to be of Mediterranean rather than of Black Sea origin. These researchers proposed a trading mechanism based on successive gift exchanges.

In the Early Bronze Age, the long-distance contacts of the Aegean region were limited chiefly to those of Crete with Egypt and the Levant (Renfrew 1972, pp. 446-448).

Egyptian stone vases have occasionally been found in Early Minoan contexts, and the presence of ivory objects indicates importation of that material in one form or another, perhaps from Syria. It is not known what was exported in exchange for these objects.

Within the Aegean itself, slightly more activity is seen during the beginning of the Early Bronze Age than in the Neolithic period. Melian obsidian continued to be widely

distributed. There are certain similarities in the grave and pottery styles of Attike and the Cyclades (this dating from the Final Neolithic phase), and in the bowl forms of the Cyclades and the Troad (Renfrew 1972, p. 450). The great increase in contact and communication among these regions, however, came later in the third millennium BC, during the second phase of the Early Bronze Age. The evidence once again comes from strong similarities in the forms of a variety of artifacts.

Certain copper and bronze objects had a wide distribution: midrib daggers, slotted spearheads, tweezers, flat axes, awls, and pins in particular (Renfrew 1972, p. 452 and fig. 16.7). If it was not the finished tools and weapons themselves that were traded, metal ore or ingots must have circulated, and close contacts from region to region must have taken place for ideas to be exchanged. Apparently such uniformity did not carry over to jewelry and other work in precious metals (Renfrew 1972, p. 454).

Several forms of pottery too show strong similarities from area to area within the Aegean. The spouted bowl known as a sauceboat (see Fig. 4-i) is extremely common on the mainland and in the Cyclades, so much so that its distribution on the mainland has been used to define the limits of the Early Helladic II culture (Renfrew 1972, p. 453). Sauceboats have also been found occasionally in Crete (Knossos: Warren 1972; Plátyvóla Cave, Khaniá: Tzedhakis 1968, p. 415)

and in the northern Aegean (Thérmi: Lamb 1936, p. 90; Poliokhni: Bernabò Brea 1964, pl. CXXIX, C; Troy: Blegen et al. 1950, pp. 165-166 and 188-193). The one-handled cup is another form whose distribution is centred on the Cyclades and east-central Greece, with examples found as far apart as Crete and Troy (Renfrew 1972, p. 453).

Stone objects, especially marble ones, were also widespread. It seems the Cyclades constituted the main region of manufacture of marble pyxides, bowls, and folded-arm figurines (Thimme 1977), which found their way also to Crete and the mainland. On Crete the existence of a workshop producing a local variety of the figurines has been deduced from the distribution of that type, known as Koumása (Renfrew 1969b, p. 22; 1972, p. 199).

It is difficult to ascertain whether trading activity diminished during the third phase of the Early Bronze Age. Although new pottery types are evident during this period in the Cyclades and the east coast of the mainland, their presence may not be due to peaceful trade (Rutter 1979). At any rate, in the Middle Bronze Age the initiative for trading activity was taken by Crete, and Middle Minoan objects are common in the Cyclades and the mainland.

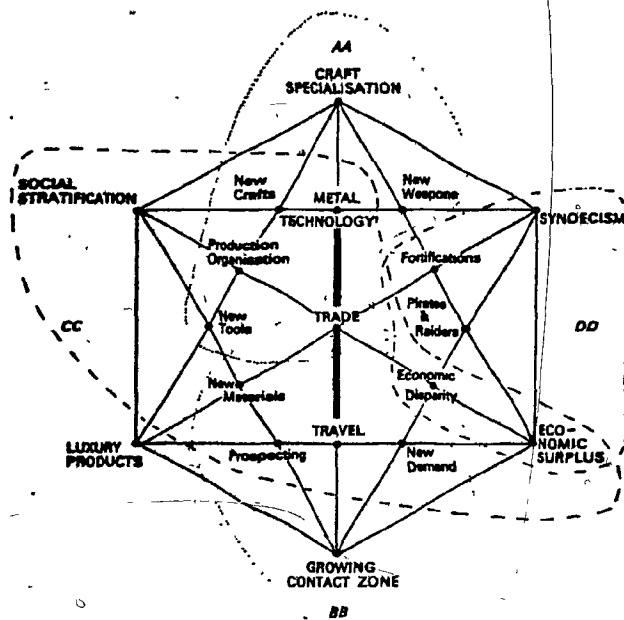
The enumeration of similarities in the artifact assemblages of the various regions of the Aegean basin during the second Early Bronze Age phase is testimony to close contacts between those regions. Evidence for trade is strong,

and it is clear that close connections between the regions, in the form of exchanges of both products and ideas, had much to do with the development of other cultural sub-systems during that period (Fig. 1-ii). The actual mechanisms of the exchanges are of considerable intrinsic interest. Furthermore, an understanding of the processes by which the objects were traded can help to explain the contribution made by trade to the flowering of culture in the Aegean during the third millennium BC.

1.4 Theoretical studies of trade

The progression in archaeological research from documenting contacts to determining trade mechanisms is not always straightforward. The study of primitive economies is a relatively recent development, and the extraction of theoretical economic data from the archaeological record is younger still. This section summarizes the approaches most commonly used today. In this discussion, the terms "trade" and "exchange" are taken to be synonymous and to mean the transfer of goods from one owner to another, to the benefit of both. The term "commerce" is more specific, referring to trade on a large scale, and implying regularity and complexity of organization. The concept of "trade" refers to movement of objects, but is intended to exclude phenomena such as abandonment, loss, piracy, and simple procurement (Petruso 1979, p. 139). However, since all of these processes can

FIGURE 1-ii: Relationship of trade to other aspects of life in the third-millennium-BC Aegean (after Renfrew 1969a, p. 160 fig. 2), with Renfrew's caption.



Urbanisation in the Aegean: the interrelationship of some of the new factors generated by the inception of metallurgy and the expansion of trade in the 3rd millennium BC. Alternatively, the points may be regarded as elements within severally overlapping sets (delineated by broken lines): set AA, industrial system; set BB, communications system; set CC, non-agricultural wealth; set DD, defence.

result in the presence of material or artifacts in a "foreign" archaeological context, they too are considered relevant to this treatment.

The pioneering studies of the theoretical aspects of ancient trade are those of Polanyi and co-workers (1957). They cautioned against seeing ancient trade mechanisms through modern eyes; that is, analyzing them using the principles of modern economics. Primitive economic systems often functioned in a radically different manner. Polanyi (1957, p. 250) proposed three mechanisms, of increasing sophistication, which could nevertheless coexist in certain cultures: reciprocity, redistribution, and market exchange. His definition is succinct:

Reciprocity denotes movements between correlative points of symmetric groupings: redistribution designates appropriational movements towards the centre and out of it again: exchange refers to vice-versa movements taking place as between 'hands' under a market system.

(quoted by Renfrew 1972, p. 461)

Reciprocity is the simplest, involving direct exchanges of commodities between individuals. The transfers may take the form of gifts, a balance of value not being a prerequisite to the transaction. The second operates under some central authority, who establishes a location for the storage and redistribution of goods. Members of the economic group bring commodities to this centre, and receive other goods in

exchange, usually with records being kept of the quantities changing hands. The third is based on a market system, and necessitates a medium of exchange, i.e., money. The money is issued and backed by an economic authority, and prices are set in terms of that money. Polanyi judged that market economies were relatively advanced, and did not exist before the 5th century BC (Athens) (Polanyi 1960; see also Finley 1973).

Ethnographic research has provided examples of all these systems, and of intermediate or hybrid ones (Bohannon and Dalton 1962). At the same time, archaeologists have sought to characterize the nature of the archaeological record that would result from the operation of each of these processes (Stjernquist 1967). Certain distinctions of scale are useful. The lowest level is exchanges between the units (individuals, families, households, clans) comprising a single settlement. Next comes transfer of goods between settlements but within a culturally homogeneous region (inter-settlement, intra-regional, or internal trade). External trade is concerned with the movement of goods between two regions occupied by different peoples, be they neighbouring (inter-regional trade) or widely-separated (long-distance trade). The qualitative and quantitative differences among these forms of trade have been discussed by Heichelheim (1958, pp. 85-95 and 130-132).

Both the development of theory and the interpretation of archaeological evidence are most advanced for long-distance trade. Two recent collections of papers, edited by Sabloff

and Lamberg-Karlovsky (1975) and by Earle and Ericson (1977), contain contributions to both topics. Mathematical models of trade, based on the "law of monotonic decrement" were discussed by Renfrew at both these symposia. He formulated this law as follows (1977a, p. 72):

In circumstances of uniform loss or deposition, and in the absence of highly organized directional (i.e., preferential, nonhomogeneous) exchange, the curve of frequency or abundance of occurrence of an exchanged commodity against effective distance from a localised source will be a monotonic decreasing one.

The shape of the curve can be an indication of the exchange mechanism involved. It may be possible to distinguish distributions of artifacts resulting from multiple exchanges and short displacements (down-the-line exchange), from those involving individual long trips. Indeed, according to these mathematical models "central place redistribution and central place market exchange are spatially identical, ...[but they should] be distinguishable from symmetrical, homogeneous, reciprocal exchange networks." (Renfrew 1977a, p. 88). Deviations from the law of monotonic decrement may be explained by postulating the existence of secondary centres, preferred trade routes, or competing sources (Bradley 1971; Hodder 1974; Hodder and Orton 1976; Clark 1979).

The successful applications of fitting curves to the plot of abundance against distance-from-source have relied on high-quality archaeological data. By this is meant, first of all, that the imported material be easily recognized among

the finds from each site, by either visual or technical means; secondly, that its presence be determined quantitatively, as an abundance or as a proportion (for instance, in relation to the total volume of earth excavated); and thirdly, that these abundance values be available for a variety of contemporary sites at different distances from the source.

An early application was Renfrew's study (1969a; see also Renfrew et al. 1968) of Anatolian obsidian. An approximately exponential fall-off was observed in the percentage of obsidian in the total chipped stone industry at several Early Neolithic sites in the Zagros area of the Near East. Extensive research by Hodder has been summarized in a treatise on spatial analysis by Hodder and Orton (1976). Hodder studied the distribution of certain types of Romano-British fine pottery in southern England, using a variety of mathematical tools, including regression analysis, trend-surface analysis, and gravity-model techniques. It was possible to characterize the distinctive marketing patterns of several wares, to distinguish land and water transport by the shallower gradient (fall-off slope) of the latter, and to examine the competition between two large production centres. A number of other, similar studies have been collected in a recent book edited by Peacock (1977). These make it clear that Romano-British pottery is well-suited to such treatment, for several reasons: 1) its typology is well-established and highly-refined; 2) most of the production centres are

known; 3) sites have been excavated and published in sufficient detail to allow quantitative studies; 4) the Romano-British economy was regular and important enough to have left a consistent and abundant pattern of evidence.

In his introduction to Peacock's book, Renfrew discussed typical modes of exchange in simpler societies, using modern ethnographic examples, where the household producers of pottery are part-time specialists. The five possible arrangements are (Renfrew 1977b, pp. 9-10):

1. the consumer travels to the producer's home or workshop to obtain his pot;
2. the producer himself carries his produce round to the consumer, acting as an itinerant pedlar;
3. producer and consumer meet at some third place, frequently a market, for exchange;
4. the producer exchanges his pots with a middleman, who transports them to, and exchange[s] them with, the consumers; or
5. the producer takes his pottery to some central agency which assigns him his goods in exchange.

Here redistribution is represented by 5 and centralized control distinguishes 5 from 4. Gift exchange can operate under arrangements 1 to 3 (although not normally at a market place), but in many societies pots are not looked upon as valuables and are thus not suitable as prestigious gifts.

Renfrew noted the paucity of studies aiming to interpret the archaeological evidence for exchange networks in early societies. He concluded that "the main thrust of research over the next few years is likely to be directed to the elucidation of exchange mechanisms in complex societies where

literacy (or rather the survival of the written records) does not already give ample evidence of trading mechanisms" (1977b, p. 14).

1.5 Internal trade in Early Helladic Greece

Of the four levels of trade listed in the previous section, internal trade may be the form involving the greatest bulk of goods. Unfortunately it is also the most difficult to document archaeologically (Renfrew 1972, p. 464). Artifacts and raw materials traded over long distances are often strikingly distinctive in their new cultural setting. Within a cultural region the very homogeneity of the artifact types indicates close contacts among the settlements. Because of this, stylistic comparisons must be quite subtle in order to subdivide a cultural area. For example, the Early Helladic, Early Minoan, and Early Cycladic cultures are easy to distinguish, though they resemble each other closely enough for Wace and Blegen (1916-18, p. 180) to have called them "all branches of one great parent stock which pursued parallel, but more or less independent, courses". On the Greek mainland, some differences in pottery styles can be seen between the Peloponnese, Central Greece, and Attike in the Early Helladic II and III periods (Kunze 1934; Weinberg 1937; Fahy 1964; Fossey 1974; see section 4.3.2), but the explanation of these differences is not yet clear. Within the Peloponnese, pottery at various sites can sometimes be distinguished by visual

characteristics of the ceramic fabric. Such criteria are only guides, however, and assignments of provenance should ideally be based on more objective tests.

The first technical provenance study of Early Helladic pottery succeeded in showing movement of pottery during the first phase of the Early Bronze Age (Attas 1975; Attas et al. 1977). Neutron activation analysis was used to determine the concentrations of fifteen chemical elements in 111 samples of pottery, clay, and mud brick from the settlement at Lake Vouliagmeni, Perakhóra (Fossey 1969; 1973; see section 3.5.8). Three chemical groups could be isolated. The largest contained mostly Early Helladic II pottery; the second consisted of Early Helladic I, Late Helladic, and Archaic sherds, and the third was made up of Early Helladic I and II pieces. The largest group, which included clay samples and mud bricks, was assigned a local origin. Pottery in the second group was deemed to be imported, since during the Late Helladic and Archaic periods occupation at Lake Vouliagmeni was very minor, and the Archaic pottery is fine, painted Corinthian ware, unlikely to have been made anywhere except at Corinth. In addition, a group of Late Helladic IIIB sherds from Mycenae, analyzed by Perlman and Asaro (Karageorghis et al. 1972), had a very similar average composition. The origin(s) of the second Vouliagmeni group must lie somewhere in the Korinthia, or at least in the North-East Peloponnese. (The third, smaller group could not be assigned a definite place of origin.) The

Analyses showed that during the first phase of the Early Bronze Age the Vouliagmeni site received much of its fine pottery from across the Gulf of Kórinthos, whereas during the second phase, vases were being produced locally and the traffic across the Gulf was much diminished.

Finds at Lerna, Tiryns, and Zygouries in the North-East Peloponnese (Fig. 3-i) demonstrate contact of another sort. Sherds from pithoi, or large storage jars, at each of these sites had been decorated with a raised band bearing the impression of the same roller (cylinder) seal, which portrayed two quadrupeds between linked spirals. In this case, the bulk and weight of the pithoi argue against their transport from a single production centre. The finds have been interpreted as the work of an itinerant potter, going from village to village with his tools, producing storage jars to order (Caskey 1959, p. 206).

1.6 Aims of this work

The two examples given above, together with the general homogeneity of Early Helladic culture, constitute the main evidence for close contacts and exchanges between villages within a region. On the other hand, visual differences in the common ceramic fabrics at many sites indicate separate centres of production. The main aim of this study is to determine the relative importance of local production and centralized distribution of pottery. The "null hypothesis"

is that there was no exchange; i.e., that every village fulfilled its own requirements. Another model would have major centres producing for their own needs and for export, some minor centres producing only the simplest wares locally, and other minor ones importing the totality of their ceramics. Indeed, the manufacture of pottery might constitute one defining attribute (among many) of a major centre, assuming the presence of a suitable clay. Alternatively, a minor centre might have specialized in pottery production, particularly if blessed with an especially good clay source.

Pottery has been chosen as the product to study for several reasons (Renfrew 1977b). Clay and ceramic objects were used in great quantities, and although breakable, the fragments are nearly indestructible. Clay sources are not difficult to find in Greece, though specific types of paint or slip might require clay with particular properties, less easily obtainable. Ordinary pots would be simple to make, but more elaborate or specialized ones would demand a certain degree of talent. The infinite variety of forms and techniques of decoration available to the potter makes it easy for styles to change frequently, allowing the archaeologist in turn to construct refined typologies and assign relatively precise dates to pot fragments. Finally, variations in the trace-element content of clays from different geological formations allow ceramic products to be attributed reliably to their points of origin by chemical analysis (see Chapter 2).

Specific questions to be answered in a study of ceramic exchange include the following: Did inhabitants of different settlements exchange pottery? If so, then how much? How far? In which directions? By what exchange or other mechanism? Can we demonstrate the dependence of some sites on others? Were certain forms, fabrics, or styles more subject to trade than others? Were some vases traded for their own sakes and others for their contents? Did these patterns of exchange vary with time? Can we say what product was traded in exchange for the pottery? Can we learn anything about the degree of craft specialization?

These are big questions, and a program designed to answer all of them would be elaborate indeed. Considerations both technical and practical restricted the scope of this particular study in several ways. First of all, it is not a priori certain that a technique of chemical analysis will be capable of distinguishing the productions of nearby villages. Natural variations within the clay sources and imprecisions of the measurements may mask the difference in mean composition between production centres. Therefore the first test of the applicability of provenance determination to a specific region is the separation of suspected production centres based on chemical analysis of pottery or other material which on independent grounds has a high probability of being locally-made. Separability of sites is more easily achieved than attribution of individual samples to a specific production

centre. It may be that the ranges of composition of several sites overlap to some extent, so that a sample whose composition falls within the overlap region cannot be unambiguously attributed. In fact, all attributions are really judgements based on probabilities (section 2.2).

A preliminary test of this sort was carried out on seven Early Helladic sites in the Argolid and Korinthia (Attas 1980). Based on analysis of ten sherds from each site, it was possible to distinguish all but one pair of the sites. However, attributions of single sherds to production centres was not possible with the small number of samples forming each group. Other technical factors affecting the success of provenance-analysis studies are discussed in section 2.3.

Obviously, close archaeological controls are required to ensure that historically significant materials are being compared. This requires that chronological variability be kept to a minimum. Since the Early Helladic period occupied over a thousand years of Greek prehistory, some subdivisions of this span are essential. Both stratigraphic and typological criteria are crucial to the selection of samples for analysis (see chapter 4). Detailed cataloguing and classification of the sherds also allows the possibility of correlation of the chemical groupings with stylistic ones, and may ultimately lead to the discovery of easily observable characteristics distinctive of individual potters or workshops.

A quantitative study of trade patterns must be based on accurate determinations of the proportion of objects at a given site which were imported. A prerequisite for doing this is that the excavation of the site be designed so that the objects found are representative; in other words, that a coherent statistical sampling strategy be followed. In addition, the entire sherd inventory, or a statistically representative selection from it, must remain in storage from the time of excavation. Finally, the choice of samples for analysis should maintain this representativeness.

Unfortunately, very few excavations in Greece were ever planned with representativeness in mind. From the older ones usually only the highest-quality material was kept. In some cases the material in museums was subsequently disrupted, mislabelled, or partially lost. These considerations make quantitative studies of ceramic exchange practically impossible.

Finally, the time and expense involved in chemical analysis of the thousands of samples necessary to determine accurately the relative quantities of pottery traded in different directions would be prohibitive. This means that only rough indications of the strength of contacts between villages can be given, and that the data are insufficiently precise for determining exchange mechanisms by studying fall-off plots of abundance against distance from source. Nevertheless, many of the above questions can still be

answered in a preliminary fashion on the basis of the limited number of analyses of partially representative samples chosen according to criteria described in chapter 4.

2. PROVENANCE DETERMINATION OF POTTERY BY CHEMICAL ANALYSIS

2.1 Principle

A simple principle lies behind the idea of using technical analysis of artifacts to determine their origin. Two prerequisites must be satisfied: that different sources of raw material can be distinguished by one or more measurable characteristics (most often the chemical composition), and that there be a consistent relationship between the composition of the raw materials and of the artifacts made from them. (Attributions of provenance based on technical characteristics of the method of manufacture will not be considered here.)

The ease with which sources of raw material can be distinguished depends in turn on two factors: the number of such sources available to the artisan and the relative magnitudes of the compositional variations within a given source and among several sources. For instance, obsidian, a volcanic glass valued in prehistoric times for its excellent chipping properties, is very well suited to studies of this kind (Taylor 1976). Sources are few, well-defined, generally homogeneous, and easily distinguishable (for an exception, see Bowman et al. 1973). Marble is another stone the characterization of which is of great interest, particularly in the Aegean region. In this case, however, neither trace-element concentrations nor isotopic ratios are uniform within source formations, and their ranges often overlap for widely

separated sources (Germann et al. 1980). Indeed, the study of Germann et al. showed petrographic examination of thin sections to be more useful than chemical analysis.

The second prerequisite can be of greater or lesser importance depending on the substance under consideration. The chemical nature of some types of objects, namely those made of shell, bone, ivory, and stone (including obsidian, flint, chert, marble, jade, steatite, chlorite, turquoise, and many others), is not altered at all during the process of manufacture. Ceramic materials undergo moderate changes in composition from the raw clay state to the fired product; the effect of these is discussed in detail in section 2.3. Finally, the nature of most metals is such that only drastic transformations can produce functional objects from mixtures of ores and other materials; hence provenance determination is quite difficult to achieve by chemical means. (However isotope ratios, e.g. for lead, may be useful invariant properties.) Re-use of metal in ancient times by melting down old or broken objects is another complication. In general, one can say that although the principle of provenance determination by chemical analysis is the same for all archaeological materials, the successful application of a specific method to a particular substance requires consideration of a number of factors which are often unique to that substance. The remainder of this chapter will concentrate on applications to ceramic materials.

2.2 Development of research

As is common in many scientific fields, advances in instrumentation paralleled theoretical developments in the technical determination of provenance. Early attempts to use technical methods in order to verify the place of manufacture of pottery relied on a very small number of samples and no control material (i.e., objects of definite, known provenance), and so produced results of limited use (Fouque 1869; Richards 1895). Petrographic study of ceramic fabrics in thin section proved effective for large-scale studies, even without the advantages of numerical data (Shepard 1942). Chemical analysis by multi-element instrumental methods began to reveal its capabilities in the late 1950's (Young and Whitmore 1957; Richards 1959). Optical emission spectrography was the relatively rapid but not particularly precise technique used in several long-term projects, including a study of Mycenaean pottery (Catling et al. 1961; Millett and Catling 1967). The nine elements sodium, magnesium, aluminum, calcium, titanium, chromium, manganese, iron, and nickel were found by Catling's team to be both simple to measure and useful for distinguishing centres of production. These investigators made some effort to select "typical" sherds for the constitution of their reference groups (control material), but they have been criticized for not being sufficiently flexible in the number and choice of elements measured (McArthur and McArthur 1974).

In its early stages, neutron activation analysis had little advantage over emission spectrography. Using a sodium-iodide detector, Sayre and Dodson (1957) measured the intensity of the gamma radiation from activated sodium and manganese in Mediterranean pottery and terracottas. Lanthanum, scandium, and chromium were soon added to the list of elements that could be determined (Emeleus 1958; Harbottle 1976, p. 36). The development of the solid-state germanium detector gave analysts a high-resolution tool with which to count gamma rays and determine their energy. Linked to an electronic system for pulse-height analysis, it was applied to the study of ancient glass by Sayre (1965) and ancient pottery by Perlman and Asaro (1967). Using two irradiations and three periods of gamma-ray detection, Perlman and Asaro could measure the concentrations of 33 elements in powdered (but chemically untreated) pottery. They stressed, as did Harbottle (1970), the importance of determining as many elements as possible, from a variety of chemical families and present in a variety of concentration ranges. These then are the main advantages of neutron activation analysis as a technique for the determination of provenance: extensive multi-element capability, and sensitivity independent of the chemical properties of the elements (but dependent on their nuclear properties, which vary over many orders of magnitude, allowing both trace elements and major components to be determined). In addition, this method does not suffer from matrix effects.

Widemann (1980b) has argued that neutron activation is the most appropriate analytical technique for provenance determination of ceramics (see also section 5.1).

Several other methods of analysis are currently used for determining the provenance of ancient pottery. X-ray fluorescence analysis is less sensitive but more rapid than neutron activation (Picon et al. 1971; Birgül et al. 1979; Asaro 1980). Atomic absorption is quite precise but lacks the capacity for simultaneous multi-element analyses (Hughes et al. 1976; Gritton and Magalousis 1978; Bomgardner 1981; Magalousis and Gritton 1981). Proton-induced X-ray emission (PIXE), a new technique with much promise, is similar to neutron activation in that it requires access to sophisticated nuclear facilities, in this case a proton accelerator (Carlsson and Akselsson 1981; Saleh et al. 1981; Rye and Duerden 1982). Even though it is relatively imprecise, emission spectrography was used until 1981 by the Fitch Laboratory of the British School at Athens, which has a considerable body of reference data at its disposal (Mountjoy et al. 1978; Catling et al. 1980).

The importance of high-precision measurement was stressed by Bieber et al. (1976a). The total observed variance of a group of samples from one clay source, S_T^2 , can be expressed as the sum of the "natural" variations in the clay, S_N^2 ; the sampling variance reflecting inhomogeneity within a sherd, S_S^2 ; and the analytical precision, S_A^2 , as follows (Bieber et al. 1976a, p. 68):

$$s_T^2 = s_N^2 + s_S^2 + s_A^2.$$

The aim is to reduce analytical and sampling uncertainties to a minimum, in order that the measured variance reflect primarily the unavoidable spread of concentrations present in a single clay bed.

The main focus of the paper by Bieber et al. (1976a) was a demonstration of the utility of multivariate statistical methods for grouping samples of similar composition and for testing the similarity of a given sample to a group. Perlman and Asaro (1969) had devised a simple scheme for deciding whether a given sample belonged to a reference group, assuming that the measured chemical elements are normally distributed and that there are no correlations among them. They realized that these assumptions sometimes do not hold true, especially the second one, clearly false for the rare earths. (Perlman and Asaro limited the number of rare earths used for grouping to one or two.) Multivariate methods allow reproducible groupings to be made objectively without necessarily making the above assumptions. (Some of the statistical tests require normal, or log-normal, distributions.) A prerequisite for treating someone else's data by these methods is that the data be published in full, sample by sample, rather than as group averages and dispersions. In addition, comparison of results from different programs of analysis obviously requires that the results be published in the form of concentrations (rather than relative activities or peak heights), and that the nature

of the standards used in determining these concentrations be stated. Bieber et al. (1976a) presented these desiderata with the expectation, now already being realized, that many laboratories would each be analyzing hundreds of archaeological samples from overlapping geographical regions, and that inter-comparisons and even common data banks would soon become a necessity (Harbottle 1976, p. 42).

Two recent reviews of pottery provenance determination using chemical analysis, by Wilson (1978) and by Widemann (1980a), may serve as guides to the current state of the art. Wilson's is the more practical of the two; some of his points are considered in detail in the next section. Widemann introduced two concepts of general applicability: the reference group ("groupe de référence") and the zone of non-resolution ("espace de non-résolution").

Ideally, analytical studies of provenance proceed by first determining the compositions of objects of known provenance, and then comparing these with the compositions of objects of unknown provenance (Schneider et al. 1979). The selection of objects of the first kind, those which will form the analytical reference groups, must be made with great care. The most straightforward approach is to characterize every known workshop which produced the pottery of interest, by analyzing abundant vase types from the site of the workshop itself. Often the excavation of a workshop will reveal masses of spoiled pottery, clay storage areas, or vases in

direct association with kilns. These are most likely to have the composition characteristic of that particular workshop's production, and so would constitute the best reference groups. Unfortunately, excavated pottery workshops are not common for many regions and archaeological periods. For instance, none are known from Early Helladic Greece, although a few overfired "wasters" have been found at Lake Vouliagmeni (Fossey 1973), testifying to pottery production there. In such cases less secure indicators must be analyzed: objects present in great abundance, objects of extremely simple manufacture, and objects whose size or fragility prohibits their transport. It is also prudent to increase the number of samples analyzed, in order to compensate for the increased chances of assuming an incorrect origin for some of the objects.

The question of the number of analyses required to form a reference group is a general one with no fixed answer. Wilson (1978, p. 227) suggested a pragmatic approach based on initial analysis of five to ten specimens of each of the selected types and styles of pottery, with continued exploration of ill-defined groups, and a final total of not less than fifty specimens per site. Obviously, increasing the number of analyses will always result in better characterization of a production; at some point, though, diminishing returns of information against expense will set in. It might be worth noting that some of the most sophisticated multivariate treatments, such as some Mahalanobis-distance

calculations, require that the number of items in a group exceed the number of elements determined for each sample. For reliable results, their ratio should be at least three to one (Harbottle 1976, p. 58). This too can put a lower limit on the number of samples in a reference group.

Other approaches to fixing the origin of reference groups were briefly mentioned by Widemann (1980a, p. 30). He noted that an analytical group can be formed whose origin is not precisely known, and then it can be linked as a whole to a specific place by comparison with other data, most commonly with analyses of clays or ceramics of different periods (including modern) whose origin is known. This method is less direct, but can be just as reliable (comparison with Attic or Corinthian painted pottery, for example). An early test of clay analysis gave confidence in its general use for pottery provenance (Millett and Catling 1967, p. 76).

The other concept introduced by Widemann was the zone of non-resolution, defined as the space, both as area and as depth of geological strata, which presents a uniform distribution of composition at the present level of our technical ability (Widemann 1979, p. 51). This concept has actually been with the field of analytical provenance determination since its inception. From early in the long-term study of Mycenaean pottery, Catling was troubled by the fact that the analytical technique of optical emission spectrography was incapable of distinguishing pottery from many sites in the

Peloponnese. He wrote (1963, pp. 3-4), "Since it is unthinkable that a single site provided the whole of the Peloponnese with its pottery in the Mycenaean period, it follows that the clays used by potters throughout the region are homogeneous enough in composition to prevent them being distinguishable by the present method". The zone of non-resolution in this case, then, is the entire Peloponnese. This zone can be different for different analytical methods. The neutron activation work undertaken by Bieber et al. (1976a) was aimed at, and succeeded in, subdividing the large compositional group established with the less-precise emission spectrographic data. Ideally, zones of non-resolution are properties of the landscape alone, but it is likely that analytical limitations are still the major contributing factor. The most precise analytical techniques, and those which measure the largest number of characteristics (chemical, mineralogical, or other) clearly stand the greatest chance of reducing zones of non-resolution to their minimum size.

2.3 Technical considerations

In this section, several factors which might affect the results of provenance determination of pottery by chemical analysis are discussed in more detail. They fall into three categories: the potters' habits of clay preparation, possible chemical alterations of the ceramic between the states of unfired pot and powdered sample, and considerations of

homogeneity. These are treated in turn.

Several related points are periodically raised concerning the processing of raw clay by potters in order to give it suitable working properties. Both primitive and industrial modern potters are known sometimes to obtain clays from distant sources, to mix two or more clays from different sources, (e.g. Brooks et al. 1974, p. 52), to purify a clay by diluting it with water and then passing it through sieves or allowing larger particles to settle out of suspension (elutriation), and to add temper (any granular non-plastic material: Shepard 1965, p. 24). All these steps will affect the chemical composition of the ceramic body to a greater or lesser extent. However they may have no effect at all on the overall study of ceramic exchange. For if the fundamental entity to be characterized is the output of the pottery workshop, that is, the manufactured ware itself (Widemann 1980a), then these considerations become of secondary importance. As long as the group of potters is consistent in its habits, each of their wares will be uniform in composition and typical of the workshop. Variations in clay preparation may cause a spread in the range of elemental concentrations characteristic of the ware, but they do not invalidate the characterization. Similarly, use of clays from a variety of sources may result in a multimodal distribution of concentrations, but this distribution is a faithful representation of the output of the workshop.

Addition of temper would have an analogous effect. The link between the composition of the raw clay and of the finished ware may be weakened, but that between the ware found locally and the same ware exported to other sites is maintained.

There are several indications that even the link between clay and pot is not severely affected by some of the clay treatments. The presence of non-clay minerals in the clay matrix, in the form of temper added by the potter or of naturally-occurring rock grains, may have a predictable effect. Two extreme (but not rare) cases can be identified (Olin and Sayre 1979). One is that the inclusions may consist of crushed sedimentary rock (chert, mudstone, etc.) readily available to the potters, rock whose trace-element composition is not very different from that of the local clay. In that case the addition of up to, say, ten percent by weight of this constituent would alter the overall trace-element concentrations only minimally. This seems to have been the case in the study of Mexican ceramics by Abascal-M. et al. (1974, p. 90). Farnsworth et al. (1977, p. 461) calculated that 15% of hornfels or mudstone, used as temper in Corinthian pottery, would leave the composition of the pottery "so close to that of the fine ware that it could clearly be recognized as Corinthian pottery".

The other situation, actually quite common, is that the inclusions consist of relatively pure sand (quartz) or of crushed shell or limestone; that is, of material low in trace

elements, whose major components may or may not be determined by the method of chemical analysis used. (The use of straw or grass as temper is a similar possibility, though usually these burn off during the firing and have no effect on the overall composition of the ceramic.) In that case, the inclusions would act as a diluting component, lowering the concentrations of all the trace elements by the same factor. When such a situation occurs, it is a simple matter to recalculate the concentrations to compensate for the dilution, if the proportion of diluent can be determined. Even when the diluent is not measured directly, empirical methods exist for trying a series of correction factors to see if one of them gives a close match with a known composition pattern (Olin and Sayre 1971, p. 200; Brooks et al. 1974; Widemann 1979). Brooks et al. determined that the presence of up to 25% sand temper in the Palestinian pottery they were studying would have a "negligible effect on the relative concentration of elements in the ceramic pattern" (1974, p. 55).

Of course, rock grains of complex composition are also suitable candidates for use as tempering material, and the effect of these on overall composition is not easily determined. For instance, the steatite-tempered sherds from Hajar Bin Humeid in South Arabia, analyzed by Al Kital et al. (1969, p. 391), contained about thirty times as much chromium as the other types found at the same site. Potters are known also to use "grog", or crushed sherds from previously-fired

0 pots, as a temper (Shepard 1965, p. 25). In general, then, it is clear that the results of analyses of sherds whose inclusions are readily visible must be treated with caution, but they may be as useful as those of fine wares.

The purification of clay by allowing the heavier particles to settle out of suspension has an effect opposite to that of addition of temper. If the particles have a composition similar to that of the clay matrix, the overall elemental concentrations in the purified clay will be little changed. If they are relatively pure particles, their removal will cause most concentrations to rise. Finally, if they are different or varied in composition, they will have a complex effect. A test using a clay from Lake Vouliagmeni in Greece showed that most elemental concentrations increased with increasing refinement of the clay (Attas et al. 1977, p. 37), corresponding to the second of these cases. However Birgül et al. (1979) found that analyzing fractions of a Turkish clay sample which had been separated into various ranges of particle size did not show any obvious correlation between particle size and elemental concentrations.

A different set of phenomena is responsible for alterations to the chemical composition of a clay once it has been moulded into the form of a pot. The potter may decorate his pot by adding paint, slip, or glaze to its surface, but these materials usually do not penetrate very deeply into the clay. () Allowing the pot to dry completely is the final step before

firing. This will trivially increase the concentrations of the component elements (except hydrogen and oxygen) by lowering the overall weight of the pot.

Non-trivial changes in composition usually occur in the firing process. The extent of volatilization of the components of a clay depends on many factors: the firing temperature and duration, the kiln atmosphere, and the immediate surroundings in the clay of the species concerned. The last factor includes both the physical and chemical (bonding) environment. In general, a long, high-temperature firing in a well-ventilated kiln will favour the disappearance of loosely-bound species, especially from porous or thin-walled pots. Compounds usually released during firing include the bound water lost by the clay lattice itself and carbon dioxide arising from the decomposition of (chiefly calcium) carbonate, as well as both of these as gases produced by the combustion of organic matter (Shepard 1965, pp. 19-22). Certain other elements are supposed to volatilize as well, though the mechanisms are not clear. A study by Franklin and Hancock (1979) showed chlorine and probably bromine to be among these, though apparently not arsenic or antimony, two elements whose broad distributions in pottery had previously been attributed to their volatility (references not given by Franklin and Hancock).

Alterations of the chemical composition of pots during use are few. Absorption of organic materials can take place,

some of which (especially fats and resins) can leave traces over millennia (Condamin et al. 1976; Condamin and Formenti 1978; Rottländer and Schlichtherle 1979). Penetration and leaching of soluble inorganic compounds during the "life" of a pot are probably negligible compared to the exchanges with groundwater while buried.

The alteration of the chemical composition of pottery while buried is of serious concern to researchers in the field of provenance studies, as it is an effect dependent not on the workshop producing the pots, but on their final resting place. Many researchers have noted variations in one element or another, but few have done extensive research. Obviously the degree of leaching or deposition will depend on soil conditions as well as on qualities of the ceramic. Elements susceptible to these processes include some alkali metals (Sayre et al. 1971; Asaro et al. 1975; Fillières 1978), particularly sodium (Bieber et al. 1976b); the alkaline earths barium and calcium (Freeth 1967; Prag et al. 1974; Gautier 1975; Bieber et al. 1976b); manganese and iron (Freeth 1967); and in one case even uranium (Asaro et al. 1975). A study now in progress promises to provide some more conclusive results (Franklin and Hancock 1981; Ajdacic and Franklin, personal communication 1981). In the meanwhile, prudence is suggested in using these elements as ultimate criteria for assignments of provenance, though they might still be useful in all but extreme conditions (e.g., very acid soil or poorly-

fired pottery). Sea water has a particularly drastic effect on Group I and II metals in pottery, raising the concentrations of magnesium and sodium (and fluorine), and lowering those of potassium, rubidium, cesium, and barium (Lemoine et al. 1981). The same study also found that overfired calcareous pottery buried underground is more susceptible than other ceramic pastes to alteration of alkali-metal concentrations.

Finally, the archaeologist and analyst themselves can be responsible for additional changes to a potsherd's composition. Although washing excavated pottery in water is unlikely to change its composition much, cleaning with hydrochloric or nitric acid might seem more drastic in its effect. Recent tests under controlled conditions by the Groupe d'Archéologie Nucléaire d'Orsay-Saclay, however, showed no significant changes to the concentrations of otherwise-reliable elements (Fontes et al. 1981, p. 105, note 11). The sampling process too can introduce some contamination. As this is actually a general problem in trace analysis, discussion of means of eliminating or at least controlling contamination is reserved for chapter 5.

The third category of technical considerations concerns those of homogeneity. The ceramic fabric of a pot is clearly not a homogeneous material. Therefore a large enough sample must be taken to be representative of the average ceramic composition. The sample may be taken from several parts of the vase, though there is no evidence of differences in the

concentration of elements from one part to another. In fact, variations within a pot would be subsumed in the variations from pot to pot of an analytical group. Most researchers extract 100 to 200 milligrams of powder, which is mixed before a portion is used for analysis (Wilson 1978). A theoretical approach using the size and statistical frequency of inclusions to calculate the minimum sample size required to achieve a specified degree of reproducibility has been proposed by Bromund et al. (1976). The quantity predicted by their formula falls below 200 mg for most cases encountered in this study. This theoretical result is supported by the experimental work of Hancock (1982), who found that "for all but the crudest coarse wares... all elements which can be measured relatively precisely can be analyzed quite reliably using either 100 mg or at most 300 mg samples".

Overall homogeneity of a pottery workshop's output is another aspect which has received some attention. This will depend, of course, on the habits of the potters, the homogeneity of the local clay bed(s) and temper sources, and the speed at which the potters use up the bed(s). Taking a direct approach, Widemann et al. (1979) found that the contents of a single firing of a Roman kiln were extremely homogeneous, but that the overall production of the workshop was less so, and probably relied on several clay sources. Birgül et al. (1977; 1979) have been exploring variations within the clay beds themselves. Although their 1977 study

showed some beds to be remarkably homogeneous, the later study revealed broader spreads of trace elements in other clay beds.

An opportunity recently arose to test the variations in trace-element concentrations of a pottery workshop functioning over several centuries (Attas et al. 1982). This work, dealing with pottery from Sparta painted in the Lakonian style, indicated that these variations were quite small, and furthermore that they were continuous and even monotonic (increasing or decreasing with time) for some elements. This is reassuring to researchers working with prehistoric pottery where dates may be precise only to the nearest century or two. It also allows analyses of pottery of different periods to be used as comparative data on a regional scale or perhaps even a finer one.

3. THE REGION UNDER STUDY: ARGOLIS AND KORINTHIA

3.1 Justification

The north-east Peloponnese was chosen for this study of intra-regional trade for several reasons. First of all, it is a natural geographical unit (Fig. 1-i). Although linked to other parts of Greece by land and sea, this area is also in many senses self-contained.

The second reason for choosing this region is that it has been extremely well-studied by archaeologists for over a century. As the home of the Mycenaean civilization, it has received constant attention in the form both of field surveys and of excavations. These naturally revealed traces of Early Helladic settlement, and several excavations have been carried out to gain more information specifically about that period.

Finally, the north-east Peloponnese seems to have been an important area of Early Helladic culture. That this is not an illusion, due solely to more concentrated archaeological work in that area, is indicated by the results of recent surveys of less-studied parts of Greece, the work of Hope Simpson and Dickinson (1979) being the most extensive. Early Helladic settlement was found to be sparser in the rest of the Peloponnese, and less diversified (Hope Simpson and Dickinson 1979, p. 372). Of course, other parts of Greece, particularly Attike and Boiotia, can claim equal prominence as core areas of Early Helladic culture. As well-excavated finds from sites

in those regions are rarer and more difficult of access, however, their analysis is left for the future.

3.2 Topography

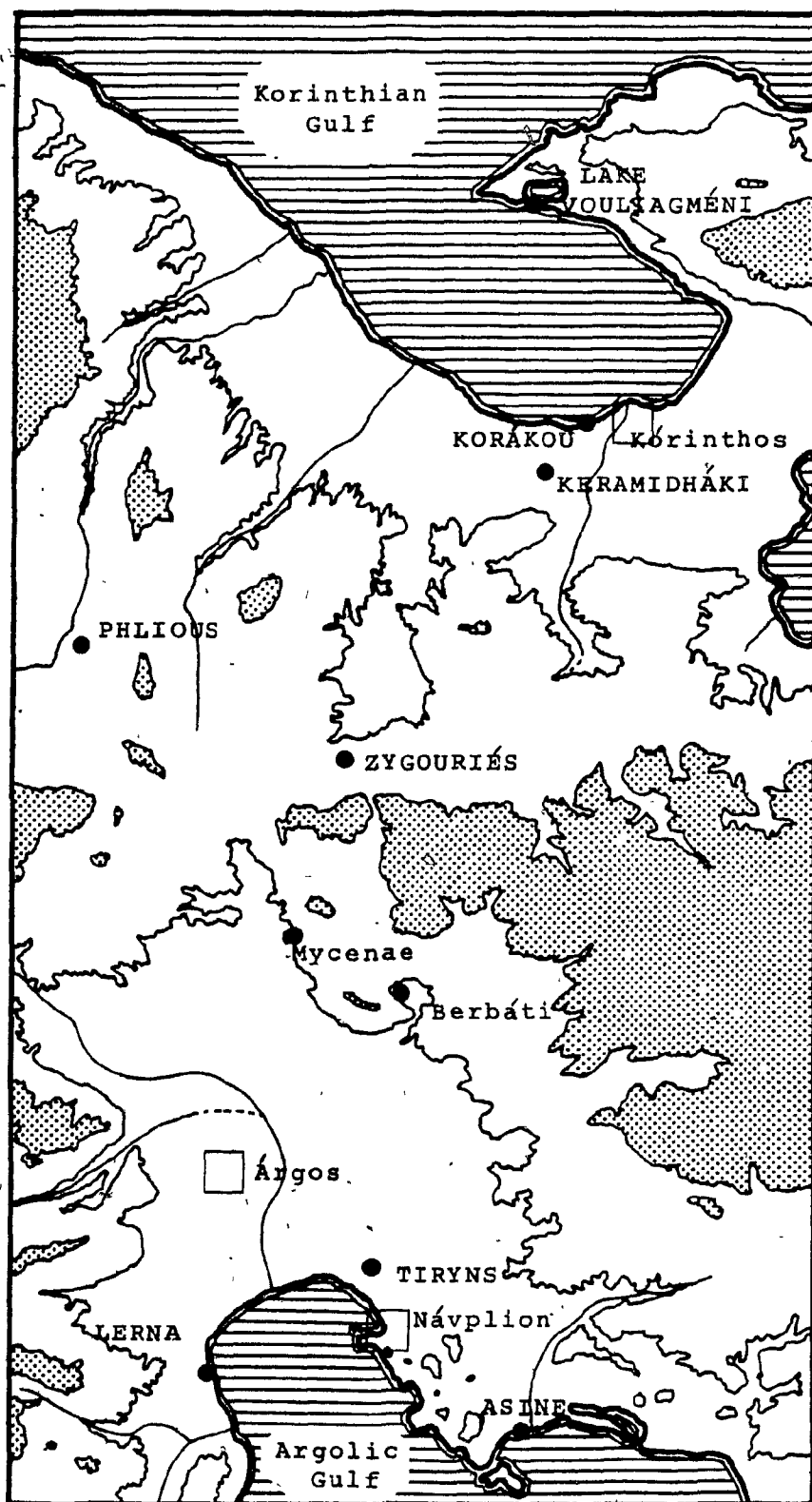
The north-east Peloponnese today comprises the two provinces ("nomoi") Argolis (or the Argolid) and Korinthia. Each of these consists of a relatively large coastal plain, several upland valleys, and extensive mountainous areas (Fig. 3-i). A range of low hills forms the east-west watershed separating the two provinces. To the west, their border is the series of peaks, from north to south named Kyllíni, Olíghyrtos, Trakhý, Lyrkeíon, Artemísion, Ktenías, Parthénion, and finally the Páron range jutting into the Mirtóan Sea. The main passes, to either side of the Parthénion, lead to Trípolis in Arkadia and thence to Lakonia. On the three other sides, the limits are the sea: the Argolic gulf to the south, the Saronic gulf to the east, and the Korinthian gulf to the north. Jutting into the Gulf of Kórinthos from the east is the Perakhóra peninsula. Although geographically part of central Greece, it is usually considered as part of the Korinthia because it is from Kórinthos that it is most easily reached, by sea or via the isthmus of Kórinthos, which joins the Peloponnese to central Greece.

The narrow plain along the north coast of the Peloponnese broadens near Kiáton, and from there east to Kórinthos it is several kilometres wide (Fig. 3-i). Near ancient Corinth it

FIGURE 3-i: The central portions of Argolis and Korinthia,
showing the sites from which pottery was
sampled.

● ancient site

□ modern town



200m
600m

0 km 10



consists of a series of terraces. Many torrents have cut ravines from the mountains north into the gulf. From west to east, the major ones are the Asopós (valley of Phlious and Sikyon), the Zapántis (valley of Nemea), the Longopótamos (valley of Kleonai), and the Lefkón or Xeriás (valley of Solomós). Because of these, communications (except along the coast) are easier in the north-south direction than in the east-west one. Today the main town is Kórinthos, located to the north-east of the ancient town of Corinth.

The Argive plain is roughly triangular in shape, with its base at the Argolic gulf and reaching northwards to Dhervenákia at the border with the Korinthia. Both the east and west sides of the plain are indented by torrents, but the main river is the Ínakhos, running down the centre. To the east of the plain is a barren plateau rising to the Arakhnaíon mountains. Farther south the mountains are more broken, forming a topographically complex peninsula known as the Aktí. It includes some small plains, especially near its southern end, around the villages of Kranídhi, Portokhéli, Ermióni, Fourni, and Dhídhyma. Most of the modern population is concentrated at Árgos and Návp lion, towns near the south-west and south-east corners of the Argive plain respectively.

3.3 Geology and geomorphology

The Aegean region is an area of complex geology which has recently received much attention. A framework for its

study was set out by Aubouin et al. (1963), and summarized by Fürst et al. (1965) and by Bintliff (1977), constituting the main sources for this brief description.

Most of the bedrock in Greece is limestone. It was formed during the Mesozoic era by the accumulation of sediments on the undulating ocean floor. The undulations, oriented north-north-west to south-south-east, comprised alternating zones of furrows, made up of deep-sea (pelagic) sediments, and ridges, made up of reef-like (neritic) sediments. The uplifting of these sediments proceeded gradually from east to west. Weathering debris from recently exposed portions would slump down, usually westwards, to form deposits ("flysch") over the neighbouring portions which were still submerged. In places, the limestone massif itself would slide westwards to cover the neighbouring zone partially or completely.

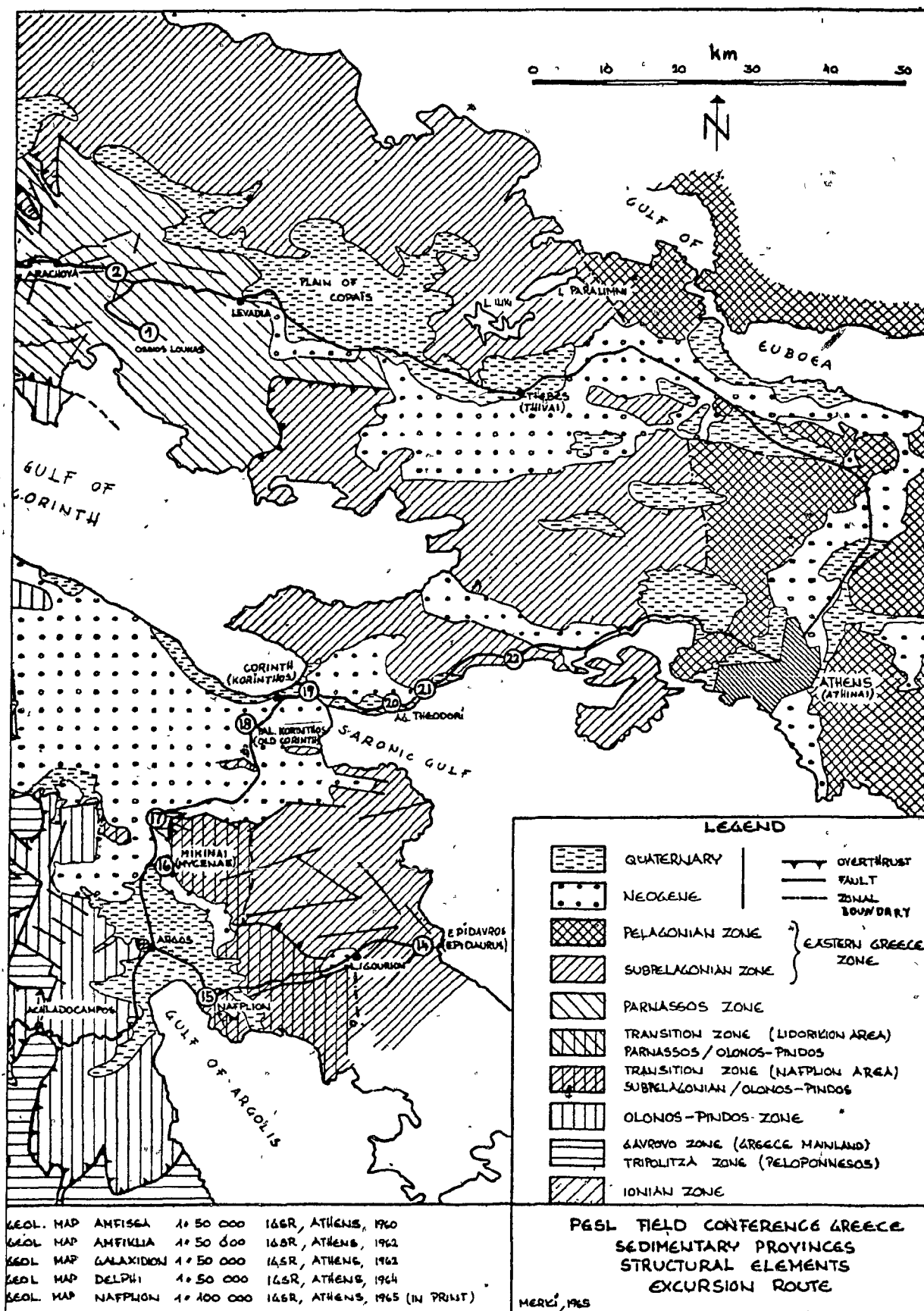
During and after this Alpine orogenic (mountain-building) phase, subsidences of many areas formed basins and gulfs, usually aligned in the same general NNW-SSE direction. Examples of these are the Argolic gulf and the system formed by the Megalopolis, Sparta, and Helos plains and the Lakonian gulf. These basins collected sediments from erosion of the surrounding mountains and in some cases from marine and lake deposits formed during periods of high sea level.

Other processes were not related to the overall trend. The creation of the east-west gulf of Kórinthos is one of these. Formed during a period of depression and deposition

of marine sediments, it subsequently rose several hundred metres, thereby shrinking the water-covered portion considerably. A general southwards tilt, evident in many parts of the Peloponnese, is another independent phenomenon.

The geology of the north-east Peloponnese can be interpreted with the preceding scheme in mind (Bintliff 1977, p. 271). Originally the four zones that concern us were arranged from west to east in the following order: the Tripolitsa-Gavrovo ridge, the Olonos-Pindos furrow, the Parnassos-Trapezona ridge, and the Sub-Pelagonian furrow (see Fig. 3-ii). However, during the Tertiary era, the Olonos-Pindos furrow was thrust westward so that it partially covered the Tripolitsa-Gavrovo massif, forming the hills west of Argos. The Arkadian mountains belong to the Tripolitsa-Gavrovo ridge. Westward shifts of the Trapezona and Sub-Pelagonian massifs caused them to overlap partially the Tripolitsa-Gavrovo and Olonos-Pindos ranges. Because of this, the hills to the east of the Argive plain belong to the Sub-Pelagonian series. Interspersed with these limestone layers is flysch, found in many pockets in the Argolid. The Argive plain itself was created by a subsequent subsidence, as was the gulf of Kórinthos. The extensive deposits of marl in the Korinthia were laid down during this phase of subsidence, in the Pliocene period. The Perakhóra peninsula belongs to the Sub-Pelagonian massif.

FIGURE 3-ii: Geological map of Greece (detail, after Norton 1965).



More recent events have also altered the landscape. Particularly relevant to ancient settlement are the cycles of alluviation and of sea-level change. The formation in recent times of valleys and coastal plains in the Mediterranean basin has been studied by Vita-Finzi (1969), who discerned two phases of alluviation: these have been termed Older (or Pleistocene) Fill and Younger (or Historical) Fill. The Older Fill consists of thick deposits of ill-sorted reddish sediments with a relatively steep gradient, indicating that they were laid down during a short (in geological terms) climatic phase of heavy precipitation. The Younger Fill, a brownish silt interspersed with gravels, is a less massive alluvium laid down by existing streams using material eroded from the Older Fill. Bintliff (1977, Ch. 2) has summarized the research done on these formations over the last decade, and added his own conclusions on soil fertility.

It appears that the deposition of the Older Fill ended before (and perhaps well before) the Neolithic period in Greece. The Younger Fill, on the other hand, can be dated independently in many areas by finds of archaeological material in context. In most of these areas it was laid down, perhaps in several phases, over a period of centuries between Late Roman and Medieval times. Although the origin of this deposit is under debate (Wagstaff 1981), its implication is clear: the ancient landscape was not the one

we observe today. The ancient land surface can nevertheless be approximated by determining the position of the upper surface of the Older Fill. In general, valleys and plains would have been steeper then than they are today. The Pleistocene alluvium is only moderately fertile, whereas the Historical Fill is extremely so. Although the sediment of the Younger Fill is finer, and perhaps better suited to the manufacture of pottery than the Older Fill, it would not have been available to ancient potters.

There is not yet agreement on a theory to explain sea level changes in the Aegean area. Bintliff (1977) argued against Flemming's (1972) contention that there has been no overall rise in sea level over the past few thousand years, and that all changes were due to local tectonic phenomena. Bintliff presented instead much evidence for an overall rise, at least in the Aegean, at a rate of about one metre per thousand years. Whichever theory fits the evidence better, there is no question that the sea has encroached on many Greek coasts. Sites that suffered sea-level rises of one or several metres include Halieis, Asine, Tiryns, Néa Kíos, and Lerna, all in the Argolid, and Kenchreai and Lake Vouliagmeni in the Korinthia (Bintliff 1977, pp. 13-26).

The paleogeographic settings of several coastal sites have been more directly studied by Kraft et al. (1977), who examined drill cores to determine subsurface stratigraphy. Their results too indicate a relative rise in sea level

around the Peloponnese. Tiryns in particular was much closer to the sea in Early Helladic times, and was perhaps even a port. In general it is clear that the surroundings of each settlement in the past may not have been as they are today, so that archaeologists should exercise caution in relating ancient sites to their settings.

3.4 Criteria for site selection

Many archaeologists have conducted extensive topographic research in the north-east Peloponnese. Two recent works of general usefulness are those of Sakellariou and Faraklas (1972) and Wiseman (1978), both concerned with the Korinthia. Recent studies of prehistoric settlement in Greece include those of Bintliff (1977) and Hope Simpson and Dickinson (1979). In the latter work are listed 61 sites in the Argolid and Korinthia where Early Helladic pottery has been found. These range from mere scatters of surface sherds to extensive fortified villages such as Lerna. Their distribution (Hope Simpson and Dickinson 1979, Map 1, from which Fig. 1-i is taken) shows a concentration along the edges of the Argive and Korinthian plains. Other sites lie along the coast (often on hilltops) or in upland valleys.

Including in this study every known Early Helladic site would obviously have been impractical. The quality of the information that can be extracted from the analysis of pottery samples depends first of all on the nature of the

sites at which they were found. The more we know about the ancient occupation of a site, the better we can interpret the results of pottery analysis. Usually excavation of a site yields much more abundant information than examination of surface remains alone. Therefore only excavated sites were chosen as sources of material for analysis. Collections of surface material have not been considered in this study, even though they may sometimes include objects of particular interest.

Although it would have been interesting to include sites spanning a range of types from isolated farmsteads through hamlets, villages, and large regional centres, in most cases only larger sites have been excavated. (They are also easier to discover.) All the sites in this study were probably at least villages in Early Helladic times.

Several other criteria can be applied to select the best sites for a study of regional trade. The thoroughness of an excavation is an important factor. So is the thoroughness of its publication. The clarity of the stratigraphy also helps where available. The disposition of finds in a museum is crucial as well. Finally, permission of the excavator and of the Greek Archaeological Service to take samples are absolute prerequisites.

Unfortunately, there are no sites which satisfy all these criteria. Older excavations were often more extensive than recent ones, but publication of the findings was not

usually as detailed. As well, the finds, if kept at all, may have been disturbed in museum storerooms. On the other hand, many of the most recent excavations, conducted with the skill and precision demanded of modern-day archaeologists, have not yet reached the publication stage. For some of them, a definitive interpretation of the stratigraphic sequence may still be pending.

With these factors in mind, a distribution of sites was sought which would encompass the varied geography of the Argolid and Korinthia (Fig. 3-1). Thus Tiryns was chosen to represent the Argive plain, Asine lies in a separate little plain to the east, and Lerna on the edge of one to the west. On the north side of the watershed dividing the two provinces, Zygouries stands at the head of the Kleonai valley. Phlious is situated in the valley of the Asopós river, farther to the west. Representing the Korinthian plain itself are the two sites Keramidhaki and Korakou. Finally Lake Vouliagmeni may be one of the principal Early Helladic villages of the Perakhóra peninsula.

Some effort was made to choose sites in separate valleys or plains, with the thought that each hydrographic system, with its own secondary clay deposit(s), might have a distinct pattern of elemental concentrations, reflecting the immediately surrounding geology. That the inverse situation holds true, namely that clays along a single, large river are remarkably similar, is supported by analyses

of clays and pottery from the Nile (Perlman and Asaro 1969, p. 35; Tobia and Sayre 1974, p. 104) and pottery from the Mississippi valley (Carole Stimmell, personal communication 1980). Two potentially useful sites in other river valleys were not included in this study, because the Early Helladic pottery from their excavation could not be located. These are Berbáti (Sáflund 1965) in the plain of the same name behind (i.e., to the east of) Mycenae, and Nemea (Tsoungíza ridge: Blegen 1927, pp. 436-437; Harland 1928) in the Zapántis river valley, which runs between the two containing Phlious and Zygouries. Finally, extensions of the area covered could be made in several directions. The most natural of these appear to be the Aktí to the south-east (Southern Argolid Survey Project: see, e.g., Bintliff 1977, pp. 183-209) and Arkadia to the south-west (Ayiorýtika: Heffner 1928, pp. 533-534; Blegen 1930-31, p. 55; Asea: Holmberg 1944). Perhaps the occasion will soon arise to sample material from these sites as well.

The following sections provide brief descriptions of sites from which ceramic material was sampled, including their position, excavation history, disposition of finds, and publication.

3.5 Brief site descriptions

3.5.1 Asine

This coastal settlement and akropolis lies about eight kilometres to the east of Návplion, on the same bay as the

modern village of Tolón (Fig. 3-1). Large-scale Swedish excavations of the akropolis, a rocky headland known as Kastráki, took place in the 1920's, revealing extensive habitation through the Bronze Age and the Geometric period, followed by renewed settlement in Hellenistic and Roman times (Frödin and Persson 1938). Although the excavators felt that the Early Helladic occupation was continuous, Caskey (1960, p. 301) re-interpreted the finds as indicating a violent destruction at the end of Early Helladic II. Most of these finds were lost during the Second World War. What remains, is divided between the Návpليون museum and its stores, known as the Lionárdho.

Swedish excavations were resumed on a smaller scale in 1970 in several areas around the Kastráki (I. and R. Hägg 1973; 1978; 1980; Wells 1976; Dietz 1980). Scatters of Early Helladic sherds were collected in deposits of later date on the south slope of the hill known as Barbouína, facing the akropolis (Fossey 1978). As they were found out of context, their identification was based on criteria of shape, fabric, and surface treatment (Fossey 1978, p. 44; see also chapter 4). This material is stored in the Lionárdho, organized by excavation lot number.

3.5.2 Tiryns

An important fortified palace and settlement in Mycenaean times, Tiryns appears to have had continuous

Bronze Age occupation. Situated about three kilometres north of Návplion, the low rocky hillock has been under investigation by German archaeologists since Schliemann's excavations in 1876. Early Helladic remains are extensive in all three parts of the site: the Oberburg or Upper Citadel, the Unterburg or Lower Citadel, and the Unterstadt or area immediately surrounding the citadel (Müller 1938; Jantzen 1975). Most recently, excavations of the Unterburg have uncovered broad expanses of Early Helladic levels (Kilian *et al.* 1981) showing apparently a continuous development from EH II to EH III, in contrast to the situation at Lerna (see below). All the finds from the latest excavations, as well as many from earlier ones, were kept in the storerooms and museum at Návplion until autumn 1981.

3.5.3 Lerna

Lerna is another coastal site, this time on the western shore of the Gulf of Árgos, about ten kilometres south of Árgos. Although excavated during the 1950's by an American team, study of the abundant material is only now reaching completion (Banks 1967; Gejvall 1969; Angel 1971; ASCS 1977). The spectacular Early Helladic finds, both structures and artifacts, have contributed much to our knowledge of that period. The implications of the stratigraphy at Lerna, namely that a violent destruction and a change in cultural assemblage separated the EH II and EH III phases, there, led

to a re-appraisal of the Early Helladic sequence at other sites in the north-east Peloponnese (Caskey 1960). Feature sherds and all other artifacts are stored (by deposit) or are on display in the Archaeological Museum at Argos.

3.5.4 Zygouries

The remains of this prehistoric village lie near the modern village of Áyios Vasílios, at the south end of the valley of Kleonai. Excavations were undertaken by the American School of Classical Studies in 1921 and 1922 (Blegen 1928). Major structures, in most cases dwellings, were uncovered belonging to the Early and Late Helladic periods. The Early Helladic finds showed good stratification, allowing Blegen to define the subdivisions EH I, EH II, and EH III (Blegen 1928, p. 217). Apparently all the sherds except "the coarser and less significant fragments" (Blegen 1928, p. 75) have been stored in the Old Museum at ancient Corinth, still arranged by level.

3.5.5 Phlious

Near its southern end, the Asopós valley broadens to form a plain, indented on the east side by a long ridge. Early Helladic sherds are the most abundant prehistoric remains both on and below this ridge, in some areas with Neolithic sherds as well (Biers 1969). One season of American trial excavations, in 1924, was never properly

published (Blegen 1925), but the finds were stored in the Old Museum at ancient Corinth. They were studied more recently by Biers (1969), who catalogued and published a selection of diagnostic pottery from the deposits, all of which had been thoroughly mixed both prior to and following excavation. All the sherds definitely attributed to the Early Helladic period belong to the EH II phase, resembling most closely contemporary pottery from Zygouriés, though slightly inferior technically (Biers 1969, p. 453). The catalogued sherds are now stored in the New Museum at ancient Corinth.

3.5.6 Keramidhaki

During American excavations of the Gymnasium Area at Corinth, the layer immediately above bedrock was found often to contain quantities of mixed Early Helladic material (Wiseman 1967a, pp. 25-27; 1967b, p. 410). This material has been studied by Cherry (1973), who attributed it to a relatively short span of habitation within EH II (1973, p. 123). Other areas at ancient Corinth show traces of occupation throughout Early Helladic I and II (Weinberg 1937, p. 521; Lavezzi 1979). All inventoried pottery from ancient Corinth is stored in the New Museum, and the rest in other storerooms nearby.

3.5.7 Korákou

The hill known as Korákou (or Korakou; Fossey, personal communication 1981) lies on the south shore of the gulf of

Kórinthos about two kilometres west of the modern city of Kórinthos. It was the first prehistoric settlement excavated by Blegen in the Korinthia (Blegen 1921), showing almost continuous occupation in the Bronze Age. Although the site was well-stratified, what pottery is stored in the Old Museum at ancient Corinth has been grouped by period rather than by layer. Therefore categorization of the Early Helladic pottery must be made on the basis of style.

3.5.8 Lake Vouliagméni

Extensive scatters of sherds along the strip of land separating Lake Vouliagméni, on the south side of the Perakhóra peninsula, from the Gulf of Kórinthos to its south, mark the position of this Early Helladic settlement. Excavations under the auspices of the British School at Athens in 1965 and in 1972 revealed, in two areas separated by about 100 metres, EH I and EH II occupation respectively, as well as small quantities of later material (Fossey 1969; 1973). Until 1981 most of the finds were stored in the Old Schoolhouse of the modern village of Perakhóra pending full publication of the 1972 excavations. The disastrous earthquake of March, 1981 led to their burial under the ruins of the schoolhouse; the small finds and the few near-complete vases were temporarily transferred to the archaeological museum at Isthmia (Fossey, personal communication 1981).

4. THE MATERIAL: EARLY HELLADIC POTTERY

4.1 Introduction

This chapter deals with a succession of topics, all related to pottery. First is presented the development by archaeologists of the three chronological subdivisions of the Early Helladic period (based on pottery), followed by brief discussions of terminology and absolute chronology. Then diachronic and regional variations within the middle, principal, phase of the Early Helladic period, again based on ceramics, are enumerated. Some of these are important to the study of exchange, as they may enable production groups and spheres of influence to be discerned on the basis of typology rather than chemical analysis. Finally, the catalogue of objects sampled is preceded by an explanation of the criteria used in selecting them from large bodies of excavated material, and by an exposition of the terms actually employed in describing them. It should be stressed that no original contribution to Early Helladic ceramic typology has been made; rather, published schemes have been assembled to facilitate the description and classification of the sampled objects.

4.2 Chronological subdivisions of Early Helladic pottery

Several varieties of pre-Mycenaean remains of the Greek mainland were recognized in the last century, but were not set in clear chronological sequence until the First World War,

with the work of A.J.B. Wace and C.W. Blegen (1916-18). It was they who, at the suggestion of Sir Arthur Evans (Caskey 1978, p. 489 note 3), first used the term "Helladic" to designate the mainland Bronze Age, and subdivided it into three periods: Early, Middle, and Late, the last being synonymous with the Mycenaean period.

The classification of Wace and Blegen organized pottery types into groups, some already known, others newly recognized. To the Early Helladic, or EH, period belonged the ware known as Urfirnis from its glossy coat of paint or slip. The succeeding Middle Helladic period was characterized by the production of a wheel-made, smoothly finished, silvery-grey pottery known as Minyan (of which varieties in other colours were also known), and a hand-made, less-smooth ware decorated with linear and curvilinear designs, called Matt-painted. The fine slipped and painted pottery of the Late Helladic period was already well known.

Urfirnis was only one of several wares assigned to the Early Helladic period, however. In fact, five groups were discerned, each with specific forms, fabrics, and surface treatments. Group I contained (a) polished and (b) slipped-and-polished monochrome wares; Group II, vases (a) partially or (b) wholly "glazed"* (i.e., Urfirnis ware proper); Group III,

*The term "glaze" was used by Blegen (and others) to describe a lustrous or glossy slip, actually not a true glaze but a suspension of fine clay particles applied with a brush or by dipping (Shepard 1965, p. 67). "Lustrous slip" is used in the present work to denote that particular finish.

patterned ware (i.e., ware decorated with lines of paint), either (a) dark-on-light (i.e., dark paint on a light background) or (b) light-on-dark; Group IV, plain ware; and Group V, large storage jars known as pithoi, sometimes slipped and often decorated with raised belts of ropelike design. All these wares were made by hand rather than on a potter's wheel. Groups I, II, and III stood chronologically in that order, though with much overlap. Group I(a), recognized only in the form of large open bowls, seemed particularly early. Shapes common to Groups I(b), II(a), and II(b) were jugs, deep and shallow bowls, jars, askoi (football-shaped closed vases), and above all sauceboats, open shapes of uncertain purpose with a loop handle near the rim, opposite a characteristic troughlike splayed spout (Fig. 4-i). A few sauceboats and askoi were decorated with simple designs in dark paint, but much more common in Groups III(a) and (b) were jars, two-handled tankards and mugs.

Blegen used these divisions in his publication of the pottery from Korakou (1921), substituting the letters A-E for his Groups I-V and I, II for (a), (b). More significant than this change of notation was his provisional subdivision of the Early Helladic period itself into three chronological stages, labelled EH I, EH II, and EH III, "without laying too much stress on the distinction" (Blegen 1921, p. 14). Polished ware of group A was typical of the earliest stage, though lustrous slipped ware was beginning to appear. This

FIGURE 4-i: Forms of Early Helladic pottery (not to scale)

- a) EH II sauceboats (4 types) and bowls from Lerna (Caskéy 1960, p. 291)
- b) EH II and III forms from Lerna and nearby sites (Hanschmann and Milošević 1976, Fig. 30; their caption, pp. 123-124, gives references to the original illustrations)

EH II forms

sauceboats:	7(type I), 23(II), 24(III), 27(IV), 89(IV)
small bowls:	5, 6, 12, 20, 28, 29, 30, 83, 84, 90, 91
askoi:	1, 25, 26, 80
jars:	16, 17, 85, 86, 87
pithoi:	77, 78
frying pans:	3, 4
jugs:	8, 15, 18, 21, 88
spoon or ladle:	22
pyxides	2, 92

EH III forms

ouzo cups:	32, 44, 106
two-handled cups (depades):	33, 108
tankards (dark-on-light):	49, 98, 101
tankard (light-on-dark):	53
jars:	34, 37, 38, 46, 47, 50
deep two-handled bowl:	40
high-handled bowls:	35, 41
jugs:	51, 105

c) EH I, II, and III forms from Eutresis.

(Hanschmann and Milojević 1976, Fig. 25;

their caption, pp. 119-120, gives references to the original illustrations)

EH I forms

bowls: 1, 2, 6, 7, 8, 9, 14, 15, 16
 jars: 3, 4, 5, 12, 13
 spoons: 10, 11

EH II forms

sauceboats: 32, 33
 small bowls: 18, 19, 20, 21, 22, 23, 24, 31
 askos: 27
 jug: 28
 pyxis: 30
 baking pans: 29

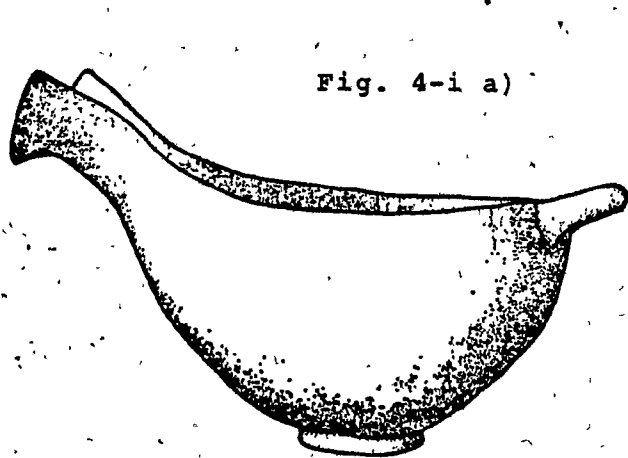
EH III forms

tankard
 (light-on-dark): 35
 jars: 37, 40
 jugs: 36, 38
 pithos: 42

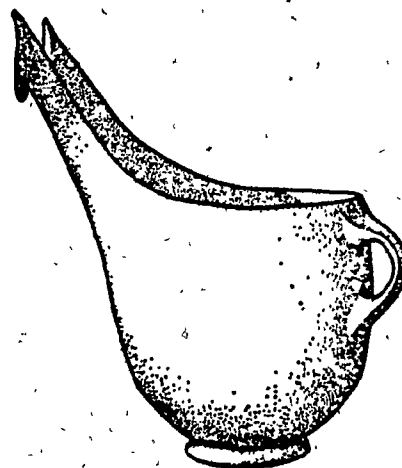
d) modes of decoration common on EH pottery

(Sedgwick et al. 1980, p. 140)

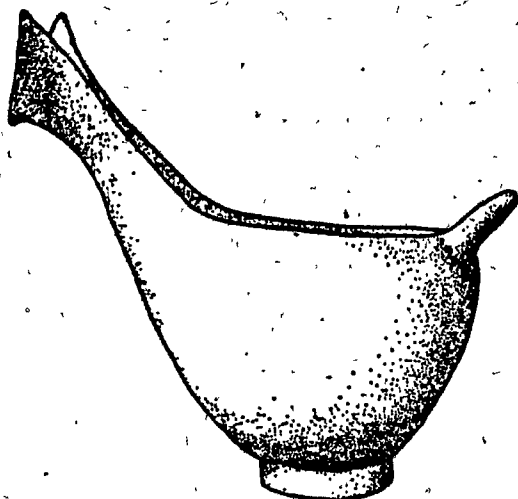
Fig. 4-i a)



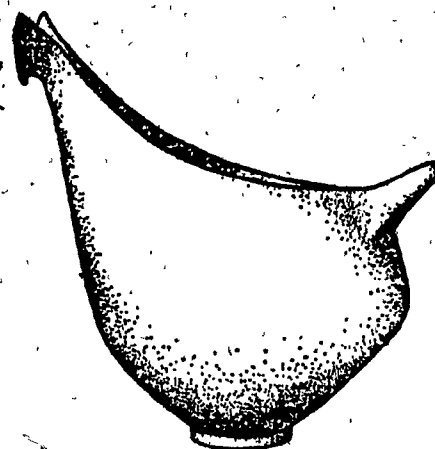
I



III

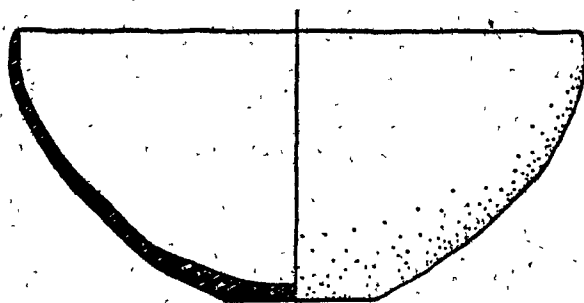


II

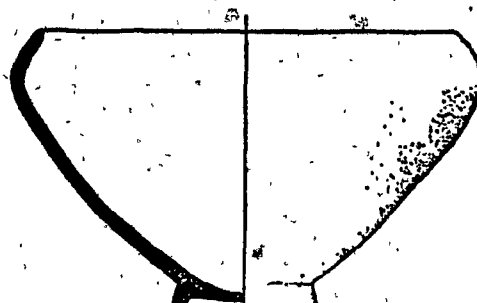


IV

Sauceboats. Lerna III (E. H. II)



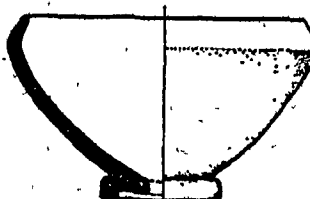
A



B



C



D

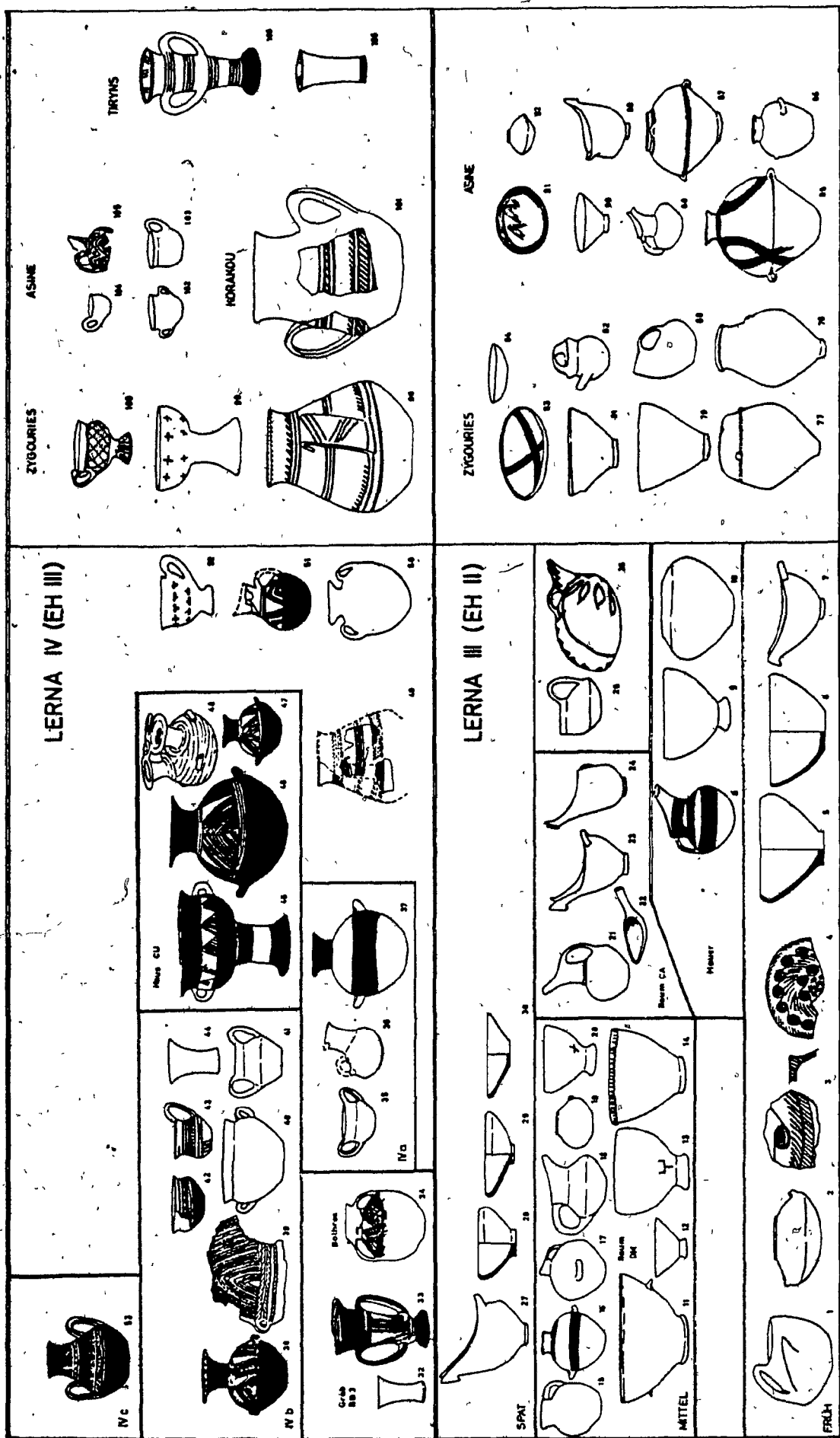


E

Bowls and Saucers. Lerna III (E. H. II)

Drawings by Davina Huxley.

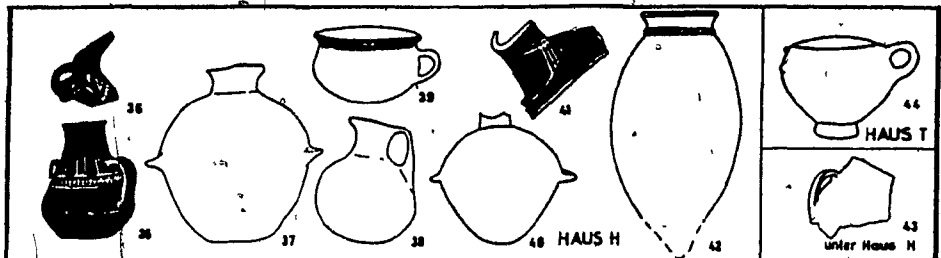
Fig. 4-i b)



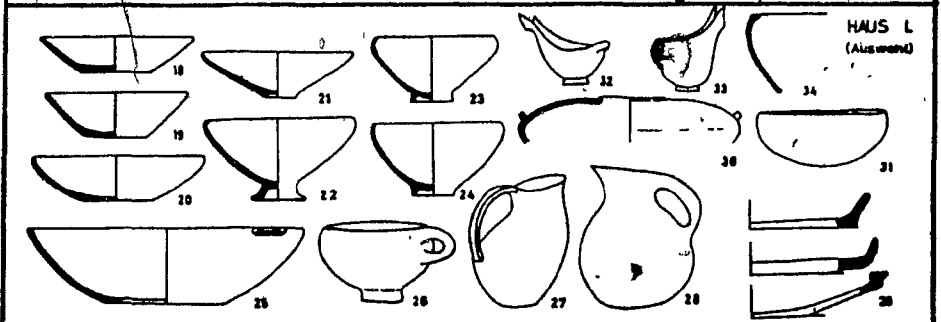
EUTRESIS

Fig. 4-i c)

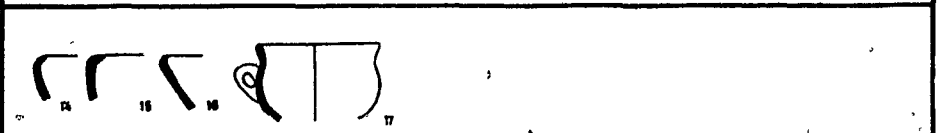
EH III



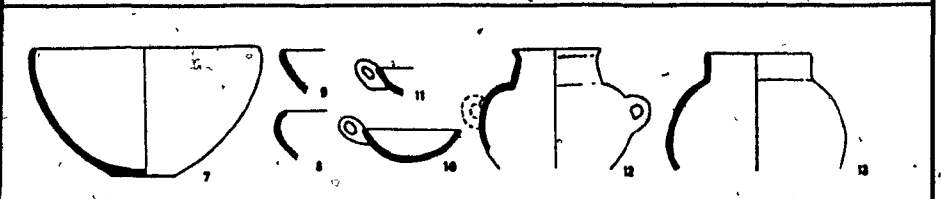
EH II



EH I



EH I



EH I

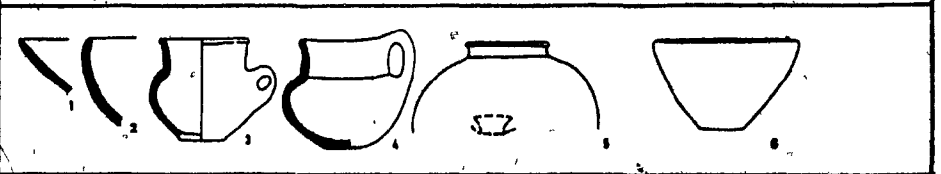
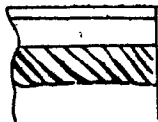
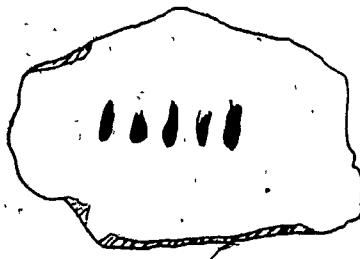


Fig. 4-i d)

DECORATION:



Incised



Impressed



Applied

Group B lustrous slipped ware characterized the second stage, of longer duration than the first. Finally during EH III although lustrous slipped ware was still predominant, patterned ware of Group C was also found. Unpainted ware, Group D, and domestic pots and pithoi, Group E, occurred in all stages of the Early Helladic period.

This same pottery classification was used by Blegen in the publication of his excavation at Zygouries (1928). He was then also able to distinguish a sub-category of slipped-and-polished ware, fine, hard and thin-walled, which he named yellow mottled ware and dated slightly later than the rest of Group AII (Blegen 1928, p. 80). Although the terms Early Helladic I, II, and III were not employed in the description of the pottery itself, their validity as chronological subdivisions for the Korinthia was confirmed. Plain polished wares and some lustrous slipped ware of excellent quality characterized EH I, good-quality lustrous slipped pottery (not quite as brilliant as in EH I) and the fine slipped-and-polished wares predominated in EH II, and degeneration in slip quality ending in a thin brownish-black wash, often only partially coating a pot, was typical of EH III. Patterned wares occurred only in the last two phases.

That these chronological subdivisions were applicable to the stratigraphic record in Boiotia as well was shown by the excavations of Hetty Goldman at Eutresis from 1924 to 1927 (Goldman 1931). In her publication the terms EH I,

EH II, and EH III were used in reference to the pottery, and in fact the pottery served in part to determine the subdivisions, especially the distinction between EH II and EH III (Goldman 1931, p. 115). One interesting contrast with the Korinthia in EH III was the predominance at Eutresis of the light-on-dark version of the patterned ware, named Ayía Marina ware after the site in nearby Phokis where so much had earlier been found (Sotiriadis 1912).

Publication in the 1930's of the Early Helladic pottery from the German excavations at Orkhomenos (Kunze 1934), also in Boiotia, and at Tiryns (Müller 1938) in the Argolid increased the corpus of material available for study, but the stratification at these sites was complex and much disturbed by later constructions. Swedish excavations at Asine east of Tiryns (Frödin and Persson 1938) and at Asea in Arkadia (Holmberg 1944), again without much success at fine stratigraphic distinctions, extended the distribution of Early Helladic sites to the south and confirmed the predominance in the Peloponnese of the dark-on-light variety of Group C.

Blegen (1951) and Wace (1953/4) each published short summaries of the state of prehistoric studies in Greece after the Second World War. Both of them cautioned against casual use of the terms EH I, II, and III for comparisons between sites, stressing that they were originally based on stratigraphic considerations at Korakou, subsequently

confirmed at Zygouriés and Goniá (Blegen 1930-31), but that in different parts of Greece three layers of Early Bronze Age occupation would not necessarily correspond chronologically with the subdivisions established in the Korinthia. Blegen went on to propose the careful excavation of several major prehistoric sites in different parts of Greece in an attempt to clear up such problems of contemporaneity and of regional and temporal variation in the Early Helladic period (and later ones as well).

In fact, in 1952 the American School of Classical Studies at Athens began excavating, under the direction of J.L. Caskey, at the site of Lerna, near Myloí south of Argos. The abundance of Early and Middle Helladic finds, whose stratification could be accurately recorded, enabled subdivisions to be much more precisely defined and pottery styles to be correlated with building and destruction phases, both at Lerna and elsewhere. Although the final publications have not yet appeared, detailed preliminary reports in Hesperia during the 1950's followed by a summary article on the Early Helladic sequence (Caskey 1960) have enabled other archaeologists to refine their chronology, beginning a new stage in the study of this period.

Lerna revealed two Neolithic periods of occupation, termed Lerna I and II, before the Early Bronze Age towns of Lerna III and IV. As none of Wace and Blegen's Class AII red slipped-and-burnished ware preceded the Urfirnis ware

of Lerna III, Caskey concluded that the site was unoccupied during the EH I period (Caskey 1960, p. 288). To the EH II period, however, belonged a long succession of architectural phases, including two large buildings, House BG and its successor the House of the Tiles, described above (section 1.2). An imposing defence wall, with gates and towers, was unearthed south of these structures. The House of the Tiles was destroyed by fire, marking the end of Lerna III; its ruins were piled into a low mound surrounded by a ring of stones and building on it was avoided (Caskey 1956, p. 165). The subsequent settlement differed radically in both architecture and ceramic remains. Lerna IV was a rather impoverished village, with smaller, less well-built houses, no fortifications, and pottery of Class CI, a light-coloured ware decorated with dark-painted linear patterns, commonest on two-handled tankards and goblets. Other fabrics included 'Smear Ware', with a sloppily-slipped surface used mostly for jars, and a variety of two-handled bowls in grey slipped clay, some wheelmade, indistinguishable in fabric from the Grey Minyan of Middle Helladic. The transition to Lerna Period V, "a characteristic Middle Helladic town" (Caskey 1960, p. 286), was in contrast peaceful, marked by the appearance of Matt-painted and "Argive" (i.e., black) Minyan pottery, and by the proliferation of the custom of intra-mural burial (Caskey 1973, p. 99). The crisp sequence of phases allowed Caskey to correlate the subdivisions of

Early Helladic occupation at Lerna with those at Eutresis (verified by supplementary excavations there in 1958: J.L. and E.G. Caskey 1960), and to re-interpret or otherwise clarify corresponding levels at other sites. Dark-on-light painted wares of Lerna III and Lerna IV were distinguished and shown to derive from separate artistic traditions (Caskey 1960, p. 295; Donovan 1961). Then Early Helladic III could be most precisely defined based on the pottery of Lerna IV. Armed with these more subtle ceramic distinctions and clearer definitions, Caskey was able to assign the violent destructions at Tiryns, Asine, Zygouries, and Ayios Kosmas (in Attike) to the end of the second EH phase rather than to the end of the third (Caskey 1960, p. 301). A bit farther north, Korakou and Eutresis were burned after EH III. (The sequences at Asea and Orchomenos were less clear.) Thus it appeared that if ever prehistoric Greece had suffered a violent population infusion, then it had taken place at the end of the Early Helladic II period (Caskey 1971, p. 786). The following phase appeared at many sites to have such close connections to the Middle Helladic period that some prefer to re-name EH III the 'Protominyan' phase of the 'Minyan culture' (Howell 1973, p. 94), or even Middle Helladic I (H. and M. van Effenterre 1975).

The last phase of the Early Bronze Age has continued to receive much attention from archaeologists, in the form of excavations, studies of material, and attempts at historical synthesis. Evidence from two excavations carried out on

islands during the 1960's, at Lefkandí on Euboia (Évvia) and at Ayía Iríni on Kéa, has complicated the scheme set out by Caskey based on the Lerna sequence. At both these sites, the pottery from a late phase of the Early Bronze Age differs from the Lerna IV material, for instance in the rarity of pattern-painting, whereas it has some close resemblances to Anatolian pottery in shapes and surface finishes (Popham and Sackett 1968, p. 8; Caskey 1972, pp. 370-375).

Together with the final-phase pottery from Kastrí on Syros (Bossert 1967), and material from Mánika on Euboia and Mt. Kýnthos on Delos, the Lefkandí and Ayía Iríni deposits indicate a widespread influx of new ceramic features, most conveniently summarized by Rutter (1979). Using the term "Lefkandi I" for this assemblage, Rutter (1979, p. 6) showed that it was, for the moment, confined to Euboia and the Cycladic islands of Kéa, Syros, Siphnos, Delos and Naxos, and was contemporary with the later stages of Early Helladic II. Rutter has examined the inventoried vases from Lerna IV in the light of this newly-defined assemblage. He observed that only the smaller open vase shapes show sharp differences at Lerna between the EH II and EH III phases. Specifically, the sauceboat, small bowl, and beaked jug of Lerna III are not found in the succeeding phase, whereas several new forms appear: tankard, two-handled bowl, one-handled cup, ouzo cup, and round-mouthed jug (Rutter 1979, pp. 9-10). This new assemblage resembles most closely the second phase of oc-

cupation at Lefkandi, Lefkandi II, and so must be later than the "Lefkandi I" ceramic phase. Rutter postulated that Early Helladic III pottery was the result of a fusion of the two ceramic traditions of Early Helladic II and of the "Lefkandi I" assemblage.

To avoid the problems of nomenclature arising from this and other possible chronological complexities (such as contemporaneity of EH II and EH III at different sites), Renfrew (1972, pp. 53-55) proposed establishing a distinction between chronological phases (Early Bronze 1, 2, and 3) and cultural groups (Eutresis, Korakou and Tiryns cultures). The one-to-one correspondence between the two sets of names would then be something that needed demonstration, rather than being an assumption. The position of the "Lefkandi I" assemblage could be established vis-a-vis these other cultural and chronological designations.

Objections to this system came fast. McNeal's article (1975) supporting Renfrew's system was answered by Caskey (1978), who felt that forcing scholars and students to learn a new system would confuse them even more than the imperfections of the old one, imperfections of which they were already well aware. The debate between Coleman (1979a; 1979b) and Renfrew (1979) about Early Cycladic terminology, in the collection of papers on Cycladic prehistory edited by Davis and Cherry (1979), illustrates the counterproductiveness of such terminological debate. Coleman argued that calling each

Early Cycladic phase a "culture" was unwarranted based on evidence that they are closely related with elements of strong continuity between material assemblages. Renfrew, on the other hand, reaffirmed that one must start with the archaeological data to define periods or phases, rather than trying to fit the evidence to a preconceived chronological scheme.

As is probably evident by now, the present work will stick to the established nomenclature. Within the limited geographical area being considered, it would seem unlikely that any great chronological disparities exist. Nevertheless, very recent finds at Tiryns (Kilian et al. 1981) indicate that perhaps Lerna IV did not follow immediately upon Lerna III, but that there was a period during which Lerna was unoccupied. During this period at Tiryns, early forms of pottery characteristic of EH III would have coexisted with sauceboats and bowls characteristic of EH II. This evidence fits in with that now emerging from the Cyclades, where the Early Cycladic III phase can be seen to have two parts (Barber and MacGillivray 1980): an early phase (EC IIIA) with strong Apatolian influence in the pottery (essentially Rutter's "Lefkandi I assemblage"), followed by a phase (EC IIIB) where pottery styles have more in common with those of the Middle Bronze Age in the Cyclades and on the Greek Mainland. Rutter (1979, p. 10) would see Lerna IV as contemporary with the later part of Early Cycladic III. Does this mean that we should label the transitional phase at Tiryns "EH IIIA" and

call Lerna IV "EH IIIB"? It is too early to tell.

The absolute chronology of the Aegean Early Bronze Age is not yet known accurately, though much progress has been made in recent years in reconciling traditional synchronisms with radiocarbon dates. The conventional method of listing imports and citing parallels serves well to show overlap among the second Early Bronze Age phases of the Cycladic, Minoan and Helladic sequences, as well as to relate the Minoan sequence to Egyptian calendar dates (Warren 1980). Radiocarbon dates from Eutresis and Lerna (J.L. Caskey and E.G. Caskey 1960, p. 164 note 28; Kohler and Ralph 1961, p. 365; Ralph and Stuckenrath 1962, pp. 149-150); and a series from Lake Vouliagmeni (as yet not fully published; see Fishman and Lawn [1978]; Linick [1979]), offer independent evidence in support of the following approximate scheme, based on the calibration of Clark (1975): Early Helladic I occupied the latter part of the fourth millennium BC; Early Helladic II ended, at Lerna at least, between 2400 and 2300 BC; and Early Helladic III at Lerna ended somewhat earlier than 2000 BC, perhaps by 2100 (Table 1-I). A full discussion of the absolute chronology of the Aegean Bronze Age is to appear soon (Warren and Hankey 1982).

4.3 Variation within Early Helladic II pottery

4.3.1 Diachronic variations

Clearly Early Helladic II was a long period, during which there was considerable continuity in the types of vases used.

Nevertheless in half a millennium some development or variation is to be expected, and indeed it appears most clearly in the quality of the lustrous slip of Group B (Urfirnis) pottery. At Lerna, as well as at other well-stratified sites (Caskey 1960, p. 289), wares with thick slips, red and lustrous at first, black later (often mottled), were typical of the first part of Period III (EH II). In later phases appeared vases slipped more thinly, less lustrously, and less carefully; partially-slipped and unslipped wares became more common. The fine, slipped-and-polished ware became rarer towards the very end of that period. Sherds with incised or impressed decoration seem to come only from the earlier EH II levels. They are, of course, a feature of deposits of the preceding EH I period at other sites.

Some variation in the shape of pots is also evident. The sauceboat has been particularly well studied for typological subdivisions which may be correlated with chronology or distribution. Fahy elaborated the fourfold division of Caskey (1960, p. 291) in her study of various aspects of that vase type, listing earlier work as well (Fahy 1964, p. 23 note 1). At Lerna Type I is early, Type IV is late, and the other two types both run through the central part of Period III (Fig. 4-i). Shallow saucers tended to replace the slightly larger incurving-rim bowls as Period III progressed (Caskey 1960, p. 290). No doubt variations such as these will be much more clearly defined in the final publication of the

Early Helladic pottery from Lerna, but already we are able to assign vases to early or late phases of EH II, if not further to subdivide the period itself.

4.3.2 Regional variations

Because the sauceboat shape is easy to recognize even among surface sherds, its distribution in Greece is fairly clear (Fähý 1964: Plate I). Of course, in peripheral areas isolated instances of sauceboat fragments can probably be considered as imports, and the settlements as not necessarily belonging to members of the EH II culture. D.H. French has produced maps of the findspots of EH II Urfinis ware (French 1968: Fig. 74; 1972: Fig. 10 and its caption) which show a distribution almost identical with that of the sauceboats; namely the Peloponnese, Attike, Boiotia, Phokis, the nearby islands (Levkás, Kythera, Spétsai, Aígina, Kéa, Euboia), and the south and east coasts of central Greece, up as far as Thessaly.

Within this area Early Helladic II remains are not absolutely uniform. The predilection of Peloponnesian potters for low ring feet rather than high or splaying ones on their sauceboats had been noticed early on by Kunze (1934, p. 76). Weinberg (1937, p. 518 note 3) realized that the same applied to Bowls; i.e., that flared feet were more common in central Greece, but nevertheless that at some sites, particularly Eutresis and Áyios Kosmás, both types occurred.

A summary of these regional variations for the sauceboat was given by Fahy (1964, pp. 104-106), who added that in general groups from individual sites were not very homogeneous.

Of course, sauceboat feet alone are not very significant as cultural indicators. A more substantial basis for differentiation was recently proposed by J.M. Fossey (1974). In describing the EH II material from the 1972 excavation at Lake Vouliagméni, Perakhóra (Fossey 1973), he was struck by the number of parallels with Peloponnesian sites in contrast to Boiotian or Attic ones, particularly for finds other than pottery. Destruction at the end of EH II, and the presence of sealings as well as vases with sculpted ram's heads and decorated hearth rims all stress the connections of Vouliagméni with the south. The EH II sites to the north and east seemed to have a slightly different repertoire of elements. Realizing that vagaries of excavation can easily change matters, Fossey tentatively proposed a geographical partitioning of the Early Helladic II cultural sphere into a Peloponnesian, a Lokro-Boiotian, and an Attiko-Euboian division. This tripartite division would parallel the better-known and more clear-cut distinctions of Early Helladic III: "Lefkandi I" assemblage material in Euboea and perhaps on the Attic coast, and the contrast between light-on-dark painted ware in Lokris and Boiotia, and dark-on-light patterns more common in the Peloponnese (Donovan 1961; Renfrew 1972, p. 115). It might be worth noting that even though EH II painted pottery

is rarely found, some differences are evident between the admittedly overlapping distributions of an Attic-Saronic rectilinear banded style and an Argolic-Korinthian varied "free" style (Donovan 1961, p. 109).

4.4 Selection of objects to be sampled

Criteria for the ideal selection of samples to be used in provenance analysis have been discussed in section 2.2; we may summarize them briefly here. They involved first of all sampling material whose local origin is certain, such as kiln wasters, clay from an ancient potter's shop, clay from modern beds, and vases produced in enormous quantities. Secondly, the various paste or fabric types from a site would be studied, and samples of each taken, in order to explore the complete range of ceramic production and utilisation at that site (Wilson 1978, p. 225). Unfortunately, for the majority of prehistoric Greek sites this is impossible. Neither methods of excavation nor conditions of storage have preserved the proportions of the various fabrics as found. Material of local origin, listed above is on principle unlikely to have been kept. In fact, until recently, the majority of sherds had been discarded after washing. Only the painted, fine, unusual, or diagnostic ones were kept (e.g. Blegen 1921, p. 4). For many sites, therefore, we are limited to just those very sherds.

The other category of information often lost since excavation (or never recorded) is the precise stratigraphic

context of each lot of sherds. As a result, from some sites it is impossible to know in which building a vase was found, or whether a deposit came early or late within a phase. Since the Early Helladic II phase lasted such a long time, probably over half a millennium, it is important to have some fixed points within this chronological span. In other words, since the sources of clay used by the potters and the distribution patterns of the finished wares may both have varied through time, an effort should be made to compare like with like (but see Attas et al. 1982). In the previous section the vase features (shape and decoration) which changed with time were discussed. It turns out that sherds with these features are the very ones which have been preserved from older excavations: the fine ware, the painted, slipped, burnished, or otherwise decorated sherds, and the vases whose entire form or profile could be restored. These, then, must form the basis of the present study. (Of course, objects of almost certainly local manufacture, such as mud bricks, are sampled when available.)

Which are the specific surface treatments and shapes involved? As far as surface treatment is concerned, Urfirnis slip in all its manifestations, from glossy to matt, polished and unpolished, coating a vase partially or completely, forms the foundation of the sampling at most sites. Among the shapes, the sauceboat, Leitmotiv of the Early Helladic II phase, is the form most subject to classification by regional

and chronological subdivision, as we have seen in the previous section. Also, because of its distinctive shape, even a small sauceboat sherd is easy to recognize and sometimes to classify by type. Furthermore, it is the form displaying the largest range of surface finishes and decorative features, including total and partial Urfirnis slip, burnish, mottling, painted patterns, incision, applied ridges, and even plastic rams' heads. It is with this shape, therefore, that the chances of observing correlations between provenance, form, paste, surface finish and decoration are the greatest.

Next to the sauceboat, the small bowl with inturned rim is the most characteristic EH III shape. It too underwent some changes through the duration of that phase (see section 4.3.1). Bowls too have therefore been sampled in abundance. Rim sherds of both these forms are the most diagnostic, though ring bases, which must belong to one of the two forms, have occasionally been sampled. Jars, askoi, and ladles also commonly bear Urfirnis slip, but since their typology is not as well determined, they have been sampled only to supplement low numbers of sauceboats and bowls from some sites.

Certain ceramics of the Early Helladic period have incited particular interest among archaeologists. Among these is the thin, smooth, and well-fired fabric here referred to as fine slipped-and-polished ware, described by Goldman (1931, p. 97) as "technically the most perfected pottery produced in Early Helladic times". Although never very common, at Zygouries it

represented "perhaps two or three vases to each house", mostly in the form of sauceboats (Blegen 1928, p. 79). Holmberg (1944, p. 67) suggested that the pieces found at Asea in Arkadia were probably imported from the Argolid, and indeed that there may have been but a few manufacturing centres there which supplied the whole "sphere of Early Helladic utilisation", though less well-made vessels might be local imitations. In this study special attention is given to sherds of this fabric in an attempt to test his hypothesis.

Pattern-painted vases of EH II type are known from several sites. Biers (1969, p. 454 note 35) has given a useful list of such sauceboats and noted that they are also found in the Cyclades. A limited number of workshops producing this ware may be argued for on the basis of the uniformity of the decoration. Once again, compositional analysis should decide for or against this view and might perhaps pinpoint the centre(s) of manufacture.

Another form thought for a long while to originate in the Cyclades and considered an import whenever found on the Greek mainland is the so-called frying pan, a flanged disk of uncertain purpose (perhaps used as a lid: Treuil 1979, p. 363) with short handle; the largest (exterior) surface of the disk is decorated with incised or impressed patterns, often including spirals. Recently Bossert (1960) and Renfrew (1972, pp. 536-537) have classified these pans on the basis of decoration and of shape respectively, and have isolated a

mainland variety. More precision in their assignment would be very useful.

Terracotta animal figurines, particularly rams, bulls, and other quadrupeds, are occasionally found in EH II contexts. Although usually crudely made, they are fresh and unpretentious examples of Early Helladic craft, often painted with stripes or spots. Provenance analysis may add to the limited amount of information on their manufacture and distribution.

Another type of find showing the love of design of the Early Helladic potters is the raised band of roll-stamp decoration, found on pithoi and on clay hearths (Wiencke 1970). Because of the large size of these objects, they probably (but not certainly) were made very near to where they were found. In fact, the presence of identical patterns on bands found at Lerna, Zygouries, and Tiryns (Caskey 1959, p. 206; 1960, p. 293) has been taken to indicate the existence of travelling craftsmen making these pithoi and hearths to order in the Argolid.

At some sites, where the full range of excavated material had been kept, a selection of sherds of a variety of paste or fabric types was studied. Finally, for sites where diagnostic sherds were available, either well-stratified or well-published, pottery from the third Early Helladic phase was sampled. The aim in these cases was to investigate continuity of manufacturing habits from one phase to the next, and

in a limited way to examine production and exchange of some of the finer wares, including the characteristic EH III pattern-painted pottery. The significance of their analysis is considered in a section of discussion devoted particularly to EH III material in its historical context (section 8.4).

4.5 Explanation of descriptive terms

4.5.1 Shape

Although many general schemes exist for the description of pot forms (e.g. Shepard 1965, pp. 325-328), it was felt that a more restricted one might be faster and yet sufficiently detailed to obviate the necessity of drawing every sherd profile. Fossey (1978) has developed a classification system for Early Helladic I and II pottery based on the assignment of feature sherds, particularly rim fragments, to the primary shape categories 'bowl', 'jar', and 'sauceboat'. ('Bowl' is used as a general name for any open vase shape; i.e., one whose maximum diameter is at or near the lip. Similarly 'jar' denotes any closed shape.) Within each of the divisions 'bowl' and 'jar', a two-dimensional grid sets categories of lip form (e.g. rounded, pointed, bevelled) against those of rim orientation (e.g. inturned, vertical, shallow). At each intersection of categories, an actual example has been drawn in profile where one is known. A later version of these grids was published by Sedgwick et al. (1980), and is reproduced here (Figs. 4-ii and 4-iii). The latest one will be

FIGURE 4-11: Early Helladic pottery classification: open
rims (after Sedgwick et al. 1980, fig. 7).

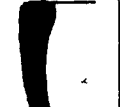
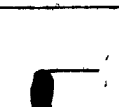
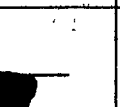
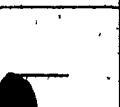
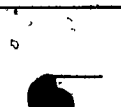
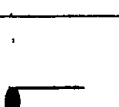
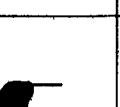
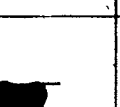
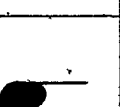
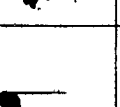
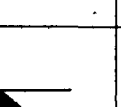
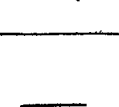
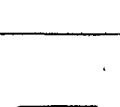
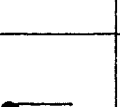
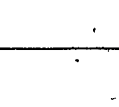
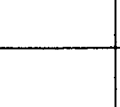
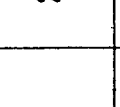
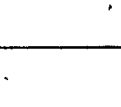
EH I - II RIM FORMS - OPEN SHAPES					not to scale		
	1 rounded	2 pointed	3 flattened	4 bevelled/ molded	5 thickened out	6 thickened in	7 thickened out & in
I. out-turned							
II. incurving							
III. inturned							
IV. offset							
V. near vertical							
VI. hemispherical							
VII. splayed							
VIII. shallow							
IX. flat							

FIGURE 4-iii: Early Helladic pottery classification: closed
rims (after Sedgwick et al. 1980, fig. 8).

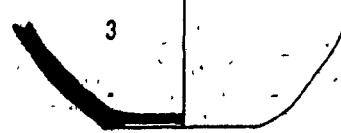
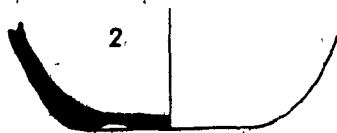
EH I - II RIM FORMS - CLOSED SHAPES					not to scale
	1 rounded	2 pointed	3 flattened	4 bevelled/ molded	5 double molded
XI. splayed a. high					
XI. splayed b. short					
XII. vertical a. high					
XII. vertical b. short					
XIII. insloping a. high					
XIII. insloping b. short					
XIV. Flaring a. high					
XIV. Flaring b. short					
XV. curved					
"High" - rim greater than 3 cm.					"Short" - rim less than 3 cm.

FIGURE 4-iv: Early Helladic pottery classification: bases
(after Sedgwick et al. 1980, fig. 9).

EH I - II BASE FORMS

not to scale

flat



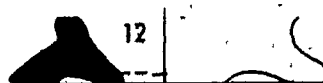
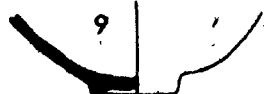
offset



vertical ring



splayed ring



pedestal



published shortly by Fossey and Mogelonsky. Almost all Early Helladic I and II bowl and jar rims can be described reasonably precisely using this system. As the name of each grid category is given on the charts, it is omitted in the catalogue entries, where instead a subjective description of the form can be found. The rest are either hybrid forms or very rare profiles which must be described verbally, as has been done for the few EH III objects sampled.

The range of bases found on Early Helladic I and II pots is surprisingly small. The chart published by Fossey (1978), here reproduced as Fig. 4-iv, has only thirteen forms. These numbered forms are used in the catalogue. (A new version is currently in preparation: Fossey, personal communication 1982.)

Although the number of possible combinations of rim and base forms amounts to $((9 \times 7) + (9 \times 5)) \times 13 = 1404$, certain combinations are much more common than others. The following general observations are based on examination of large bodies of excavated material only at Lake Vouliagmeni, and on perusal of the most accessible excavation reports. (A detailed study of the development and range of shapes in Early Helladic pottery is currently being prepared by Marcia K. Mogelonsky at McGill University.) At Lake Vouliagmeni (Fossey 1969), EH I bowls are often hemispherical with a flat base and a rounded, flattened, or thickened rim (Fig. 4-i). They may bear lugs or more elaborate handles. This type continues in use during EH II, but is accompanied by a variety of smaller forms without

handles, and with a maximum diameter of less than 15 or 20 centimetres (Caskey and Caskey 1960, p. 150 and p. 154, fig. 11). J.L. and E.G. Caskey have called these 'saucers' (1960, p. 165 note 33), a term well-suited only to the shallowest variety. The deeper ones usually have a ring or pedestal base and an inturned rim, whereas the shallow ones may instead have a form VIII rim and a flat base, usually form 3. 

Jars seem most often to have a flat or slightly concave base (Fossey 1969). A wide variety of rim forms is found on both EH I and EH II vases (e.g. J.L. and E.G. Caskey 1960, p. 141 fig. 7). Vertical round handles (i.e., of circular cross-section) are common, either plain or twisted to look like a rope. An asymmetrical variety of jar is the askos (Fig. 4-i). Also flat-based, it may have a round or strap handle. At Lake Vouliagmeni, askoi are found only in the EH II levels, but a related form, the scoop, was found in the EH I trench (Fossey 1969, p. 64).

The sauceboat is an asymmetrical open shape with handle and spout, occurring only in Early Helladic II (but see section 4.2). Indeed its presence may be considered a defining attribute of the middle phase of the mainland Early Bronze Age. The variations of its shape in space and time have been discussed above. They are also the subject of a study being prepared by M.H. Wiencke (personal communication 1977). The catalogue uses the system of Caskey's four types as expanded.

by Fahy (1964), with transitional types where required, and gives some indication of the nature of the handle and spout when this is known. Vertical handles, found most often on Type III sauceboats, may have a vertical groove making them appear double. Horizontal handles may rise above the rim or stay on the same level. Both kinds may join the body at or below the lip. In some cases, an applied ridge extends along the vase surface in prolongation of the handle. The corners of the spout may be right-angled, or may be exaggerated to an elongated shape with an acute-angled tip (classified in the catalogue as 60, 45, or 30 degree). The bottom of the lip may be straight or may curve sharply downwards. Sauceboats from this part of Greece almost invariably have a ring base. The bowl is the only other small form of relatively fine fabric which often has a ring base. When such a base sherd has been sampled, it is therefore listed in the catalogue as "sauceboat or bowl".

The hearth and the baking pan are two large, relatively immobile, circular terracotta objects. Hearths generally have a flat bottom and a wide flat edge often bearing incised or impressed decoration such as spirals or zigzags (Lavezzi 1979). Baking pans are concave, with a narrow, plain rim which may be lower at one portion of the circumference, forming a broad spout (Blegen 1921, p. 13).

Pithos is the term commonly used for a large storage jar. Some pithoi are decorated with raised bands bearing the impres-

sion of a roll-stamp (Wiencke 1970).

Terracotta ladles are often found on Early Helladic sites (though apparently not at Lake Vouliagmeni). They generally have a spoonlike lower end, a shaft whose section varies from rectangular near the bottom to circular near the top, and a handle, usually in the form of a loop, at the top. Some other common terracotta objects are loomweights and spindle whorls. The ratio of height to diameter has been taken as a useful criterion to distinguish between them, spindle whorls being shorter (Cherry 1973, pp. 25-26). Both have a vertical, axial hole. Loomweights of later periods have a horizontal hole, and it seems peculiar that such a design, which would allow them to hang straight, was not adopted earlier.

Terracotta tiles have also been sampled, with the expectation that they had been locally made. The ones from the House of the Tiles at Lerna are plain, rectangular slabs of well-fired clay. Treuil (1979, p. 387) has recently suggested that they may have been used to pave the upper floor rather than (or in addition to) roofing the building.

Fire-dogs are coarse terracotta stands of uncertain (multiple?) purpose, found in both domestic (Harland 1951) and funerary (Mylonas 1959, p. 147) contexts.

Unfired objects include sealings, described in section 1.2, and mud bricks, sun-dried rectangular blocks of clay. Their preservation can usually be attributed to accidental heating

during a conflagration, though fragmentary unfired bricks are commonly found as well.

4.5.2 Surface treatment

The surfaces of almost all of the objects sampled had been prepared in some way by the Early Helladic potters. At the very least they had been smoothed before the clay hardened completely. Some EH I pots were burnished, or polished with a smooth object such as a pebble, until their surface shone. More often, a slip was applied to coat a vase partially or completely. This may have been achieved by dipping in some cases, but in others, the marks of a brush are visible in the slip. A raspberry-red slip is characteristic of some Early Helladic I pottery (French 1972, p. 18). In the early part of EH II, the slip can be quite lustrous, in which case it can be called Urfirnis. Later EH II slips are most often matt, and sometimes quite thin. When thickly applied, slip has a tendency to crackle; that is, to break up into a fine pattern of little patches of slip separated by cracks. Burnishing a slipped vase yields a very smooth surface pleasing to the touch as well as to the eye. This technique reached its apogee with the variety of fine, thin-walled EH II pottery known as 'slipped-and-polished ware'.

The colour of a slip can vary enormously depending on its composition and thickness, on the firing temperature, and on the firing atmosphere. Often a single vase will bear a

slip whose colour ranges from orange through pink, red, and brown, to black. Sometimes this effect was intentional, leading to two or more zones of colour. Another deliberate effect is mottling of pinks or yellows with greys, found particularly on the fine slipped-and-polished ware. The fluctuations of slip colour, especially on a single vase, can be taken to indicate that an attempt at precise description of the colour(s) leads to no useful characterization of the pot. Therefore in the catalogue slip colours are given using the Munsell system (see below) only when they are particularly distinctive or uniform.

A study of Early Helladic pottery with painted decoration has been made by Donovan (1961). On EH I and EH II pottery it is very rare. In EH III, however, it becomes quite common on finer wares. In both cases the 'paint' is actually a slip, and its colour varies in the same way as that of slip. It was applied with a brush to the smoothed surface of the vase. There was a restricted range of motifs employed in Early Helladic II: straight lines, stripes, triangles, hatching, and a few curvilinear shapes. Animal figurines were often banded (Cherry 1973, pp. 27-33). Early Helladic III decoration is more organized, often running in zones around a vase. Rectilinear motifs are again prevalent (see Fig. 4-i).

Incision as a decorative technique seems to be most at home in Early Helladic I. Handles and rims both receive patterns of incision, with a preference for herringbone. Early

Helladic II pottery may bear incision in the form of potters' marks, or as a simple form of decoration on the base of plates or shallow bowls (as at Lake Vouliagmeni), or on raised bands of pithoi and hearth rims. Pictorial representations are rare. 'Frying pans' usually bear incised decoration in both periods. Impression is a rival technique of decoration for these bands. A cylindrical roller, perhaps carved of wood, would be run along them while the clay was still damp to produce the design (Wiencke 1970). A stamp seal would sometimes be used to decorate a vase. This is rare except for the case of 'frying pans', where concentric circles and spiral motifs were often stamped (Bossert 1960).

Finally, decoration in the form of clay strips or dots was frequently applied to larger vases. A ropelike design could be created by incising periodic diagonal strokes on an applied strip of clay or by twisting the strip before applying it, and a 'piecrust' effect could be produced by periodically indenting it with the fingers. These designs are particularly common on pithoi and on or just below the rims of large bowls.

4.5.3 Paste

The term 'paste' is used here to refer to the ceramic material itself, what potters call the fired clay body, and archaeologists often call fabric. Several of its properties are described in the catalogue. The first is colour. Both a subjective description (e.g., "pink") and a reference to

the Munsell (1975) designation are given. This system of notation uses the three variables hue, value, and chroma to represent a colour; in the Munsell Soil Color Charts these become the page, row, and column of the closest-matching chip. A space separates the first of these designations from the second, and a diagonal stroke separates the second from the third, so that 5YR 8/3, for example, is a pale pink. When the core of the sherd differs in colour from the surface, each is noted separately. If the paste is poorly fired, crumbly, or particularly soft or hard, these facts are noted as well.

The other major category of paste description is the fineness. This is an evaluation, admittedly subjective, of the quantity of naturally-present inclusions or added tempering material present in the paste. Fine ware has no visible inclusions in a break or a clean surface, semifine has few, medium has several, and coarse has many. The nature of any inclusions present is described in a nontechnical way. Their abundance (few, several, or many), angularity (rounded, subangular, or angular), colour, and maximum size are listed. Occasionally the inclusions themselves have been altered or have disappeared, during or since the pot's firing. Their nature can be inferred from the traces left behind: holes from which bits of straw or other vegetable matter had been burnt out ('stalk impressions'), holes from which calcareous inclusions had been leached during burial or dissolved by

treatment with acid during cleaning, and white and beige stains or rounded specks marking the partial fusion of lime or calcite grains with the ceramic matrix during firing.

With this information some comparison may be made between sherd pastes without having the sherds at hand. Aberrant analytical results may perhaps be traced to the presence of large numbers of unusual inclusions.

4.5.4 Other information

A variety of miscellaneous information is also included in each catalogue entry. At the right end of the first line is the archaeological reference for the object or its stratum. The chronological phase is indicated only for objects not belonging to the EH II phase, except for the Tiryns material, where the unusual stratigraphic sequence makes complete indications useful. At Zygouries, 'Snails .10-.40' is a late deposit within EH II (House of Snailshells, Blegen 1928, p. 15), and 'VIII bothros' is an early one (Blegen 1928, p. 76). The paste descriptions for most of the Keramidhaki sherds contain an additional entry, namely the 'Cherry fabric number'. This is an attempt by this author to group these sherds according to the paste categories established by Cherry (1973, pp. 74-75). The categories are as follows: 1, yellow-green with small black grains; 2, semifine to fine buff, with very small white inclusions; 3, moderately coarse, orange, varied temper, crumbly; 3a, pale orange, more black grains

than 1; 3b, reddish-orange, with large red grains added as temper; 3c, as 3b, but with a grey core; 4, reddish-orange, very coarse, crumbly; 5, grey to buff, crumbly, small grains of ?sand temper; 6, grey to buff, very coarse, very hard, contains large red grit and grog temper; 7, miscellaneous.

If the sampled object has been published, reference to the publication is given. Unusual sampling methods, such as breaking off ceramic chips, are explained where they occur.

All dimensions are expressed in centimetres. The following is a list of abbreviations used in the catalogue:

c. approximately ('circa')

d. diameter

h. height

ind. indeterminate

inv. inventory

l. length

m.p. maximum preserved

no. number

th. thickness

w. width

4.6 Catalogue4.6.1 Asine

ASI 1 mud brick fragment 75:6

two parallel flat surfaces; th. 1.4;
paste: fine orange 5YR 8/4, well-baked; many stalk
impressions up to th. 0.2; no grains visible

ASI 2 mud brick fragment 77:18

two parallel flat surfaces; th. 1.7-1.8;
paste: semifine orange 5YR 7/4, slightly crumbly;
many stalk impressions up to th. 0.2; few black
rounded grains up to 0.02

ASI 3 mud brick fragment 123:4, larger piece

m.p.l. 7.0;
paste: fine orange 7.5YR 7/6, soft; many stalk
impressions up to th. 0.4; no grains visible

ASI 4 mud brick fragment 123:4, smaller piece

m.p.l. 6.5
paste: semifine buff 10YR 7/4, soft;
many stalk impressions up to th. 0.2; few white,
dark grey, and dark red grains up to 0.02

ASI 5 mud brick fragment 126:1

one flat surface; m.p.l. 6.0;
paste: fine orange 7.5YR 7/6, soft; many stalk
impressions up to th. 0.3; very few black grains up
to 0.02

ASI 6 mud brick fragment 79:4

two parallel flat surfaces: wall surfacing? th.
1.0-1.2; one surface beige 10YR 8/2, scraped;
paste: coarse red-brown 5YR 6/6, crumbly; several
stalk impressions up to th. 0.02; many angular to
subangular white, black, and dark red grains up to
0.1

ASI 7 wall sherd 114:8

closed shape; th. 0.5; burnished outside;
paste: semifine pink 5YR 7/4; few white specks up to 0.05

ASI 8 wall sherd 114:8

closed shape, preserving attachment of round handle;
th. 0.5-0.8; smoothed outside;
paste: medium pale yellow 2.5Y 8/2; several subangular black grains up to 0.1; few white specks up to 0.1

ASI 9 base sherd 111:5

form 1 (flat); d. 8; th. 0.7; smoothed inside and out;
paste: semifine pale yellow 2.5Y 8/2; several subangular black grains up to 0.05; very few white specks up to 0.1;
Fossey 1978, p.28 no. 208 and fig. 16

ASI 10 base sherd 111:5

form 1 (flat), not truly circular; d. c. 15; th. 1.8-2.0; red 5YR 5/4 slip outside, including on bottom; some careless incised lines inside: accidental?
paste: coarse grey to light brown 10YR 5/1 to 6/3; many subangular dark grey grains up to 0.1; few specks of ?silver mica

ASI 11 bowl rim 90:3

form VI.5, (thickened out); d. c. 20; th. 0.6; burnished red (5YR 5/4) slip inside and on top of lip; worn piecrust below rim, perhaps of overlapping disk type;
paste: semifine grey-pink 7.5YR 6/2 to 7/6; few rounded dark grey grains up to 0.1;
Fossey 1978, p. 14 no. 24 and figs. 2 and 5

ASI 12 bowl base 115:2

form 1 (flat); d. c. 15; th. 1.0; smoothed inside and out;
paste: coarse grey-pink 7.5YR 7/2; many angular dark grey-brown grains up to 0.3

ASI 13 sauceboat rim 143:1

vertical pointed rim (as form V.2); th. 0.4; lustrous crackled red slip inside and out;
paste: semifine grey N 6/0; few subangular black grains up to 0.05

ASI 14 bowl rim 143:1

form III.2 (incurved); d. not measurable; th. 0.4; lustrous crackled black slip inside and out;
paste: semifine buff 10YR 8/3; few rounded light red grains up to 0.1

ASI 15 bowl rim 143:1

form VIII.5 (shallow, thickened out); d. 15-20; th. 0.6; lustrous red (2.5YR 4/6) slip inside, very worn, dull brown (2.5YR 3/4) slip outside;
paste: medium, core grey 5YR 7/1, surface orange 5YR 6/6; several beige specks up to 0.1; few rounded dark grey grains up to 0.1; very few specks of ?silver mica

ASI 16 bowl rim 143:1

form VI.6 (hemispherical, thickened in); d. c. 30; th. 0.8; lustrous red (2.5YR 5/6) slip inside and on top of rim; traces of piecrust outside;
paste: semifine pale orange 5YR 6/6; few angular red grains up to 0.1; few white specks up to 0.1

ASI 17 base of bowl or sauceboat 130:7

form 11 (well-developed ring); d. 5.5; th. 0.5; lustrous red to brown slip inside and out;
paste: fine pale orange 7.5YR 7/6; few white specks up to 0.05

ASI 18 ladle shaft 130:3

section round at one end, slightly flattened at the other; d. at round end 2.0; flattened section 2.4 by 1.6; m.p.l. 5.6; lustrous crackled black slip; paste: fine pale yellow-buff 10YR 8/3; few white and beige specks up to 0.05; very few rounded light red grains up to 0.05

ASI 19 bowl rim 130:3

form III.2 (incurved); d. c. 15; th. 0.4; lustrous crackled black to brown slip inside and out; paste: fine pale pink 7.5YR 8/4; very few white specks up to 0.05

ASI 20 bowl rim 130:3

form VI.3 (thickened, flattened); d. c. 40; th. 0.6; worn lustrous red-brown slip inside and on top of rim; deep irregular short diagonal incisions outside below rim; paste: medium orange-pink 5YR 7/6; many rounded and subangular light grey grains up to 0.02; few specks of ?silver mica

ASI 21 wall sherd 80:2

open shape; th. 0.7-0.8; slipped and burnished inside and out, a mottled grey; paste: fine grey N 6/0; very few white specks up to 0.01

ASI 22 modern clay

obtained September 1977 from C. Zerner; collected from marshy area just to the east of the Kastraki; 10YR 7/3 dry, unfired; 7.5YR 5/8 fired in an electric kiln; semifine: several white and several black subangular grains up to 0.05

ASI 24 sauceboat rim 117:3

pointed but vertical rim; th. 0.4; lustrous crackled black slip inside and out; paste: semifine: surface 7.5YR 8/4, core N 7/0; few white rounded grains up to 0.02; Fossey 1978, p. 30 no. 245

ASI 25 rim of bowl or sauceboat 138:5

form III.2 (pointed, slightly inturned); d. (if bowl) c. 15; th. 0.5; worn matt slip, red inside, brown to black outside;
paste: semifine: surface 7.5YR 7/6, core 7.5YR 7/1; few white rounded grains up to 0.05; few red rounded grains up to 0.02;
Fossey 1978, p. 17 no. 58

ASI 26 sauceboat rim 119:2

plain rim; th. 0.2-0.4; thin matt black to brown slip inside and out; brush marks evident;
paste: semifine: surface 7.5YR 8/2, core 7.5YR 7/1; few white rounded grains up to 0.05;
Fossey 1978, p. 31 no. 267

ASI 27 wall sherd 112:24

th. 0.3-0.4; smoothed inside, perhaps slipped but definitely polished outside; fine incised straight line outside;
paste: fine: outside surface 5-7.5YR 7/4, with patches of grey, as core and inner surface N 7/0; one white rounded grain 0.05;
Fossey 1978, p. 24 no. 122

ASI 31 sauceboat acc. no. 4093 (old excavations)

type III; double vertical handle; h. 11 to rim at side, 15 to top of spout; w. 9.5 at rim; l. c. 17; 60 degree tip; surface slipped and polished, mottled red to buff (e.g., 5YR 7/6, 7.5YR 8/5, 10YR 8/4, 10YR 6/3, 10YR 4/1);
paste: fine, 7.5YR 7/6; no inclusions visible;
Frödin and Persson 1938, p. 221 fig. 161 no. 5

ASI 32 small bowl acc. no. 8455 (old excavations)

rim form III.2 (inturned, pointed); base form 10; rim d. 14.5-15.0 (slightly oval); base d. 4.0-4.2; h. 5.8-6.0; matt red (2.5YR 5/7) slip inside and over lip down 1 cm outside rim, turning dark brown (5YR 5/2) in one area;
paste: semifine 7.5YR 8/6; few white subangular grains up to 0.1; several specks of ?silver mica up to 0.02

ASI 33 small bowl acc. no. 3569 (old excavations)

form quite shallow: angle as VIII, but rim as III.2; base form 6; d. rim 14.8-15.2; d. base 3.8-3.9; h. 4.5-5.2; band of grey-brown (2.5YR 5/4 to 4/1) slip at lip, inside and out; paste: semifine 10YR 7/1; few dark grey angular grains up to 0.1; few dark red angular grains up to 0.1; few white rounded grains up to 0.05; few specks of ?silver mica up to 0.01; Frödin and Persson 1938, p. 213 fig. 158 no. 4

ASI 34 small bowl acc. no. 8453 (old excavations)

rim form III.2; base form 8; d. rim 10.8-11.0; d. base 3.9; h. 5.4-5.9; lustrous red to black (10R 6/6 to 4/1) slip inside and out, except within base ring; crackled in parts; paste: medium 7.5YR 8/3; several dark red rounded grains up to 0.1; several grey subangular grains up to 0.1; few white rounded grains up to 0.1; Frödin and Persson 1938, p. 224 fig. 164 no. 2

ASI 35 small bowl acc. no. 4090 (old excavations)

rim form V.4 (bevelled, near vertical); base form 9; rim d. 12.0-12.3; base d. 3.5; h. 6.0-6.8; crackled matt black slip inside and out, except under base ring; paste: semifine 10YR 8/4; few light grey rounded grains up to 0.1; few white rounded grains up to 0.1; Frödin and Persson 1938, p. 223 fig. 163 lower left

4.6.2 Tiryns

TIR 1 sauceboat spout Ti LXII 38/36, VI (EH II)

most of centre and left tip (60 degree); th. 0.4-0.6; matt black slip inside and out, adhering well;

paste: semifine pale brown 5YR 7/4; few beige rounded specks up to 0.2; few grey rounded grains up to 0.1

TIR 2 sauceboat spout Ti LXII 38/43, VI aR (EH II)

part of centre and right tip (45 degrees); th. at centre 0.3, at tip 0.5; matt black slip, red patches inside, worn outside under centre;

paste: medium, grey core N 8/0, pale brown surface 7.5YR 6/4; several beige, light grey, and reddish grains, rounded, up to 0.05; few specks of ?silver mica.

TIR 3 sauceboat spout Ti LXII 38/43, VI aR (EH II)

left tip (30 degree); th. 0.4-0.5; thin matt black slip inside and out;

paste: semifine orange 5YR 7/5; few red subangular grains up to 0.05

TIR 4 sauceboat spout Ti LXII 38/35, VI (EH II)

centre of spout; wide trough; th. 0.4-0.5; thin matt worn brownish-black slip inside, thicker crackled reddish-brown (2.5YR 6/4) slip outside;

paste: semifine pink 5YR 7/6; several grey and several brown rounded grains up to 0.05

TIR 5 sauceboat handle Ti LXII 39/8, VI (EH II)

left half of horizontal round handle attached to rim; rises slightly above rim and stretches down along wall; wall th. 0.4-0.5; handle d. 0.8; matt black slip inside and out;

paste: fine grey N 8/0; no inclusions visible

TIR 6 sauceboat handle Ti LXII 39/8, VI (EH II)

right attachment of horizontal handle to rim, with ridge stretching down along wall; th. 0.4-0.5; matt black slip inside and out, worn at rim; paste: fine grey N 7/0; no inclusions visible

TIR 7 sauceboat handle Ti LXII 38/35, VI (EH II)

vertical handle attached below rim; perhaps grooved; wall th. 0.4; handle w. 1.1, th. 0.6; crackled matt black slip inside and out; paste: medium grey-brown 5YR 7/2; several reddish-brown rounded grains up to 0.1; few white rounded grains up to 0.05

TIR 8 sauceboat rim Ti LXII 39/8, VI (EH II)

type ind.; th. 0.3-0.4; matt slip black to red outside, red inside; paste: medium, grey core 5YR 6/1, orange surface 5YR 6/6; several white and several beige rounded grains up to 0.05

TIR 9 sauceboat rim Ti LXII 39/8, VI (EH II)

type ind.; th. 0.4-0.5; thin slip, matt, varying dark brown to reddish-brown, inside and out; paste: semifine, grey core 5YR 6/1, light brown surface 5YR 5/6; several white and several beige rounded grains up to 0.05

TIR 10 sauceboat rim Ti LXII 39/8, VI (EH II)

type ind.; perhaps near spout; th. 0.4-0.5; matt slip, dark brown to black, inside and out; paste: semifine buff 7.5YR 8/4; several white and several beige rounded grains up to 0.05

TIR 11 bowl rim Ti LXII 38/25, VI (EH II)

form III.2, but slope of wall as "splayed"; d. 15; th. 0.5; matt slip, black to dark brown to reddish-brown, inside and over lip to 1 cm down outside; paste: semifine pink 7.5YR 8/4, core greyer 7.5YR 8/1; few beige rounded grains up to 0.1

TIR 12 bowl rim Ti LXII 38/35, VI (EH II)

form III.2 (inturned, pointed); d. 18; th. 0.5; matt black slip at rim only: smooth inside, crackled outside;

paste: semifine reddish 2.5YR 5/4; few white rounded grains up to 0.05; few specks of ?silver mica

TIR 13 bowl rim Ti LXII 38/44, VI aR (EH II)

form III.2; th. 0.5; matt black slip inside and on lip outside;

paste: semifine buff 7.5YR 6/4; few white rounded grains up to 0.1

TIR 14 bowl rim Ti LXII 38/53, VI aR (EH II)

form III.2; 2 sherds joined; d. 14; th. 0.4-0.5; matt black slip, crackled, inside and on lip outside;

paste: semifine pale brown 7.5YR 7/4; few beige and few white rounded grains up to 0.1.

TIR 15 bowl rim Ti LXII 38/64, VI aR (EH II)

form III.2 or .4 (actually, neither pointed nor bevelled, but bent quite sharply); d. 15; th. 0.4; surface rough outside, smooth inside (some striations inside); even, matt red (2.5YR 6/6) slip at lip, 2.0 wide inside, 0.6 outside;

paste: medium, greyish core 5YR 6/1; reddish surface varying 5YR 6/4 to 7.5YR-8/4; several grey angular grains up to 0.1; few white subangular grains up to 0.1

TIR 16 bowl rim Ti LXII 39/8, VI (EH II)

form VIII.4 (shallow, "bevelled", but actually just upturned); d. 11; th. 0.4; smoothed inside and out (some striations inside); thin matt red slip at lip, 2.0 wide inside, 0.6 outside;

paste: semifine, light grey core 5YR 7/1, reddish to buff surface 5 to 7.5YR 7/4; several greyish and several reddish rounded grains up to 0.1; few specks of ?silver mica

TIR 17 bowl rim Ti LXII 39/8, VI (EH II)

form VIII.4; d. c. 15; th. 0.5; smoothed inside and out, traces of matt red slip around lip;
paste: medium, grey core N.7/0, buff surface 7.5YR 7/4; several subangular grey grains up to 0.2; several rounded white grains up to 0.02

TIR 18 bowl rim Ti LXII 38/53, VI aR (EH II)

form VIII.2 (shallow pointed); d. 17; th. 0.4; smoothed inside; thin matt slip around lip, crackled black outside, red to reddish-brown inside;
paste: semifine, light grey core 7.5YR 7/1, pink surface 7.5YR 6/4; few rounded white grains up to 0.1; few specks of ?silver mica

TIR 19 bowl rim Ti LXII 38/25, VI (EH II)

form VI.1 (hemispherical rounded); d. 22; th. 0.4-0.5; traces of smoothing and ?black slip inside;
paste: semifine, light grey core 5YR 7/1, buff surface 5YR 7/4; several black subangular grains up to 0.02; few white rounded grains up to 0.05; few specks of ?silver mica

TIR 20 bowl rim Ti LXII 38/35, VI (EH II)

form VII.1 (splayed, rounded); d. c. 20; th. 0.4; smoothed better inside than out;
paste: semifine grey 2.5YR 5/1; several holes, some with white rounded grains up to 0.1

TIR 26 sauceboat sherd Ti LXII 38/27, VI (EH II)

wall sherd; th. 0.3-0.4; slipped and polished, mostly light grey (10YR 6/1), with patches up to 10YR 7/4;
paste: fine light brown 7.5YR 7/4; no inclusions visible

TIR 31 bowl rim Ti LXII 39/19, V (trans. EH II/III)

form III.2 (inturned and pointed), but angle is shallow, as VII (splayed); d. 16; th. 0.4; smoothed inside and out; striations inside; band of matt slip at lip, black outside, red to black inside; paste: medium, surface pale orange 5YR 7/5, core greyer 5YR 6/1; core greyer 5YR 6/1; several beige rounded grains up to 0.05; (several holes up to 0.1); few specks of ?silver mica

TIR 32 bowl rim Ti LXII 39/28, V (trans. EH II/III)

form III.1 (inturned, rounded), but angle is shallow, as VII (splayed); d. 14; th. 0.4; smoothed better inside than out; striations inside; band of matt slip outside lip, varying red to black; paste: semifine, surface orange 5YR 7/4, core grey 5YR 6/1; few white rounded grains up to 0.02; few red subangular grains up to 0.02

TIR 33 bowl rim Ti LXII 38/26, Vb (trans. EH II/III)

form VII.2, slightly inturned; d. c. 15; th. 0.4; smoothed better inside than out (some striations inside); band of thin matt, brownish slip at lip, inside and out; paste: semifine, surface pale orange 5YR 7/5, core grey 5YR 7/1; few white and few grey rounded grains up to 0.2.

TIR 34 bowl rim Ti LXII 39/8, V (trans. EH II/III)

form III.2; d. 12; th. 0.4; smoothed better inside than out; paste: semifine, various shades of buff to grey 5YR 7/3 to 6/1; few white rounded grains up to 0.1; few grey rounded grains up to 0.05; few specks of ?silver mica

TIR 35 bowl rim Ti LXII 39/2, V aR (trans. EH II/III)

form III.2 but slope as VII (shallow); d. 14; th. 0.3-0.4; smoothed better inside than out; paste: medium, varying 5YR 7/3 to 5/1; several grey-brown subangular grains up to 0.05; few white rounded grains up to 0.05

TIR 36 bowl rim Ti LXII 39/49, Va (trans. EH II/III)

form III.2, but slope seems near vertical; d. c. 15; th. 0.5; slipped(?) and polished inside and out; paste: medium grey-brown 10YR 7/3 to 4/1; several dark grey subangular grains up to 0.1

TIR 37 bowl rim Ti LXII 38/25, Vb (trans. EH II/III)

form III.2; d. 16; th. 0.4-0.5; smoothed inside and out, some striations inside; traces of reddish matt band of slip at lip, inside and out; paste: medium, surface pink 5YR 7/3, core greyish 5YR 6/1; several grey rounded grains up to 0.1; few white rounded grains up to 0.05; few specks of ?silver mica

TIR 38 bowl rim Ti LXII 38/26, Va (trans. EH II/III)

form VIII.2 (shallow, pointed); d. c. 20; th. 0.4; paste: semifine buff 7.5YR 8/2; few beige rounded grains up to 0.05; few red subangular grains up to 0.05

TIR 39 bowl rim Ti LXII 39/28, V (trans. EH II/III).

form III.1; d. 16; th. 0.4; smoothed inside and out; band of thin, matt, brown to black slip at lip inside and out; paste: medium reddish 2.5YR 6/4; several white rounded grains up to 0.1

TIR 40 bowl rim Ti LXII 37/71, V (trans. EH II/III)

form III.4 (bevelled); d. 12; th. 0.4; smoothed inside, with striations; paste: medium, dull grey-brown 5YR 7/2 to 5/1; several dark grey subangular grains up to 0.1

TIR 41 sauceboat rim and handle Ti LXII 38/22, V (trans. EH II/III)

probably type II; rim with horizontal handle (left part) rising from outside of lip; th. 0.3-0.5; black slip, lustrous outside, matt inside, omitted under handle; paste: semifine buff 7.5YR 8/4; few white rounded grains up to 0.05; few specks of ?silver mica

TIR 42 sauceboat rim and handle Ti LXII 39/18, Va (trans. EH II/III)

probably type II; rim with horizontal handle (left part) coming straight out from outside of lip (i.e. not rising); a ridge extends down from its base; th. 0.3-0.4; crackled matt slip, red inside, black to brown outside, omitted under handle; paste: semifine pink 5YR 6/4; few dark grey subangular grains up to 0.02; few specks of ?silver mica

TIR 43 sauceboat rim and handle Ti LXII 38/55, Vb (trans. EH II/III)

probably type II; rim with horizontal handle (left part) rising from outside lip; th. 0.05; traces of matt black slip inside and out, except under handle; paste: semifine, surface light brown 5YR 7/4, core grey 5YR 6/1; few white and fewer black rounded grains up to 0.1

TIR 44 sauceboat rim and handle Ti LXII 38/22, V (trans. EH II/III)

probably type II; rim with horizontal handle (left part) coming straight out from lip (i.e. not rising); th. 0.3-0.4; matt black slip inside and out, except under handle; paste: semifine grey N 5/0; few white rounded grains up to 0.05

TIR 45 sauceboat rim and handle Ti LXII 38/45, Vb (trans. EH II/III)

probably type II; rim with horizontal handle rising from outside lip; ridge extends below handle where it meets pot wall; th. 0.4; thick matt slip inside and out, except below handle, red inside, black to red outside; paste: semifine orange 5YR 7/4; few white and few dark grey rounded grains up to 0.02

TIR 56 jar handle Ti LXII 38/1, IV (EH III)

horizontal loop handle, flattened horizontally; th. handle 1.9 by 1.4; th. wall 0.8-1.0; mottled inside and out; thin matt black slip sloppily applied outside;
paste: coarse, core 5YR 7/4, surface 2.5Y 8/2; many dark red-brown angular grains up to 0.2

TIR 57 jar base Ti LXII 38/57, IV (EH III)

flat base; d. c. 6; th. 0.5-0.6; thin matt brown to black slip outside;
paste: medium, 10YR 6/2 to 7/6; several black angular grains up to 0.2; several white rounded grains up to 0.1; few red and few white rounded grains up to 0.1

TIR 58 jar base Ti LXII 38/45, IV (EH III)

flat base; d. c. 15; th. 0.6-1.0; worn matt black slip inside and out;
paste: coarse, surface 10YR 8/3, core 10YR 7/1; many grey angular grains up to 0.3

TIR 59 jar base Ti LXII 38/57, IV (EH III)

flat base; d. c. 7; th. 0.6-0.7; thin matt black slip outside;
paste: medium, 7.5YR 7/4; several grey subangular grains up to 0.2; few white subangular grains up to 0.2

TIR 60 jar base Ti LXII 38/96, IV (EH III)

flat base; d. c. 6; th. 0.5-1.1; thin matt. slip outside, brown to black;
paste: semifine buff 7.5YR 8/2; core varies to pink 5YR 8/4; few light red subangular grains up to 0.2; few grey subangular grains up to 0.1; few white rounded grains up to 0.1

TIR 61 jar sherd Ti LXII 38/57, IV (EH III)

wall fragment; th. 0.4-0.7; thin worn brown to black slip outside; brush marks evident; JOINS TO TIR 86; paste: medium 7.5YR 6/2 to 7/4; several dark grey subangular grains up to 0.1; several white rounded grains up to 0.1; few dull red rounded grains up to 0.05

TIR 62 jar sherd Ti LXII 38/57, IV (EH III)

wall fragment; th. 0.4-0.6; worn matt black slip outside
paste: medium 7.5YR 7/3 to 10YR 8/3; several dark grey subangular grains up to 0.2; several white rounded grains up to 0.1; few dull red rounded grains up to 0.05; same vase as TIR 61?

TIR 70 pyxis sherd Ti LXII 38/39, V (trans. EH II/III)

wall fragment, at 90 degree carination; th. 0.5-0.6; d. less than 20; smoothed outside; a Cycladic import? (H.-J. Weisshaar, pers. comm. 1980); paste: semifine grey 10YR 6/1; many holes, rounded, up to 0.2; few dark red angular grains up to 0.1

TIR 73 cup base Ti LXII 39/25, V (trans. EH II/III)

flat base of 'ouzo cup' with near vertical sides; joined to sherd marked Ti LXII 39/16, V Nt 12R; d. base 4.5; th. 0.5; red to black matt slip outside; perhaps same vase as TIR 74; paste: semifine, surface light brown 7.5YR 6/4, core grey 7.5YR 6/1; few grey rounded grains up to 0.1

TIR 74 cup rim Ti LXII 39/16, V Nt 12R (trans. EH II/III)

form VII.1, from an 'ouzo cup'?; d. 7; th. 0.5; red to black matt slip inside and out; does not join to TIR 73 but perhaps same vase; paste: semifine, surface light brown 7.5YR 7/4, core grey 7.5YR 6/1; few grey rounded grains up to 0.1

TIR 75 ?sauceboat base Ti LXII 38/60, IV (in red: 2/234) (EH III)

form 9; d. 5.8-6.2; th. wall 0.4-0.7; thin worn matt brown slip inside and out;
paste: semifine, surface red-brown 2.5YR 6/4, core grey N 6/0; few white rounded grains up to 0.1

TIR 76 ?sauceboat base Ti LXII 39/48, IV (EH III)

form 6; d. 5.5; th. wall 0.2-0.5; smoothed inside and out; lustrous polished white (10YR 8/2) slip outside, except under base ring;
paste: fine beige 7.5YR 7/4; several very small specks of ?silver mica

TIR 77 sauceboat rim and handle Ti LXII 39/18, IV (EH III)

horizontal handle attached just below rim and rising above it; th. wall 0.4-0.5; lustrous black slip inside and out, except below handle;
paste: semifine buff 7.5 to 10YR 8/3; few black angular grains up to 0.1; few reddish-brown angular grains up to 0.05; few white angular grains up to 0.02

TIR 79 bowl rim Ti LXIII 41/62, IVa (EH III)

offset rim and part of vertical strap handle of deep bowl, form as Caskey 1960, p. 296 and Pl. 70i; d. 15; th. 0.3-0.6; polished black slip inside and out; same vase as TIR 80?
paste: semifine, buff surface 7.5YR 7/4, grey core 7.5YR 7/1; several holes up to 0.02; few specks of ?silver mica

TIR 80 bowl rim Ti LXIII 41/62, IVa (in red: 2/362) (EH III)

offset rim of deep bowl, as TIR 79; d. 13; th. 0.4-0.5; polished black slip inside and out; same vase as TIR 79?
paste: semifine, varying 7.5YR 6/2 to 6/4; several holes up to 0.02

TIR 81 bowl rim Ti LXII 38/66, VII aR (in white: 2/54) (EH III)

offset rim of deep bowl, as TIR 79; d. c. 20; th. 0.5; polished dark brown slip inside and out; two grooves on shoulder outside; paste: fine, light brown surface 7.5YR 6/4; grey core 10YR 7/1; very few white rounded grains up to 0.05

TIR 82 bowl rim Ti LXII 39/47, IIIa (EH III)

offset rim of deep bowl, as TIR 79; d. 20; th. 0.5-0.6; highly polished black slip inside and out; paste: semifine light brown 7.5YR 6/4; few white rounded grains up to 0.1

TIR 83 bowl rim Ti LXII 38/16, IVa (in red: 2/255) (EH III)

offset rim and vertical strap handle of deep bowl, as TIR 79; d. c. 15; th. 0.4-0.6; smoothed outside, polished inside; paste: medium, varying 5YR 4/1 to 7/4; several grey-brown angular grains up to 0.1

TIR 84 ?bowl handle Ti LXII 38/16, IV (in red: 2/265) (EH III)

attachment of vertical strap handle to wall; th. 0.4-0.6; matt black slip outside; highly polished black slip inside; vertical incisions on handle, horizontal ones beside it; paste: semifine light grey-brown 7.5YR 8.2; few dark red subangular grains up to 0.05; few specks of ?silver mica

TIR 85 bowl rim Ti LXII 39/38, IV (in red: 2/216) (EH III)

form V.3 (flattened, near vertical); d. 16; th. 0.5-0.6; thin matt slip inside and out, black to brown, with brush marks evident; paste: medium, surface orange 5YR 7/6, core grey-brown 10YR 7/2; several light grey angular grains up to 0.1; few white rounded grains up to 0.2; several white subangular grains up to 0.02; few specks of ?silver mica up to 0.01

TIR 86 jar spout Ti LXII 38/57, IV (in red: 2/238) (EH III)

spout joined to wall; d. hole 2.4; th. wall 0.4-0.6; thin matt brown to black slip outside and within spout; JOINS TO TIR 61; paste: medium buff 7.5YR 7/4; several dark grey subangular grains up to 0.2; few white rounded grains up to 0.2; few dark red angular grains up to 0.1

TIR 87 bowl rim Ti LXII 38/1, IV (in red: 2/257) (EH III)

offset rim of relatively deep bowl; beginning of ?handle on shoulder; d. 22; th. 0.5-0.7; cream slip 10YR 8/3 inside and out, covered outside and below offset part inside by lustrous crackled black slip; same black slip used to decorate flat top of lip with blobs pendant from outer edge; paste: medium, surface orange 5YR 7/6, core grey N 7/0; several dark red angular grains up to 0.2

TIR 88 bowl rim Ti LXII 38/1, IV (in red: 2/235) (EH III)

outturned flat-topped rim, similar to I.1; d. c. 30; th. 0.8-1.3; cream slip 10YR 8/3 visible inside; above that, and outside, worn matt black slip; on flat top of lip, 2 opposed groups of 3 broad diagonal lines, of the same black slip; paste: medium, surface buff 10YR 8/4, core grey N 8/0; several dark red-brown angular grains up to 0.2

4.6.3 Lerna

For ease of consultation, this section has been reproduced from the author's IIIe cycle thesis (Attas 1980, pp. 41-50). Descriptions of LER 8, 9, 10, and 40, analyzed at McGill, have been inserted.

Ces objets sont conservés au musée d'Argos. Toutes les dimensions sont en centimètres. Le code de couleur pour les pâtes suit le système des Munsell Soil Color Charts (1975). La couleur des engobes varie trop pour que ce système soit utile; on utilisera seulement une description. La texture de la pâte est divisée, à l'oeil, en quatre catégories: fine (sans inclusions), semi-fine (peu d'inclusions), semi-grossière (plusieurs inclusions), et grossière (beaucoup d'inclusions). La typologie des saucières est celle de Caskey (1960, p. 291), et la dénomination des empreintes de sceaux (CMS V, etc.) celle de Wiencke (1975). Lorsqu'elle est connue, l'indication de contexte stratigraphique est reportée entre guillemets à la fin de chaque description. Le plan donné par Caskey (1957, p. 144) aide à interpréter les indications, mais leur signification précise sera plus évidente lorsque le rapport final des fouilles sera publié. Dans l'immédiat elles peuvent servir à retrouver les objets dans les réserves du musée. Les abréviations employées sont les suivantes:

d.	diamètre
env.	environ
ép.	épaisseur
ext.	extérieur
h.	hauteur
int.	intérieur
inv.	numéro d'inventaire des fouilles de Lerne
la.	largeur
lo.	longueur
m.c.	maximum conservée
pl.	planche

Argile, tuiles, et briques crues de la Maison des Tuiles
de Lerne III (Helladique Ancien II)

- LER 1 motte d'argile soutenant une tuile; pâte semifine beige (7.5YR 5/4 à 10YR 6/3); les inclusions > 0,02 enlevées avant analyse; "Area BI, W destruction débris".
- LER 2 coin de tuile à bord biseauté; pâte semigrossière rouge-brune (5YR 6/4), ép. 1,5; une surface mieux aplanie que l'autre; inv. L2.273.
- LER 3 bord biseauté de tuile; pâte grossière orange (2.5YR 6/6), ép. 1,3-1,5; une surface mieux aplanie que l'autre; inv. L2.275.
- LER 4 fragment (? coin) de tuile; pâte grossière brune pâle (7.5YR 6/6), ép. 1,1-1,4; une surface mieux aplanie que l'autre.
- LER 5 fragment de brique crue, plâtré sur une face; pâte grossière orange à rose (5YR 6/4-8), ép. m.c. 3,5; manifestement brûlé.
- LER 6 fragment de brique crue conservant des impressions de roseaux sur une face; pâte semigrossière orange à rose (5YR 6/4-8), ép. m.c. 4,3; manifestement brûlé.

Hearth rims

- LER 8 inv. L.1598; Pit 26 (Lerna IIIC), Area BE; high rim with flat top; h. 8.6, w. rim 4.8, th. pan 2.8; thin red slip inside; bottom rough, with stalk impressions; on rim, impressed pattern of 3 even rows of zigzags; paste: coarse, grey N 6/0 core, pale brown 7.5YR 7/4 surfaces; many angular and subangular dark red-brown and dark grey grains up to 0.2; few white ? lime specks up to 0.1; traces of ? silver mica; Wiencke 1970, p. 102, pattern S117 (Pl. 30) and fragment 269, pl. 26.
- LER 9 Lot HTN3 (EH II); rim not set off; ends in straight edge; th. 3.0; smooth on top and side, less so below; grooved border on outer edge; parallel chevrons incised on top; paste: very coarse, dull pink 5YR 6/4; very many angular dark red-brown lustrous grains up to 0.3; Wiencke 1970, p. 103, fragment 274; pl. 26.

LER 10 inv. BE564; Area BE, Lerna IV (but EH II in style); flat rim raised above the pan; th. rim 3.5; pan c. 2.0; smooth on top, very rough below; grooved border, hatching with horizontal and slanting lines; paste: very coarse, grey 5YR 7/1 to orange 5YR 6/4; crumbly; very many angular dark red-brown lustrous grains up to 0.4; few white ? lime specks up to 0.2; Wiencke 1970, p. 103, fragment 275, pl. 26.

Céramiques des premières couches de Lerne III (Helladique Ancien II)

- LER 11 moitié gauche du bec d'une saucière de type I, inv. L.1463; pâte grossière beige (7.5YR 7/4); ép. 0,8; surfaces lisses; appliques à l'ext. en forme de corde entaillée sous le bec et parallèle au bord; bandes peu soignées de peinture rouge à noir au bord et recouvrant les appliques; "Lpt HTS(80); Lerna IIIA (pre-filling)".
- LER 12 pied annulaire de bol ou de saucière, d. 5,1; pâte fine rose (5YR 7/7), ép. 0,4-0,5; engobe métallique rouge à noir à l'int. et ext. sauf sous l'anneau; "bothros BD-AI; Lerna IIIA (pre-filling)".
- LER 13 fragment de bol à pied plat et lèvre fine verticale, d. 17, h. 11,6; pâte fine beige (7.5YR 8/4), ép. 0,3-0,7; engobe métallique rouge à noir, craquelé à l'int., marbré à l'ext.; "bothros BD-AI; Lerna IIIA (pre-filling)".
- LER 14 fragment de bol à pied annulaire et lèvre fine verticale, d. 16, h. 8,7; pâte fine beige, (7.5YR 7/4), ép. 0,5; engobe noir craquelé à l'int. et l'ext.; "bothros BD-AI; Lerna IIIA (pre-filling)".
- LER 15 fragment de bol à pied plat et lèvre fine verticale, d. 13, h. 8,7; pâte fine beige, (7.5YR 7/4), ép. 0,4; engobe noir craquelé à l'int. et l'ext.; "bothros BD-AI; Lerna IIIA (pre-filling)".
- LER 16 lèvre fine verticale de bol (ou saucière), d. 16; pâte fine orange (5YR 7/6), ép. 0,6; engobe métallique à l'int. et l'ext.; noir près du rebord et rouge plus bas; "bothros BD-AI; Lerna IIIA (pre-filling)".
- LER 17 bec d'une saucière du type I; pâte semifine beige (7.5YR 7/4); ép. 0,4; engobe noir un peu écaillé à l'int. et l'ext.; "HTS(79); Lerna IIIA (pre-filling)".
- LER 18 bec d'une saucière du type de transition I/II; pâte semifine beige (7.5YR 7/4), ép. 0,4; engobe noir métallique à l'int. et l'ext.; "30; Lerna IIIA (pre-filling)".
- LER 19 anse horizontale (remontant légèrement) de saucière, écartement des attaches env. 6,5; pâte semifine beige à rose (7.5YR 7/4-6), ép. 0,4;

engobe noir métallique à l'int. et l'ext., sauf sous l'anse; "30 joining to 38; Lerna IIIA (pre-filling)"

LER 20 anse horizontale (remontant légèrement) de saucière, écartement des attaches env. 4,3; pâte fine rose (5YR 7/4), ép. 0,3; surfaces engobées et polies, jaune à l'ext. et bleu-gris à l'int.; "HTS(80); Lerna IIIA (pre-filling)".

Céramiques de la Salle XI de la Maison des Tuiles de
Lerne III (fin Helladique Ancien II)

- LER 21 bec d'une saucière du type IV, fortement recourbé; pâte semigrossière jaune pâle (2.5Y 7/2), ép. 0,4; surfaces aplanies mais pas engobées.
- LER 22 pointe droite du bec d'une saucière du type IV, fortement recourbé; pâte semigrossière rougeâtre (5YR 5/4), ép. 0,5; surfaces aplanies mais pas engobées.
- LER 23 anse horizontale (remontant légèrement) de saucière, écartement des attaches env. 2,5; pâte semigrossière beige (7.5YR 7/4), ép. 0,5; surfaces grossièrement aplanies mais pas engobées.
- LER 24 anse horizontale (remontant légèrement) de saucière, écartement des attaches env. 1,4; pâte semigrossière grise (N 7/0), bien cuite (ou brûlée), ép. 0,5; surfaces grossièrement aplanies mais pas engobées.
- LER 25 fragment de bol hémisphérique avec pied annulaire aigu (d. 3,5) et lèvre arrondie, d. 16; pâte semigrossière gris-brun (10YR 6/2); ép. 0,4; surfaces marbrées en gris et bruns, mieux aplanies à l'int. qu'à l'ext., mais pas engobées.
- LER 26 fragment de bol peu profond avec pied plat et lèvre arrondie, d. 16; pâte semifine rouge foncée (5YR 6/6), ép. 0,3-0,4; surfaces mieux aplanies à l'int. qu'à l'ext.
- LER 27 lèvre arrondie de bol peu profond, d. 15,5; pâte grossière gris-brun (7.5YR 7/1) contenant beaucoup d'inclusions angulaires grises, ép. 0,5; surfaces mieux aplanies à l'int. qu'à l'ext., mais pas engobées.
- LER 28 lèvre (légèrement épaissie à l'int.) de bol peu profond, d. env. 20; pâte semifine gris-brun (10YR 6/3), ép. 0,6; surfaces mieux aplanies à l'int. qu'à l'ext.
- LER 29 lèvre recourbée de bol peu profond, d. 15; pâte semifine grise (7/0), ép. 0,4-0,5; surfaces engobées en beige et polies, 10YR 7/3 à l'int. et 7.5YR 6/4 à l'ext.
- LER 30 lèvre recourbée, avec biseau abrupte, de bol peu profond, d. env. 12; pâte semifine rougeâtre (5YR 5/4), ép. 0,5; surfaces mieux aplanies à l'int. qu'à l'ext., mais pas engobées.

Empreintes de sceaux de la Salle XI de la Maison des Tuiles

- LER 31 cachet d'argile conique, 1/4 conservé, lo.m.c. 6,6; pâte peu cuite semigrossière rose (5YR 7/4 à 3/2); porte 6 impressions d'un sceau circulaire, d. 2,7, répertorié CMS V Nr. 56; au revers l'impression d'une corde entourant une cheville; inv. L4.409.
- LER 32 cachet d'argile discoïde, 1/3 conservé, lo.m.c. 6,5; pâte peu cuite semigrossière rouge à pourpre (5YR 5/2 à 3/4); porte 3 impressions d'un sceau circulaire, d. 2,7, répertorié CMS V Nr. 56; inv. L4.410.
- LER 33 cachet d'argile conique, 1/3 conservé, lo.m.c. 7,4; pâte peu cuite semifine rouge-brune (5YR 4/1 à 6/4); porte 2 impressions de chacun de 2 sceaux circulaires, d. 3,3, répertorié CMS V Nr. 93 et d. 2,1, répertorié CMS V Nr. 94; au revers l'impression d'une corde; inv. L4.352.
- LER 34 cachet d'argile fragmentaire, lo.m.c. 6,8; pâte non cuite grossière grise à orange (5YR 4/1 à 6/7); porte une impression d'un sceau circulaire, d. 5,1, répertorié CMS V Nr. 86; inv. L4.459.
- LER 35 cachet d'argile fragmentaire, lo.m.c. 6,1; pâte peu cuite grossière grise à orange (5YR 3/1 à 6/4); 5 impressions d'un sceau circulaire, d. 2,8, répertorié CMS V Nr. 112; au revers l'impression du col d'un vase (une jarre ?); inv. L4.451.

Autres objets se rattachant par leur style à la phase Helladique Ancien II (mais trouvés hors de contexte)

LER 7 fragment de la panse d'un pithos; pâte grossière beige (7.5YR 7/4), grise (N 7/0) au centre, ép. 1,4; bande saillante à l'ext, la. 8,1, h. 0,3, décorée d'un sceau cylindrique de deux rangées de spirales continues, entre lesquelles se trouvent un chien, un autre quadrupède, et un point (CMS V Nr. 120); hors de la bande à l'ext., engobe léger noir mat; inv. L.1564(c). Des impressions du même sceau sont aussi conservées à Tirynthe (Müller 1938, pl. XIX) et à Zygouries (Blegen 1928, pl. 114,6), comme l'a remarqué Caskey (1959, p. 206, et pl. 42c-e) à l'aide d'autres tessons de ce même pithos de Lerne; "Lerna IV, Area JA, western part of square E7".

LER 49 partie antérieure de quadrupède en terre cuite lo.m.c. 7,1; h.m.c. 6,1; pâte semifine beige (7.5YR 8/4), surface lisse, plus jaune (10YR 8/3); décoré de traits d'engobe noir craquelé; inv. L7.179. Ressemble fortement à une figurine plus complète de Corinthe, MF 2270; "Phase C, bothros (HTS-4)".

Céramiques peintes du Néolithique Moyen (trouvées hors de contexte dans la Salle CA de Lerne III)

- LER 36 fragment de paroi; pâte fine gris-brun (7.5YR 6/3), ép. 0,5; surfaces polies; à l'ext., traits en contrehachure en peinture rouge à brune (5YR 4-5/3).
- LER 37 fragment de lèvre simple verticale (trop petit pour mesurer d.); pâte fine orange (7.5YR 8/6), ép. 0,5; engobe noir lustré à l'int. et partiellement à l'ext.; à l'ext. aussi des traits larges et de la contrehachure fine en peinture noire à brune.
- LER 38 fragment de lèvre fine verticale (trop petit pour mesurer d.); pâte fine rose (5YR 7/6), ép. 0,4; engobe rouge à l'int.; à l'ext., un trait horizontal lié à 4 diagonaux en peinture rouge.
- LER 39 fragment de paroi; pâte fine rose (5YR 7/4), ép. 0,4; à l'ext., surface polie et décorée d'une zone rouge et des traits diagonaux en peinture noire; les couleurs sont marbrées (l'effet du feu?).
- LER 40 askos base; Room CA (EH II); type 1 (flat) base rising asymmetrically to mid-body height; th. 0.3; polished yellow (10YR 8/4 to 8/6) slip outside, unpolished inside; paste: semifine, pale brown 7.5YR 7/6; several very small flakes of ? silver mica.

Céramiques des premières couches de Lerne IV (Helladique Ancien III)

- LER 41 bol profond à lèvre recourbée vers l'ext. et (probablement deux) anses verticales dont une conservée, d. 18; pâte semifine grise (10YR 5/1), ép. 0,6, probablement fait au four de potier, d'après les stries à l'int.; surfaces polies; inv. L.1354; "(606)".
- LER 42 fragment de chope conservant le profil complet de pied plat, lèvre droite, une anse plate verticale, d. env. 18, h. env. 20; pâte semifine grise à rose (5YR 5/2 à 7/6), ép. 0,4-0,6; couche légère d'engobe beige à l'ext., sur laquelle 3 groupes de motifs linéaires en peinture rouge; inv. L.1433; "(608)".
- LER 43 fragment de l'épaule d'un vase; pâte fine rose-beige (7.5YR 8/4), ép. 0,5; surfaces aplanies; à l'ext., traits horizontaux et motifs "d'échelle" en peinture noire ou brun foncé un peu lustré; "Area D, phase CV".
- LER 44 fragment de paroi; pâte semifine rose-beige (7.5YR 8/4), ép. 0,7; surfaces aplanies; à l'ext., 5 traits horizontaux en peinture rouge-brun foncé (2.5YR 4/2) dont 2 reliés par des barres de traverse; "Area D, phase CV".
- LER 45 fragment de l'épaule d'un vase; pâte semifine rose-beige (7.5YR 8/4), ép. 0,7; surfaces aplanies; à l'ext., triangle en contrehachure partielle en peinture noire; "Area D, phase CV".
- LER 46 fragment de paroi, peut-être de l'anse d'une chope; pâte semifine rose (5YR 7/4), ép. 0,4-0,6; à l'ext., engobe léger brun sous traits horizontaux et diagonales de peinture beige; "Area D, phase CV".
- LER 47 fragment de bol profond à lèvre recourbée vers l'ext., conservant une anse verticale, d. 20; pâte semifine beige grisâtre (10YR 6/2), ép. 0,5; surfaces polies; fait au tour du potier? (d'après les stries à l'int.); "Area D, phase CV".
- LER 48 fragment de bol profond à lèvre recourbée vers l'ext., d. 20; pâte semifine grise (10YR 5/1), ép. 0,5; surfaces polies; fait au four du potier? (d'après les stries à l'int.); "Area D, phase CV".

Céramiques du début de l'Age du Bronze Moyen (Lerne V)

- LER 51 bouteille incisée ("flacon balkanique"), inv. L.1062; h.m.c. 13 (la lèvre manque), d. du pied plat 5,5; pâte semifine noire, marbrée en rouge (5YR 5/4), brun foncé (7.5YR 4/2), et gris (N 4/0); surface ext. polie, incisée sur l'épaule avec huit panneaux verticaux hachurés; "Area BE".
- LER 52 fragment d'épaule de bouteille incisée ("flacon balkanique"), inv. L.1197a; h.m.c. 9, lo.m.c. 16; pâte grossière (?) rouge (2.5YR 5/8) et gris-brun (10YR 5/2) avec surface ext. polie, grise (10YR 4/1), incisée avec des triangles hachurés et une partie d'une spirale en creux; "Area BE".
- LER 53 bouteille incisée ("flacon balkanique"), inv. L.1050; h. 13,9, d. lèvre 7,2, d. pied 5; pâte semigrossière rouge (2.5YR 4/6 à 8) avec surface ext. polie, brune foncée (7.5YR 5/4), incisée en traits larges avec quatre grandes spirales bordées de pointes et de traits diagonaux; Caskey 1957, p. 150 et pl. 40d; "Area BE, Room 44".
- LER 54 fragment d'épaule et de lèvre de jarre à lèvre évasée, h.m.c. 9; pâte semigrossière orange (env. 7.5YR 7/6); surface ext. couverte d'engobe rose clair (7.5YR 7/2), peinte en gris foncé (5YR 4/1) avec des groupes de traits obliques entre bandes horizontales; d'après C. Zerner (communication personnelle 1979), "Dark-on-light Lustrous-Decorated (Mainland) Ware"; "D(439) and (599)".
- LER 55 fragment d'épaule de jarre, h.m.c. 5,5; pâte semigrossière brune claire (7.5YR 6/4), faite au tour de potier; surface ext. beige (10YR 8/4) couverte d'engobe gris foncé (5YR 3/1) sauf entre deux nervures horizontales; d'après C. Zerner (communication personnelle 1979), "Light-on-dark Lustrous-Decorated (Minoanizing) Ware"; "BD(VA)".
- LER 56 fragment d'épaule de jarre, h.m.c. 4; pâte semigrossière orange (env. 7.5YR 7/6), faite au tour de potier; surface ext. couverte d'engobe gris foncé (5YR 3/1) sauf entre deux nervures horizontales, où l'engobe est blanc (2.5YR 8/2); d'après C. Zerner (communication personnelle 1979), "Light-on-dark Lustrous-Decorated (Minoanizing) Ware"; "B(1476)".

4.6.4 Zygouries

ZYG 1 ram's-headed sauceboat Z-260 MK736 Snails East VII

similar to type II sauceboats; rising horizontal handle, base probably form 4 (restored); solid head; applied eyes; applied horns curve forward below them but do not meet; h. 9.5; l. 15; w. 8.2; th. 0.4; traces of lustrous black slip N 4/0 inside and out; paste: medium yellow 2.5Y 8/2; many subangular black, dark grey, light red, and beige grains up to 0.05; few white specks up to 0.1; Blegen 1928, pp. 92-93 and Pl. X

ZYG 2 ram's-headed sauceboat Z-351 House of Pithoi

similar to type II sauceboats; level horizontal handle; type 4 (ring) base; solid head; applied horns come forward, meeting on top of nose; no eyes; body twisted; h. 11.4; l. 11.0; w. 7.6; th. 0.5; base d. 3.2; smoothed; paste: semifine grey-brown, varying 5YR 5/2 to 7/6; few white specks up to 0.05; Blegen 1928, p. 93 and Pl. X (called no. 251)

ZYG 3 impressed sauceboat spout Z-569 ("from J")

probably type II; th. c. 0.6; red-brown (7.5YR 7/4) slip, poorly preserved, inside and out; pattern of short impressed dashes outside, in rows 2, 3, and 4 dashes wide; paste: semifine buff 10YR 8/3; few beige lime specks up to 0.1; Blegen 1928, p.92 fig. 81

ZYG 4 jug neck with sauceboat mouth Z-238 MK747
("stereo under House of Pithoi")

tall neck opening slightly at top to a sauceboat (Type I) spout; restored strap handle from below back of lip to shoulder; neck d. c. 5.6; neck h. 16.5; peeling black lustrous slip outside and around lip, except underneath handle; two applied dots inside back lip to either side of applied 'worm' of flaring U-shape, and one dot (opposite one not preserved?) on right side at top of handle; paste: medium pale yellow 2.5Y 8/2; many angular black grains up to 0.05; several flakes of ?golden mica;
Blegen 1928, pp. 93-94 and Pl. X

ZYG 6 impressed pithos sherd

wall sherd; th. 0.9; band w. c. 6.5; band h. 0.2-0.3; smoothed inside; thin brown (5YR 3/2 to 6/3) slip outside; raised band of impressed (rolled) decoration: spirals and "animal chasing prey": matches Lerna and Tiryns fragments (see sections 1.5 and 4.4);
paste: coarse grey N 7/0; many angular red, ?grey, and beige grains up to 0.2;
Blegen 1928, pp. 121-122, fig. 114 no. 6; Pini 1975, p. 397, inv. 504

ZYG 7 sauceboat spout Corinth Lot 7166-1 (Snails .10-.40)

Type II; includes front right part of rim; lip is slightly downturned, tip is high, 45 degrees; th. 0.4; smoothed inside; sloppy smeared thin lustrous slip outside and inside tip of spout, varying black to red-brown to orange;
paste: fine pale pink 7.5YR 8/3; very few subangular dark red and light red grains up to 0.05; very few white specks up to 0.05

ZYG 8 sauceboat spout Corinth Lot 7166-2 (Snails .10-.40)

Type II; includes rim to both sides; tips broken but probably 45 degrees; U-shaped trough; lip downturned; th. 0.4; good but thin black lustrous slip outside and inside spout and rim;
paste: semifine pink 5YR 8/3; few white and beige specks up to 0.1; few light red and dark red grains up to 0.05

ZYG 9 sauceboat spout Corinth Lot 7166-3 (Snails .10-.40)

probably type II; includes rim and left tip, 45 degrees; th. 0.5; good mottled light-to-dark red (2.5YR 4/4 to 6/6) lustrous slip inside and out; paste: semifine buff 7.5YR 8/2; few angular dark grey grains up to 0.05; few white specks up to 0.05

ZYG 10 sauceboat spout Corinth Lot 7166-4 (Snails .10-.40)

type II; highish 60 degree tip; lip slightly downturned; th. 0.4; thin orange to brown to black lustrous slip inside and out; paste: medium buff 7.5YR 8/2; several beige specks up to 0.1; few dark red subangular grains up to 0.1

ZYG 11 sauceboat spout Corinth Lot 7166-5 (Snails .10-.40)

may be type III; both tips broken; lip sharply downturned; th. 0.5; thin pale orange (7.5YR 5/4 to 7/6) lustrous slip inside and out; small (accidentally?) applied blob of clay axially inside spout; paste: medium pale pink 7.5YR 8/4; several holes up to 0.2

ZYG 12 sauceboat spout Corinth Lot 7166-6 (Snails .10-.40)

probably type II; one 45 degree tip; lip seems not downturned; th. 0.5; thick crackled lustrous slip, black outside, dark red (2.5YR 5/4) inside; paste: fine pale orange 5YR 7/6; no inclusions visible

ZYG 13 sauceboat spout Corinth Lot 7166-7 (Snails .10-.40)

probably type II; both tips broken; slight downturn to lip; th. 0.6; traces of thin reddish (5YR 7/6) slip inside and out; paste: medium buff 10YR 8/4; several subangular dark grey and dark brown grains up to 0.01; few beige specks up to 0.1

ZYG 14 sauceboat spout Corinth Lot 7166-8 (Snails .10-.40)

probably type II; mostly right tip, less than 45 degrees; th. 0.5; worn crackled black lustrous slip inside and out;
paste: semifine buff 10YR 8/3; few subangular dark grey and subangular beige grains up to 0.05

ZYG 15 bowl or sauceboat base Corinth Lot 7166-9 (Snails .10-.40)

form 5 (ring base), asymmetric; d. 6.0; th. 0.6; good black and dark red mottled lustrous slip outside;
paste: semifine pink 5YR 7/4; few angular dark red grains and white specks up to 0.1

ZYG 16 bowl rim Corinth Lot 7166-10 (Snails .10-.40)

offset lip, as form IV.2 but still more pronounced; d. c. 12; th. 0.4; traces of crackled black lustrous slip inside and out;
paste: medium pale green 5Y 8/2; several beige specks up to 0.1

ZYG 17 bowl rim Corinth Lot 7166-11 (Snails .10-.40)

incurved, as form III.2 but with a carination; d. c. 13; th. 0.3-0.4; lustrous black slip, good inside but worn outside;
paste: fine pale greenish 2.5Y 7/2; very few beige specks up to 0.1

ZYG 18 bowl rim Corinth Lot 7166-12 (Snails .10-.40)

form IV.2 (offset); d. c. 13; th. 0.4; good glossy crackled black slip inside and out, mottled red (10R 6/4) in places;
paste: medium buff 10YR 8/4; several rounded pale brown and rounded light red grains up to 0.1

ZYG 19 bowl rim Corinth Lot 7166-13 (Snails .10-.40)

form IV.2 (offset); d. 11; th. 0.5; good black lustrous slip inside and out;
paste: semifine pink-buff 7.5YR 8/2; several subangular dark red grains up to 0.05; very few white specks up to 0.1

ZYG 20 bowl rim Corinth Lot 7166-14 (Snails .10-.40)

form III.2 (incurved); d. 14; th. 0.4; worn red (2.5YR 6/6) lustrous slip on lip inside and out; paste: semifine buff 7.5YR 7/3; few subangular light red grains up to 0.05; few white specks up to 0.05

ZYG 21 sauceboat spout Corinth Lot 7166-15 (VIII bothros)

probably type I; rounded trough; tips just over 90 degrees; lip curves gradually; w. 4.5; th. 0.4; good crackled matt black slip inside and out; paste: medium buff 10YR 8/2; several rounded light red grains up to 0.1; few subangular black grains up to 0.1; few beige specks up to 0.1

ZYG 22 sauceboat spout Corinth Lot 7166-16 (VIII bothros)

only trough preserved, curving gently to lip; th. 0.6; good black lustrous slip inside and out, crackled outside only; paste: semifine buff 10YR 8/3; few subangular black grains up to 0.1; very few white specks up to 0.1

ZYG 23 sauceboat rim Corinth Lot 7166-17 (VIII bothros)

type ind.; rim to left of spout; th. 0.5; good crackled lustrous slip, black outside, red (10R 5/6) inside, changing to black at spout end; paste: semifine pink 7.5YR 7/4; few white specks up to 0.1; few angular dark red grains up to 0.1

ZYG 24 ?sauceboat base Corinth Lot 7166-18 (VIII bothros)

form 10 foot (splayed); d. 6.5; th. 0.7; thin but tenuous lustrous slip inside and out, varying black to brown to red; paste: medium pale brown 7.5YR 8/2; several subangular black grains up to 0.1; few subangular dark red grains up to 0.05

ZYG 25 bowl profile Corinth Lot 7166-19 (VIII bothros)

slightly incurved rim, as form III.2 but less pronounced; form 5 base, d.c. 6; rim d. 11; h. ind.; th. 0.4; lustrous slip: inside, black turning silvery and glossy (overfired?); outside, crackled and mottled black to dark red, peeling in places; paste: semifine pink 5YR 8/4; few angular dark red grains up to 0.05; very few beige specks up to 0.05

ZYG 26 bowl rim Corinth Lot 7166-20 (VIII bothros)

form VII.6 (shallow, slightly thickened inside); d. 23; th. 0.4; good lustrous slip, red inside, black outside and around lip; paste: semifine pink 5YR 7/4; several beige specks up to 0.05; several angular red grains up to 0.01

ZYG 27 bowl rim Corinth Lot 7166-21 (VIII bothros)

form III.1 (gradually incurving); small lug at lip; d. 16; th. 0.5; good crackled lustrous red slip inside, mottled red to black outside; paste: medium grey to pink 5YR 6/1 to 7/4; several beige specks up to 0.1; few subangular dark grey grains up to 0.1

ZYG 28 ladle handle Corinth Lot 7166-22 (VIII bothros)

toroidal loop, tapering to join; m.p.l. 6.3; w. 4.0; th. 1.0-1.2; good crackled lustrous slip varying black to red; paste: fine pink 5YR 7/3; few holes up to 0.1

ZYG 29 ladle handle Corinth Lot 7166-23 (VIII bothros)

stubs of loop attached to shaft; th. 1.2-1.5; crackled lustrous black slip, a bit worn; paste: semifine buff 10YR 8/3; few angular black grains up to 0.05

ZYG 30 ladle handle Corinth Lot 7166-24 (VIII bothros)

oval loop at end of shaft; th. 1.1-1.6; thin crackled lustrous slip, dark brown (10YR 3/2) to red (10R 5/6); paste: semifine buff 7.5YR 8/2; few white specks up to 0.1

4.6.5 Phlious

PHL 1 animal head Ph-p-50

tapering cylinder (perhaps a handle); at small end, two 'ears' point in one direction, and a broken 'snout' in the other; m. p. l. 5.8; d. c. 1.8; thin worn red (2.5YR 6/4) slip;
 paste: fine grey 10YR 6/1; very few dark grey subangular grains up to 0.01
 Biers 1969, p. 456 and Pl. 118 no. 75

PHL 2 ladle shaft Ph-p-59

flattened cylinder, rounded at handle end, opening to bowl at other end; m. p. l. c. 17; d. (handle end) 1.8-2.0; thin brown (7.5YR 4/2) slip;
 paste: fine buff-pink 7.5YR 8/6; very few dark red angular grains up to 0.1;
 Biers 1969, p. 454 and Pl. 117 no. 52

PHL 3 ladle shaft Ph-p-60

flattened cylinder; beginning of bowl; section 3.1 by 1.6; m. p. l. 8.7; worn lustrous black (N 4/0) slip;
 paste: semifine buff 10YR 8/2; few dark grey and dull red subangular grains up to 0.05;
 Biers 1969, p. 454 and Pl. 117 no. 54

PHL 4 ladle handle Ph-p-62

toroidal loop; m. p. l. c. 6.0; w. c. 4; shaft section 2.0 by 1.1; hole d. 1.1; thin lustrous brown (7.5YR 6/3) slip;
 paste: coarse pale green 5Y 8/1; many dark grey angular grains up to 0.1;
 Biers 1969, p. 454 and Pl. 117 no. 53

PHL 5 ladle handle Ph-p-61

toroidal loop, tapering to join; m. p. d. 4.0; th. 1.6, tapering to 0.9; traces of lustrous crackled black slip;
 paste: semifine pale green 5Y 8/1; few dark grey subangular grains up to 0.05;
 Biers 1969, p. 454 and Pl. 117 no. 55

PHL 7 bowl rim Ph-p-65

form III.2 (incurving); d. c. 18; th. 0.5; lustrous black slip inside and out;
 paste: medium buff 10YR 8/3; several subangular black grains up to 0.1;
 Biers 1969, p. 454 and Pl. 116 no. 48

PHL 8 sauceboat spout Ph-p-69

probably Type III; th. 0.5; worn lustrous black slip inside;
 paste: medium green 5Y 7/3; several subangular dark grey grains up to 0.1; few white specks up to 0.1

PHL 9 bowl or sauceboat base Ph-p-68

form 9; d. 7; th. 0.9; red (2.5YR 5 $\frac{1}{4}$) slip inside and out;
 paste: semifine buff 10YR 7/3; few dark grey and dark red subangular grains up to 0.1; several holes up to 0.05

PHL 10 sauceboat sherd Ph-p-74

probably near rim; th. 0.3; crackled lustrous red (2.5YR 6/6) slip outside; inside, hatched shapes (triangles?) in crackled lustrous black slip; beginning of zone of solid lustrous brown slip on one corner
 paste: fine buff-pink 7.5YR 8/3; few white specks up to 0.05;
 Biers 1969, p. 454 and Pl. 117 no. 56

PHL 11 sauceboat rim and handle Ph-p-76

type II; long horizontal loop, probably raised; span c. 6; handle d. 1.2; wall th. 0.4; crackled lustrous black slip inside and out;
 paste: medium grey-green 2.5Y 7/2; several subangular dark grey grains up to 0.1;
 Biers 1969, p. 453 and Pl. 116 no. 38

PHL 12 sauceboat rim Ph-p-77

type ind.; portion of bowl to left of spout; th. 0.4-0.5; slightly crackled lustrous black slip inside and out;
 paste: medium green 2.5Y 8/2; many subangular black grains up to 0.05; several subangular grey grains up to 0.05; few white specks up to 0.05;
 Biers 1969, p. 453 and Pl. 116 no. 40 (but his concordance no. 39)

PHL 13 bowl or sauceboat base Ph-p-78

form 9; d. 5; th. 0.5; crackled lustrous black slip inside and out, except beneath base ring;
 paste: semifine grey-green 2.5Y 7/2; several subangular dark grey grains up to 0.05;
 Biers 1969, p. 453 and Pl. 116 no. 39 (but his concordance no. 40)

PHL 14 loomweight Ph-p-79

truncated, slightly bulging cone; h. 4.3; d. 5.0 at base, c. 2.5 at top; hole d. 1.0; smoothed;
 paste: semifine: mottled orange surface; grey N 5/0 core; many stalk impressions up to 0.3 long; few rounded beige grains up to 0.1;
 Biers 1969, pp. 456-457 and Pl. 118 no. 77

PHL 18 ladle handle Ph-p-83

oval loop; m. p. l. 5.6; w. 4.4; th. 1.7, tapering to 1.0; crackled lustrous black slip everywhere;
 paste: medium yellow 2.5Y 8/3; several angular black grains up to 0.1;
 Biers 1969, p. 454 and Pl. 116 no. 43

PHL 23 bowl or sauceboat base Ph-p-88

intermediate between forms 3 and 4; d. 8; th. 0.6; crackled lustrous black to dark brown slip inside and out;
 paste: medium pink 5YR 8/3; several beige specks up to 0.1; several white specks up to 0.05;
 Biers 1969, p. 454 and Pl. 116 no. 51

PHL 24 sauceboat handle Ph-p-101

probably type III; double vertical handle attached just below lip; w. 1.5; span 3.2; th. 0.5; crackled lustrous black slip everywhere;

paste: semifine pale yellow-green 2.5Y 8/2; few beige specks up to 0.1;

Biers 1969, p.453 and Pl. 116 no. 41

4.6.6 Keramidhaki and Corinth

KER 1 ?jar handle Corinth Lot 7164-1

strap handle attached to wall; w. c. 8; th. 0.6;
paste: medium 5Y 8/3 (Cherry fabric 1); several
angular black grains up to 0.1

KER 2 bowl rim Corinth Lot 7164-2

form V.5; d. c. 40; th. 0.7; brown (7.5YR 5/4)
lustrous slip inside;
paste: medium 2.5Y 8/2 (Cherry fabric 1); many
angular black grains up to 0.05

KER 3 jug rim and handle Corinth Lot 7164-3

form XV.1; round (twisted rope?) handle; d. c. 8; d.
handle c. 2; th. 0.7;
paste: coarse 5Y 8/2 (Cherry fabric 1); many angular
black grains up to 0.1; few white specks up to 0.1

KER 4 jar rim and handle Corinth Lot 7164-4

form XIb.1; horizontal strap handle; d. c. 20; th.
0.6; handle w. c. 3.5; smoothed;
paste: medium 2.5Y 8/2 (Cherry fabric 1); several
angular black grains up to 0.1

KER 5 ?jar handle Corinth Lot 7164-5

strap handle attached to wall; th. 0.6;
paste: medium 2.5Y 8/2 (Cherry fabric 1); many
angular black grains up to 0.05; few light grey
grains up to 0.05

KER 6 ?bowl base Corinth Lot 7164-6

form 1 (flat); d. 5; th. 0.5-0.7; smoothed inside;
lustrous black (10YR 5/1) slip outside;
paste: fine 2.5Y 8/2 (Cherry fabric 1); very few
white specks up to 0.1

KER 7 base of bowl or sauceboat Corinth Lot 7164-7

form 9 (ring base); d. 4.5; th. 0.3-0.5; lustrous black (10YR 4/1) inside and out, except beneath base ring;
paste: fine 2.5Y 8/2 (Cherry fabric 1); very few beige specks up to 0.01

KER 8 bowl rim Corinth Lot 7164-8

form III.4 (incurved); d. 13; th. 0.5; lustrous black (10YR 5/1) slip inside and out;
paste: semifine 10YR 8/2 (Cherry fabric 2); few beige specks up to 0.05

KER 9 sauceboat rim Corinth Lot 7164-9

probably type II; includes part of horizontal handle; th. 0.4; crackled lustrous slip inside and out, varying red to black (5YR 6/3 to 10YR 4/1);
paste: fine 10YR 8/3 (Cherry fabric 2); very few white specks up to 0.1

KER 10 sauceboat rim Corinth Lot 7164-10

probably type II; includes part of horizontal handle; th. 0.4; lustrous slip inside and out (except under handle), varying red to black (5YR 6/3 to 10YR 4/1);
paste: fine 10YR 8/3 (Cherry fabric 2); no inclusions visible

KER 11 base of bowl or sauceboat Corinth Lot 7164-11

form 9 (ring base); d. 8; th. 0.4-0.6; crackled lustrous dark brown (10YR 4/2) slip inside and out, except beneath base ring, where there are random dabs; worn on inside at bottom;
paste: fine 7.5YR 8/3 (Cherry fabric 2); very few white and beige specks up to 0.01

KER 12 bowl base Corinth Lot 7164-12

form 1 (flat); d. 8; th. 0.3-0.6; lustrous slip, brown (7.5YR 5/1) inside and red (2.5YR 5/6) outside;
paste: semifine 7.5YR 7/4 (Cherry fabric 2); few beige and white specks up to 0.1; few rounded translucent grains up to 0.05

KER 13 base of bowl or sauceboat Corinth Lot 7164-13

type 10 (ring base); d. 5; th. 0.4-0.5; red (2.5YR 6/6) slip inside and out, except beneath base ring; paste: fine 10YR 8/3 (Cherry fabric 2); few beige specks up to 0.05

KER 14 bowl rim Corinth Lot 7164-14

form III.2 (incurving); d. 12; th. 0.4; worn lustrous black (10YR 4/1) slip inside and out; paste: fine 10YR 8/3 (Cherry fabric 2); very few beige and white specks up to 0.1

KER 15 sauceboat spout Corinth Lot 7164-15

relatively open trough (type I?); th. 0.3; crackled lustrous black (10YR 5/1) slip inside and out; paste: fine 10YR 8/3 (Cherry fabric 2); very few beige specks up to 0.05

KER 16 sauceboat rim Corinth Lot 7164-16

type ind.; near spout; th. 0.3; crackled lustrous red-brown (5YR 5/3) slip inside and out; paste: fine 10YR 8/3 (Cherry fabric 2); no inclusions visible

KER 17 sauceboat spout Corinth Lot 7164-17

broad, open spout (Type I?); th. 0.3; lustrous black (10YR 4/2) slip inside and out; paste: fine 7.5YR 8/4 (Cherry fabric 2); no inclusions visible

KER 18 sauceboat spout Corinth Lot 7164-18

Type II; th. 0.3; lustrous dark red-brown (5 to 7.5YR 5/2) slip inside and out; paste: fine 10YR 8/3 (Cherry fabric 2); few beige specks up to 0.05

KER 19 bowl rim Corinth Lot 7164-19

form VI.6; d. c. 50; th. 1.0; red (10R 5/6) slip inside and on top of rim;
paste: coarse 5YR 7/8 (Cherry fabric 3); many grey, brown, and dark red angular grains up to 0.2

KER 20 bowl rim Corinth Lot 7164-20

form VI.5; d. c. 40; th. 0.9; red (10R 6/6) slip inside and on top of rim;
paste: coarse 7.5YR 8/3 (Cherry fabric 3); many grey, brown, and dark red angular and subangular grains up to 0.2; several white specks up to 0.1

KER 21 jar rim Corinth Lot 7164-21

form XIa.1 (flaring); d. c. 9; th. 0.8-0.9;
paste: coarse 10YR 7/4 (Cherry fabric 3); many angular and subangular brown, grey, and dark red grains up to 0.2

KER 22 ladle shaft Corinth Lot 7164-22

rounded rectangular cross-section; w. 3.0-4.0; th. 1.5; smoothed;
paste: coarse 2.5YR 5/6 (Cherry fabric 4); many subangular and rounded beige, grey, and dark red grains up to 0.1

KER 23 ?fire-dog leg Corinth Lot 7164-23

one right angle preserved; th. at least 3.0; smoothed;
paste: coarse 5YR 7/6, crumbly (Cherry fabric 4); many angular dark grey grains up to 0.1; several very fine stalk impressions

KER 24 wall sherd Corinth Lot 7164-24

perhaps from large bowl; one edge thicker; th. 1.3-1.6; smoothed inside and out;
paste: coarse 2.5YR 6/6 (Cherry fabric 4); many angular and subangular white, beige, grey, and dark red grains up to 0.2

KER 25 wall sherd Corinth Lot 7164-25

th. 0.8; smoothed;
paste: coarse 5YR 6/2 to 6/4 (Cherry fabric 4); many angular dark grey and dark red grains up to 0.2

KER 26 wall sherd Corinth Lot 7164-26

perhaps a pithos neck or a fire dog leg; th. 1.2-1.4; one side smoothed;
paste: very coarse 5YR 5/6, crumbly (Cherry fabric 4); very many angular dark grey and dark red grains up to 0.2

KER 27 ?fire-dog fragment Corinth Lot 7164-27

two relatively flat surfaces almost parallel; th. 2.0-3.0; flat surfaces smoothed;
paste: coarse grey 7.5YR 5/1, crumbly (Cherry fabric 5); many angular grey and brown grains up to 0.2

KER 28 wall sherd Corinth Lot 7164-28

th. 0.7; inner surface smoothed, outer one scraped;
paste: coarse 5YR 5/1 to 5/8, crumbly (Cherry fabric 5); many subangular and rounded beige and grey grains up to 0.1

KER 29 wall sherd Corinth Lot 7164-29

th. 0.9-1.0; smoothed;
paste: coarse 10YR 7/2, very hard (Cherry fabric 7: misc.); many angular and subangular grey grains up to 0.1

KER 31 ?bowl base Corinth Lot 7164-31

form 1 (flat); d. c. 30; th. 0.5-0.8; smoothing marks outside, smooth inside;
paste: medium pale green 5Y 8/2 (Cherry fabric 1); several beige specks up to 0.2; several white specks up to 0.1; few angular black grains up to 0.1

KER 32 jar rim Corinth Lot 7164-32

form XIb.1, preserved to shoulder; d. 1.4; th. 0.6; traces of ?brown slip outside; paste: medium yellow-buff 10YR 8/2 (Cherry fabric 1); several dark grey angular grains up to 0.1; few beige and few white specks up to 0.1

KER 33 jar handle Corinth Lot 7164-33

round handle flattening to strap at join to shoulder; handle d. 1.8-2.0; wall th. 0.6; beginning of twisted-rope incision at broken end of handle; paste: semifine yellow 2.5Y 8/3 (Cherry fabric 1); few beige specks up to 0.2

KER 34 bowl or sauceboat base Corinth Lot 7164-34

form 6 (ring base); d. 5.5; wall th. 0.4; lustrous black (10YR 5/2) slip inside (worn at bottom) and outside around ring; paste: medium buff 10YR 8/3 (Cherry fabric 2); several dark grey grains up to 0.1; few dark brown grains up to 0.05

KER 35 bowl or sauceboat base Corinth Lot 7164-35

form 5 (ring base); d. 4.5; lustrous slip, varying black (5YR 4/1) to red (2.5YR 5/6) inside and out; paste: fine, varying 7.5YR 8/4 to 10YR 7/2, soft (Cherry fabric 2); no inclusions visible

KER 36 sauceboat handle Corinth Lot 7164-36

horizontal round handle attached below rim; handle d. 0.9; wall th. 0.5 lustrous slip inside and out, varying through brown (5YR 5/3) and black (N 4/0); paste: semifine buff 10YR 8/3 (Cherry fabric 2); few holes up to 0.1

KER 37 bowl rim Corinth Lot 7164-37

form VI.6 (thickened), with 'collapsed loop' handle, almost a lug, at lip; d. c. 40; th. 0.9; red (2.5YR 6/6) slip inside and on top of rim; paste: coarse buff 10YR 8/3 (Cherry fabric 3); many dark grey and dark brown angular grains up to 0.1; several white specks up to 0.2

KER 38 bowl rim Corinth Lot 7164-38

form VI.5 (thickened), with a rudimentary lug at the lip; d. c. 25; th. 0.8; red (2.5YR 4/6) slip inside and on top of rim;
paste: coarse pink 7.5YR 7/4 (Cherry fabric 3); many dark red angular grains up to 0.2; many holes up to 0.2

KER 39 base fragment Corinth Lot 7164-39

form 7 (vertical ring) base from large open vase; d. c. 20; th. 1.0; red 10R 5/6 slip inside;
paste: medium buff 7.5YR 7/4 to 10YR 8/4 (Cherry fabric 3); several dark grey angular grains up to 0.1; several holes up to 0.1

KER 40 jar or askos rim Corinth Lot 7164-40

form XIIa.1 (straight) d. 11; th. 0.5;
paste: coarse pink 6.75YR 7/4, hard (Cherry fabric 3); many dark grey and dark brown angular grains up to 0.1; several white specks up to 0.1

KER 41 bowl rim Corinth Lot 7164-41

straight (form VI.1?); d. c. 25; th. 0.6; red (2.5YR 5/6) slip outside;
paste: medium buff 7.5YR 7/4 (Cherry fabric 3); several dark red subangular grains up to 0.2; few dark grey and dark brown grains up to 0.1; few holes up to 0.1

KER 42 bowl rim Corinth Lot 7164-42

form VI.6 (thickened), with 'collapsed loop' handle, almost a lug, at lip; d. c. 50; th. 1.0-1.2; lustrous brown (7.5YR 5/2) slip inside;
paste: medium buff 10YR 8/3 (Cherry fabric 3a); several dark grey and black angular grains up to 0.2; several white specks up to 0.1

KER 43 jar rim Corinth Lot 7164-43

form XIVA.1 (flaring); d. 13; th. 0.8;
paste: very coarse 7.5 to 10YR 8/4 (Cherry fabric 3b); many dark red angular grains up to 0.4; few white specks up to 0.1

KER 44 ?bowl base Corinth Lot 7164-44

form 1 (flat) base of large open vase d. c. 10-20;
th. 1.3-1.5; smoothed inside and out;
paste: coarse red 2.5YR 5/6 (Cherry fabric 4); many
dark grey-brown angular grains up to 0.2; few white
specks up to 0.1

KER 45 baking pan spout Corinth Lot 7164-45

rim-to base section of baking pan at point where rim
dips; th. 1.0-1.5; smoothed inside;
paste: coarse, surface 7.5YR 6/4, core 10YR 6/1
(Cherry fabric 5); many rounded dark grey grains
(sand?) up to 0.1; several white specks up to 0.1

KER 46 ?bowl rim Corinth Lot 7164-46

form VI.7 (T-rim) from large bowl or pithos; d.
greater than 50; th. 1.2-1.4;
paste: very coarse, surface 7.5YR 8/4, core N 7/0
(Cherry fabric 6); very many angular dark grey
grains up to 0.2

KER 47 ?jar handle Corinth Lot 7164-47

round handle of 2-coil twisted-rope type attached to
lip of jar or askos (rim form XV.1); handle d. 1.9;
rim th. 0.7;
paste: coarse green 5Y 8/3 (Cherry fabric 1); many
subangular black grains up to 0.2

KER 48 spout fragment Corinth Lot 7164-48

half of spout and part of ?rim, perhaps from
'feeding bottle'; th. 0.5; spout d. c. 2.5;
paste: coarse buff-yellow 10YR 8/2, soft (Cherry
fabric 1); many subangular black grains up to 0.1;
several angular grey grains up to 0.1; few white
specks up to 0.1

KER 49 jar shoulder Corinth Lot 7164-49

th. 0.7-0.9; vertical smoothing marks outside;
paste: medium yellow 2.5Y 8/2 (Cherry fabric 1);
several rounded black grains up to 0.1; few holes up
to 0.1

KER 50 wall sherd Corinth Lot 7164-50

from a large vessel; th. 0.4-0.8;
paste: coarse green 5Y 8/2 (Cherry fabric 1); many
rounded black grains up to 0.2; several holes up to
0.2

KER 51 bowl or sauceboat base Corinth Lot 7164-51

form 9 (ring base); d. 4.4; th. 0.5; crackled
lustrous black (10YR 5/1) slip inside and out,
except beneath base ring;
paste: semifine buff 7.5YR 8/4 (Cherry fabric 2);
few holes up to 0.2

KER 52 sauceboat rim Corinth Lot 7164-52

type ind. (from side); th. 0.5; crackled lustrous
black (10YR 4/1) slip inside and out, with patches
of brown;
paste: fine buff 10YR 8/3 (Cherry fabric 2); no
inclusions visible

KER 53 bowl rim Corinth Lot 7164-53

form III.3 (incurving) rim with flattened top
bearing an incised groove; d. c. 15; th. 0.5;
crackled lustrous black (10YR 4/1) slip inside and
out;
paste: medium buff 10YR 8/2 (Cherry fabric 2);
several white specks up to 0.1

KER 54 jar rim Corinth Lot 7164-54

form XIb.1 (short, straight); d. 16; th. 0.8; traces
of red (2.5YR 6/6) slip outside, and inside lip
paste: coarse buff 7.5YR 8/5 (Cherry fabric 3); many
subangular dark grey and dark red grains up to 0.2;
several beige specks up to 0.1

KER 55 bowl rim Corinth Lot 7164-55

form V.5 (thickened); d. c. 40; th. 0.9; purplish
(2.5YR 5/3) slip inside and on top of lip;
paste: medium 7.5YR 8/4 (Cherry fabric 3); several
dark red angular grains up to 0.1; few dark
grey-brown angular grains up to 0.1

KER 56 base fragment Corinth Lot 7164-56

form 10 (high ring base) of large open vessel; d. 14; th. 0.7; traces of red (2.5YR 4/4) slip inside; paste: coarse 7.5YR 8/5 (Cherry fabric 3); many subangular black and dark grey grains up to 0.1; several holes up to 0.1

KER 57 wall sherd Corinth Lot 7164-57

th. 0.7; worn slip outside, varying brown to black; paste: coarse 7.5YR 7/4 (Cherry fabric 3b); many dark red subangular grains up to 0.2; few white specks up to 0.1

KER 58 base fragment Corinth Lot 7164-58

form 1 (flat) base from large vessel; d. c. 10; th. 1.4-1.8; smoothed inside and out; paste: very coarse, core grey 5YR 6/1, inside surface pink 5YR 7/4, outside surface buff 7.5YR 7/4 (Cherry fabric 4); very many angular and subangular grey-brown grains up to 0.2

KER 59 ?bowl rim Corinth Lot 7164-59

perhaps form VI.3 (thickened) rim of large bowl; th. 0.9-1.2; smoothed inside; paste: very coarse orange 5YR 7/6, crumbly (Cherry fabric 4); very many dark grey-brown subangular grains up to 0.2

KER 60 wall sherd Corinth Lot 7164-60

th. 0.8; thick crackled lustrous red (10R 5/4) slip outside; applied snakelike coils in zigzag pattern on outside surface, similar to those of the vase illustrated by Goldman (1931, p. 105 fig. 139); paste: very coarse, core grey 5YR 5/1, inner surface orange 5YR 7/5 (Cherry fabric 4); very many dark red-brown angular grains up to 0.2; few rounded brown grains up to 0.2

KER 61 wall sherd Corinth Lot 7164-61

th. 0.9-1.0; thick red 10R 5/4 slip outside; applied strips of snakelike zigzags outside, as KER 60; possibly from the same vase;
paste: very coarse, core and outer surface greyish 5YR 5/1, inner surface red 2.5YR 6/6 (Cherry fabric 4); very many subangular dark red grains up to 0.2; few subangular beige and brown grains up to 0.2

KER 62 baking pan spout Corinth Lot 7164-62

rim-to-base section at the lowest point of the rim; th. 1.0-2.0; smoothed inside;
paste: medium dull buff 7.5YR 7/3, crumbly (Cherry fabric 5); many rounded white, beige, dark grey, and dark brown grains (sand?) up to 0.05

KER 63 ?bowl rim Corinth Lot 7164-63

form V.5 (thickened) rim of large bowl or pithos; d. greater than 40; th. 1.0; periodic depressions, about finger-sized, along outside of thickened lip;
paste: medium, core grey 7.5YR 6/1, surface buff 7.5YR 8/4 (Cherry fabric 6); many rounded red, brown and grey grains (sand?) up to 0.05

KER 64 bowl rim Corinth Lot 7164-64

form II.5; d. c. 30; th. 1.2; smoothed inside and out; band of applied 'piecrust' on outside of lip;
paste: coarse, core brown 7.5YR 4/2, surface pink 7.5YR 7/4 (Cherry fabric 6); many dark grey-brown angular grains up to 0.2

KER 65 animal figurine MF 12233

rear half of quadruped torso; cylindrical body, stubby tail, rear legs broken; m. p. l. 5.7; d. c. 2.0; smoothed; traces of lustrous black slip on tail, belly, and left side, probably not in a striped pattern;
paste: medium buff 10YR 8/2 (Cherry fabric 2); several subangular grey grains up to 0.05; few white specks up to 0.05;
Cherry 1973, p.28

KER 66 animal figurine MF 12234

front half of quadruped torso; neck, legs, and waist broken; semicircular (round side up) in section; deep incision runs full length of underside; m. p. l. 6.0; w. 2.8; smoothed; dots of lustrous black slip (crackled where thick, brown where thin) on sides and back, d. 0.6-1.0; paste: semifine pink 7.5YR 8/4 (Cherry fabric 2); few angular dark red-brown grains up to 0.05; few white specks up to 0.05; Wiseman 1967a, p. 41 and Pl. 16dl; Cherry 1973, p. 28

KER 67 sauceboat rim C-69-193

perhaps near back (type I?); th. 0.4; outside, worn lustrous slip varying orange to red to brown to black; inside, cross-hatched triangles descending from rim, in dark brown (7.5YR 3/1) lustrous slip; paste: semifine yellow 2.5Y 8/2 (Cherry fabric 1?); few beige specks up to 0.1; Cherry 1973, pp.83-84

KER 68 sauceboat base C-65-354

type 13 (flaring foot, deeply formed underneath); d. 9.; th. 0.5; slipped and polished; mottled grey to buff to brown outside; paste: fine grey 10YR 6/1; very few subangular black grains up to 0.05; Cherry 1973, p. 83

KER 69 sauceboat rim and handle C-65-354

probably type II; horizontal handle attachment with right side of rim; probably same vase as KER 68; th. 0.4-0.5; slipped and polished; mottled grey to buff to brown; paste: fine grey 10YR 6/1; no inclusions visible

KOR 1 animal figurine MF6731

rear half of quadruped; stubby applied tail; concave underside, smoothed; m. p. l. 7.2; smoothed; traces of black (N 4/0) painted stripe down middle of back, from which descend vertical stripes;
paste: coarse yellow-green 5Y 8/2 (Cherry fabric 1); many angular black grains up to 0.1; several beige specks up to 0.2;
Weinberg 1937, p. 523 fig. 44

KOR 2 animal figurine MF2270

quadruped, tail broken, snout and ends of ?horns as well; eyes applied as elongated blobs with a horizontal slit; underside is deeply carved out, left rough; one deep gash from neck to tail, other shorter ones as well; incised gash below each 'horn'; h. 11; m. p. l. 17.3; smoothed, painted stripe down middle of back, from which descend vertical stripes on one side, back-sloping ones on the other; paint on 'horns' and eyes as well; colour varies 2.5YR 3/2 to 5/6;
paste: semifine buff 10YR 8/3 (Cherry fabric 2); few white specks up to 0.05; very few flakes of ?silver mica up to 0.01;
Kosmopoulos 1948, pp. 59-60, figs. 41-43

KOR 3 sauceboat rim C-76-344 (Temple Hill)

type ind.; vertical sides; traces of handle attachment; th. 0.5; good lustrous red-brown slip outside; vertical lines of lustrous red slip inside, only to the left of the handle area;
paste: fine pink 5YR 8/4 (Cherry fabric 2); very few white specks up to 0.05

KOR 4 sauceboat rim C-31-512

type I; left side to spout; gentle curves, perhaps shallow; m. p. l. c. 15; th. 0.5-0.7; thick lustrous black slip inside and out; shallow indentations along rim, except at spout; vertical band of slashed rope form applied to left of spout;
paste: coarse grey N 5/0 (Cherry fabric 7: miscellaneous); many angular grey grains up to 0.1

4.6.7 Korá kou

KRK 3 base of bowl or sauceboat Corinth Lot 7165-3

intermediate between forms 10 and 13 (splayed high foot, only slightly concave below); d. 5.4; h. to narrowest point 2.0; burnished lustrous black slip, mottling to grey-brown (5YR 4/1); paste: semifine grey N 5/0; several subangular dark grey grains up to 0.05

KRK 4 base of bowl or sauceboat Corinth Lot 7165-4

form 13 (splayed high foot, deeply curved beneath); d. 7.2; h. to narrowest point 1.7; mottled red-brown (2.5YR 3/2 to 5/6) slip inside and out; paste: fine pink 5YR 7/4; no inclusions visible

KRK 5 sauceboat rim and handle Corinth Lot 7165-5

probably type II; horizontal loop handle, rising slightly; handle d. 0.9; span 2.8; wall th. 0.4; mottled brown-black (5YR 3/1 to 5/3) slip inside and out, except below and on inner surface of handle; paste: fine buff 7.5YR 7/3; few beige specks up to 0.05

KRK 6 sauceboat rim and handle Corinth Lot 7165-6

probably type II; rising horizontal handle; handle d. 0.8; wall th. 0.5; worn lustrous black slip inside and out; paste: fine yellow 2.5Y 7/2; few beige specks up to 0.05

KRK 7 sauceboat rim and handle Corinth Lot 7165-7

probably type II; horizontal handle rising from below lip; handle d. 0.9; wall th. 0.4; thin lustrous brown to black slip outside (except beneath handle) and inside lip; paste: semifine yellow 2.5Y 8/2; few beige specks up to 0.1

KRK 8 sauceboat rim and handle Corinth Lot 7165-6

probably type II; horizontal handle rising from below lip; handle d. 0.8-1.2; wall th. 0.4-0.6; good red (2.5YR 6/4) slip inside and out, except beneath handle;

paste: fine pink 7.5YR 6/4; very few white specks up to 0.01; very few specks of ?silver mica

KRK 9 sauceboat rim and handle Corinth Lot 7165-9

probably type II; horizontal handle, rising slightly; handle d. 1.0; wall th. 0.4; red-brown (5YR 4/2 to 7/3) slip inside and out;

paste: semifine grey N 5/0; few holes up to 0.1

KRK 10 sauceboat rim and handle Corinth Lot 7165-10

probably type II; horizontal handle rising from rim; wall th. 0.6; handle d. c. 1.0; mottled red-black (10YR 4/1 to 5/3) slip inside and out; on handle at join to wall, 2 applied clay dots ('rivets'), one above the other; from each extends a horizontal applied band of slashed rope decoration;

paste: fine buff 7.5YR 7/4; few angular dark red grains up to 0.05

KRK 11 sauceboat spout Corinth Lot 7165-11

sharply downturned lip (type II?); th. 0.6; flaky lustrous black slip inside and out;

paste: fine yellow 2.5Y 8/2; few beige and white specks up to 0.05

KRK 12 sauceboat spout Corinth Lot 7165-12

sharply downturned lip (type II); th. 0.6; worn lustrous black slip inside and out;

paste: semifine yellow 2.5Y 8/2; few beige specks up to 0.1

KRK 13 sauceboat spout Corinth Lot 7165-13

type ind.; right tip, 60 degree; th. 0.5; good red-brown slip inside and out;

paste: fine pink 5YR 8/3; few dark red angular grains up to 0.05

KRR 14 sauceboat spout Corinth Lot 7165-14

type ind.; left tip, 90 degree; th. 0.4; good lustrous uncrackled black slip inside and out; fine buff 10YR 8/2; few subangular black grains up to 0.05

KRR 15 sauceboat rim Corinth Lot 7165-15

type ind.; from side of vase; th. 0.6; smoothed inside and out; paste: semifine green 5Y 8/2; small cracks, splits easily (overfired?); few beige specks up to 0.1

KRR 16 sauceboat rim Corinth Lot 7165-16

type ind.; pointed lip; th. 0.3; slipped and burnished; mottled grey to orange (5YR 5/1 to 6/4); paste: fine grey 5YR 6/1; no inclusions visible

KRR 17 wall sherd Corinth Lot 7165-17

th. 0.4-0.5; inside smoothed; outside, slipped and polished: two zones, one light grey (5Y 7/2), the other dark grey to orange (5YR 3/1 to 6/3); paste: fine grey 5YR 5/1; very few white specks up to 0.05

KRR 18 bowl rim-to-base section Corinth Lot 7165-18

rim form VII.1 (very open); base form 1 (flat); d. c. 15; th. 0.4; crudely burnished inside and out; mottled grey (7.5YR 4/1) near base to buff (7.5YR 8/2) near rim; paste: semifine grey N 5/0; several white specks up to 0.05

KRR 19 bowl rim-to-base section Corinth Lot 7165-19

rim form III.2 (incurved); base form 9 (ring); d. 13; base d. c. 3.5; th. 0.4-0.5; smoothed inside and out; paste: medium buff 7.5YR 8/4; several white specks up to 0.2; few subangular dark grey grains up to 0.1

KRR 20 bowl rim Corinth Lot 7165-20

form III.2 (pointed, incurved); d. c. 16; th. 0.4;
 crackled lustrous black slip inside and out;
 paste: medium buff 7.5YR 7/4; several angular black
 grains up to 0.1; few white specks up to 0.05

KRR 21 bowl rim Corinth Lot 7165-21

form III.1 (slightly inturned); d. 13; th. 0.5;
 uncrackled lustrous slip inside and out, varying
 dark red to black (2.5YR 5/4 to 3/1);
 paste: medium pink 7.5YR 7/4; several white specks
 up to 0.1; few light red angular grains up to 0.01

KRR 22 bowl rim Corinth Lot 7165-22

form IV.2 (offset); d. 18; th. 0.6; worn lustrous
 black slip inside and out;
 paste: semifine green 5Y 8/2; few angular black
 grains up to 0.1

KRR 23 bowl rim Corinth Lot 7165-23

form III.2 (inturned); d. 11; th. 0.5; worn lustrous
 black slip applied over rough surface inside and
 out;
 paste: fine yellow 2.5Y 8/2; few beige and white
 specks up to 0.05

KRR 24 ?bowl base Corinth Lot 7165-24

form 1 (flat); d. 7; th. 0.7-0.9; worn glossy
 burnished red (10R 5/6) slip inside and out, except
 beneath base;
 paste: semifine buff 10YR 7/3; few subangular dark
 grey grains up to 0.05; very few flakes of lustrous
 black ?stone up to 0.05; very few angular
 transparent grains up to 0.05

KRR 25 ?askos rim Corinth Lot 7165-25

form XV.1; round handle at lip; handle d. 1.9; wall
 th. 0.6;
 paste: medium green 5Y 7/2; several angular black
 grains up to 0.1; few white specks up to 0.1

KRR 26 jar rim Corinth Lot 7165-26

form XIa.2 (high, out-turned); d. c. 13; th. 0.8;
 paste: medium green 5Y 8/2; several angular and
 subangular black grains up to 0.1; few white specks
 up to 0.1

KRR 27 ?jar base Corinth Lot 7165-27

form 1 (flat); d. 4.8; th. 0.7; smoothed inside and
 out (thin green slip?);
 paste: fine green 5Y 7/3; very few white specks up
 to 0.1

KRR 28 jar shoulder Corinth Lot 7165-28

th. 0.7; smoothing marks outside; join of neck to
 shoulder visible inside;
 paste: fine green 5Y 8/2; no inclusions visible

KRR 29 ladle shaft Corinth Lot 7165-29

flattened, tapered; w. 2.5-4.0; th. 1.7; dark
 red-brown slip on one side;
 paste: coarse orange 5YR 6/6; very hard; many
 subangular dark red grains up to 0.1; several
 rounded dark grey grains up to 0.1

KRR 30 ladle shaft Corinth Lot 7165-30

round section; beginning of loop; d. 1.9-2.3; good,
 lustrous red-brown slip everywhere;
 paste: fine, orange surface 5YR 7/6, grey core 5YR
 6/1; very few white specks up to 0.1

KRR 31 baking pan rim-to-base section Corinth Lot 7165-31

rim form VIII.1 (shallow); base form 1 (flat); d.
 greater than 50; th. 0.8; smoothed inside and out,
 except beneath base;
 paste: coarse, red surface 2.5YR 6/4, grey core
 2.5YR 6/1; many angular dark grey and dark red
 grains up to 0.2

KRR 32 baking pan rim Corinth Lot 7165-32

form VIII.1 (shallow); th. 1.0; thin slip, buff inside, grey outside;
 paste: very coarse, buff-pink 5YR 6/4 near inside, grey 10YR 6/2 near outside; crumbly; very many angular dark grey and dark red grains up to 0.3

KRR 33 baking pan rim Corinth Lot 7165-33

near spout area; form VIII.1 (shallow); flat (as form 1) base; th. 1.3; smoothed;
 paste: coarse buff-pink 7.5YR 7/4; many subangular white grains up to 0.1; several rounded light brown, light grey, dark red, and dark grey grains (sand?) up to 0.1

KRR 34 bowl rim Corinth Lot 7165-34

form VI.3 (flattened, hemispherical); 'collapsed loop' handle below lip; d. c. 35; good polished red (10R 6/8) slip inside and on top of lip;
 paste: coarse pink 5YR 7/4; many angular dark red grains up to 0.2

KRR 35 frying pan rim Corinth Lot 7165-35

shallow slope, but steeper than VII.1; d. c. 20; th. 0.6; polished black slip inside and out: 2 rows of vertical incisions outside: just below lip and near base, both with white fill ('Mainland' type?);
 paste: medium grey-brown 7.5YR 6/2; many rounded black, dark brown, orange, beige, and white grains (sand?) up to 0.05

KRR 36 wall sherd Corinth Lot 7165-36

probably from a closed vessel; th. 0.7; inside smoothed; lustrous black slip outside, except between applied horizontal bands of incised rope decoration; as Blegen 1921, p. 5 fig. 3 no. 7;
 paste: coarse buff-pink 7.5 to 10YR 8/4; many subangular dark grey grains up to 0.2

KRK 37 weight Corinth Lot 7165-37

cylindrical, tapering slightly; d. 5.7 at base; m. p. h. 7.0; two vertical holes d. 0.6; smoothed (with a thin grey slip?);
 paste: medium pale orange 7.5YR 7/6; very soft and crumbly; unfired; several angular white shell fragments up to 0.2; few angular dark grey grains up to 0.1;
 as Blegen 1921, p. 104 fig. 129 nos. 4 and 5; see also KRK 48

KRK 38 bowl rim-to-base section "EH XIII" written on sherd

rim form VIII.3; base form 2 (indented); d. 16; th. 0.4; band of red (2.5YR 6/6) slip at edge of lip inside;
 paste: medium buff 7.5YR 8/4; several subangular beige grains up to 0.2; few white specks up to 0.2; several beige specks up to 0.05;
 Blegen 1921, p. 6 fig. 5 no. 2

KRK 39 bowl rim

form VIII.1 (shallow); d. 18; th. 0.4; band of red (2.5YR 6/6) slip at edge of lip inside;
 paste: semifine buff 7.5YR 8/1; several subangular dark grey grains up to 0.01;
 Blegen 1921, p. 6 fig. 5 no. 3

KRK 40 bowl rim "g IV" written on sherd

short splayed rim, similar to form XIb.2; d. 12; th. 0.5; good red (2.5YR 5/4) slip outside and inside over lip;
 paste: fine buff 7.5YR 8/4; no inclusions visible;
 Blegen 1921, p. 6 fig. 5 no. 1

KRK 41 askos handle

strap handle, widening toward bottom; section 2.5 by 1.2 near rim, 4.0 by 0.8 near bottom; good dark brown (10R 3/2) slip everywhere;
 paste: fine pink 5YR 7/4; few white specks up to 0.05;
 Blegen 1921, p. 7 fig. 7

KRK 42 tankard belly "SX" or "XS" written on sherd (EH III)

low bulge of tankard; th. 0.7; beige (7.5YR 8/4) wash outside, over which is a painted pattern of bands of horizontal red (2.5YR 6/6) lines, some pairs joined with short diagonal strokes, upper ones with these strokes along the top as a 'fringe'; paste: fine pink 5YR 7/4; few white specks up to 0.05; Blegen 1921, p. 9 fig. 9 no. 10 (joins to no. 18), and Pl. I no. 3

KRK 43 wall sherd "E II" written on sherd (EH III)

th. 0.5; beige (10YR 8/3) wash outside, painted with a pattern of red (10R 4/4) lines, parallel (with oblique cross-strokes) and cross-hatched; paste: fine orange 5YR 7/6; no inclusions visible; Blegen 1921, p. 9 fig. 9 no. 13

KRK 44 tankard belly "E III" written on sherd (EH III)

low bulge of tankard; th. 0.4-0.6; beige (7.5YR 7/6) slip, largely painted over by 2 areas of black (7.5YR 4/1), between which is a horizontal zone consisting of 2 bands of 4 horizontal black lines each, between which is a cross-hatched zigzag 3 lines thick; paste: semifine beige 7.5YR 6/4; few white specks up to 0.1; Blegen 1921, p. 9 fig. 9 no. 17, and Pl. I no. 2

KRK 45 wall sherd "EA XVII" written on sherd (EH III)

th. 0.7-0.9; buff (10YR 8/3) slip, painted with black (N 5/0) lines, 5 or 6 of them parallel, a pair of oblique ones, the line from each set closest to the other set being fringed with short oblique strokes; paste: fine grey-brown 10YR 7/2; no inclusions visible; Blegen 1921, p. 9 fig. 9 no. 3

KRK 46 ?tankard rim "S IV" written on sherd (EH III)

form XIIa.5; d. 9; th. 0.6; smooth beige (10YR 7/3) inside, covered just below lip by crackled lustrous black slip which extends over the lip to cover the exterior; on it is painted in beige (10YR 8/3) at least 2 horizontal lines, the uppermost having oblique 'fringes' on its upper side;
paste: semifine yellow-green 2.5Y 8/2; few white specks up to 0.1;
Blegen 1921, p. 9 fig. 9 no. 15

KRK 47 wall sherd "g II" written on sherd (EH III)

th. 0.5; dull, slightly crackled black (N 4/0) slip outside, on which two parallel stripes of beige (2.5Y 7/2);
paste: fine grey N 6/0; few flakes of ?silver mica up to 0.05; few white specks up to 0.05;
Blegen 1921, p. 9 fig. 9 no 16

KRK 48 earth from holes of KRK 37

semifine; brownish 10YR 6/4 unfired, buff 10YR 7/3 fired in an electric kiln; several rounded to subangular white, beige, red, and black grains up to 0.02

4.6.8 Lake Vouliagméni

For ease of Consultation, this section has been reproduced from the author's M.Sc. thesis (Attas 1975, pp. 24-44).

Samples of the Natural Clay (010-016)

A large quantity of the clay immediately beneath the bottom layer (levels (13) and (14)) of the pottery dump in trench AI was available for analysis. Samples of other clays from the immediate vicinity of Lake Vouliagméni were also taken, but have not yet been analyzed. Small amounts of the natural clay were refined to various extents and fired to various temperatures before they were sampled for analysis, in an attempt to duplicate the treatment accorded to clay by the prehistoric potters. It is felt that the degree of refining of 012-014 corresponds to "semifine" pottery, that of 010 and 011 to coarse vases, and that of 015 and 016 to the liquid "slip" applied to the surface of some fine vases. Firing temperatures were intended to cover the range from that of unfired clay, through loss of bound water and loss of carbon dioxide from the carbonate ion, to the beginnings of sintering or vitrification.

<u>010</u>	AI	natural clay	10YR 7/2
		raw lump dried overnight at 110 C	

- 011 AI natural clay 7.5YR 6/4
raw lump mixed with water, left to dry, and fired to 700 C for one hour in an electric (oxidizing) kiln.
- 012 AI natural clay 7.5YR 7/4
raw lump mixed with water, left to settle for one hour; upper part of sediment removed, left to dry, and fired to 700 C as 011.
- 013 AI natural clay 7.5YR 7/3
raw lump treated as 012 but fired to 900 C.
- 014 AI natural clay 2.5Y 5/6
raw lump treated as 012 but fired to 1100 C.
- 015 AI natural clay 5YR 5/8
upper part of sediment (as 012) centrifuged for one minute; upper part of that dried and fired to 700 C for one hour.
- 016 AI natural clay 10YR 5/6
sediment treated as 015 but fired to 1100 C.

Objects from the Square Structure (101-108)

This collection of eight vases was found as a group in a corner of the structure making up the second phase of EH II occupation at Lake Vouliagmeni. They are thus all accessioned in level (18sq), and are given individual vase numbers.

- 101 AII (18sq) Vase no. 1 saucer: complete (mended)
7.5YR 7/5

semicoarse buff, varying to orange and pink (10YR 7/4 to 5YR 6/6), with large (c. 0.2) dark red grains, some smaller orange-brown and many tiny dark grey and black ones; no traces of either slip or burnish inside or out; low foot-ring and inturned rim: cf. Siedentopf 1973: 4, fig. 2, 7; long-tailed T incised outside below rim; h. 6.1, max. d. 12.3; ("Saucer" is the technical term used by Caskey and Caskey (1960: 165 n.33) for these small bowls, which can be very shallow or relatively hemispherical, as this one is).

- 102 AII (18sq) Vase no. 2 saucer: complete (mended)
10YR 7/3

semifine pale buff, varying to yellow and pink (2.5Y 8/4 to 7.5YR 7/4), with various tiny inclusions in dark red, orange-brown, brown, black, and dark grey; poorly preserved dark red-brown slip inside (2.5YR 6/6 to 7.5YR 5/4), with traces of horizontal brush marks; low foot-ring and inturned rim (ill. Michaud 1973: 275 fig. 43): cf. Caskey and Caskey 1960: 154 fig. 11, VIII.34; h. 6.2, max. d. 11.2.

- 103 AII (18sq) Vase no. 3 sauceboat: spout missing
5Y 8/2

fine pale green, with no traces of slip or burnish inside or out; low foot-ring, deep cylindrical body, double vertical handle like an 8 in horizontal section; cf. Caskey 1960: 291 fig. 1, III; h. (as preserved) 13.8; max. d. 12.6.

- 104 AII (18sq) Vase no. 4 sauceboat: rim fragment
with handle
5YR 8/4

semifine orange with some dark red, orange-brown, brown, white and beige inclusions c. 0.1 and smaller, and some impressions of plant-stalks c. 0.1 long; no traces of slip inside or out; squat horizontal handle at level of rim; cf. Caskey 1960: 291 fig. 1, intermediate between types II and IV.

105 AII (18sq) Vase no. 5 bowl: rim to base preserved
7.5YR 7/4

coarse buff, with large (0.2 - 0.5) angular grey-brown inclusions, smaller dark red ones, and others; thick cream slip inside and out; very shallow (cf. Caskey 1972: 371 fig. 6, C34 for rim), with a low foot-ring; h. 6.9, d. 70.

106 AII (18sq) Vase no. 6 bowl: rim fragment
10YR 7/4

coarse dark red (5YR 5/8) with large (c. 0.2) white, beige, dark red, grey and black inclusions; unslipped, but smoothed on outside; lug handle just below thickened rim, cf. Säflund 1965: 147 fig. 112, 19; d. greater than 50.

107 AII (18sq) Vase no. 7 "salt pot": complete
7.5YR 7/4

semicoarse buff, poorly fired, with small (c. 0.1) angular dark grey and black inclusions; many traces of red slip (2.5YR 4/6) inside and out; flat oblong dish divided into two compartments, with small vertical ribs and horizontal lugs, applied outside; h. 4.6, l. 16.4, w. 8.1.

108 AII (18sq) Vase no. 8 ram vase: complete
5YR 6/6

semicoarse orange, with large (c. 0.2) dark red inclusions and smaller white, brown, grey and black ones; plastic vase in form of crouched ram, with the opening on its back, off centre; similar heads have occasionally been found on sauceboat spouts, cf. Weinberg 1969: l. 13.6, h. 6.6, w. 5.2.

Miscellany from the Pottery Dump (111-116)

These six samples were taken from objects of particular archaeological interest found in the lower levels of trench AI; levels (12) and (13) correspond to the dump

proper, and (9A) to its levelling in preparation for the large building of the third phase of occupation.

Object subcodes enclosed by triangles indicate objects separately recorded as small-finds. The subcode UT is short for "Unaccessioned Tile"; i.e., tile fragments only separately recorded after the excavation, during study. The waster fragments were also separately recorded then, and given capital letters for identification.

111 AI (12) incised sherd 7.5YR 7/4

semifine, well-fired buff with a few tiny (less than 0.1) orange-brown, dark red, and black inclusions; no traces of slip either inside or out; a few deep incised lines outside, many lighter scratches inside, all made before firing; 8.2 by 7.5.

112 AI (13) bowl(?): impressed base 7.5YR 7/4

semifine buff, dense and well-fired, with very small dark red, dark grey, and black inclusions; very fine stalk impressions visible on fresh break; traces of red slip (5YR 6/4-6/6) inside and out; impression of a woven mat on the bottom, probably the mat on which the pot was resting while it was being formed; cf. e.g., Blegen 1928: 177 fig. 109; base d. 6.0.

113 AI (12)  sealings on fired clay lump 10YR 7/1

semifine pale buff, hard and well-fired, with a few very small black inclusions; stamped four times with the same seal (circular, d. 2.55, of complex non-symmetric design); lump dimensions 5.4 by 4.2 by 1.9.

114 AI (9A) plastic vase fragment: head of fish
10YR 7/3

semifine pale buff, hard, dense and well-fired, with specks of dark grey, brown and black inclusions; reddish slip (2.5YR 4-5/6) outside; preserved l. 4.6, h. 3.5, w. 3.2.

115 AI (13) UT.3 tile: large portion including edge
10YR 7/3

semifine pale brown with small (c. 0.1) grey-brown stone inclusions; unslipped; along edge, three parallel rows of impressed slanted triangles, similar to the decoration on a pithos rim from Eutresis (cf. Goldman 1931: 96 fig. 124,2); l. 11, w. 12, th. 3.7-3.9 at edge, 2.4 elsewhere.

116 AI (12) waster B 2.5Y 8/2

extremely hard, semifine greenish clay with small, (c. 0.1) black or dark grey inclusions, and patches of bluish grey-green (7.5Y 8/2?) on surface; large mass (18 by 16 by 7) of collapsed overfired pottery from a kiln accident, twisted and stuck together.

Objects from an Occupation Layer (151-160)

All ten objects in this group come from level (17) in trench AII, which is part of the third phase of EH II occupation, immediately preceding the final destruction of the site. The sherds chosen for sampling were typical in colour and fabric of most wares found in occupation levels, except for 160, an example of the rare "fine mottled ware".

151 AII (17) 2 bowl(?): handle fragment 5Y 8/2

coarse green with tiny black, white, and grey inclusions; unslipped; lug or strap handle attached to plain bowl rim; th. 0.7.

152 AII (17) 4 jar: rim fragment 2.5Y 7/2

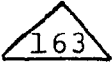
semifine green with tiny black inclusions; unslipped; neck of jar with flaring rim, d. 12; cf. Säflund 1965: 151 fig. 119b, 4.

- 153 AII (17) 5 jar(?): handle fragment 5Y 8/1
semifine green with tiny black inclusions; unslipped; handle circular in section, d. 1.8.
- 154 AII (17) 13 bowl: rim fragment 7.5YR 7/4
semifine buff with a few dark red inclusions; bowl with thickened, flat-topped rim, d. 46; dark red (10R 5/6) thick matt worn slip inside; cf. Säflund 1965: 147 fig. 112, 10.
- 155 AII (17) 30 large bowl(?): wall fragment 5YR 6/4
semifine pink with tiny dark grey and dark red inclusions; wall or possibly rim fragment of large bowl (or pithos?), d. 55, with two horizontal applied bands of "piecrust" decoration on outside; light brown (7.5-10YR 8/3) matt slip inside and out.
- 156 AII (17) 31 bowl: rim fragment 10YR 7/4
coarse red with large (c. 0.2) dark grey angular inclusions; flat rim, d. 60, cf. Säflund 1965: 147 fig. 112, 23a.
- 157 AII (17) 33 bowl: rim fragment 7.5YR 6/4
coarse red with large dark grey inclusions; thickened rim with flat top, d. 33; thick matt cream slip (2.5Y 8/2) inside and out; cf. Säflund 1965: 149 fig. 117, 5.
- 158 AII (17) 35 bowl: rim and handle fragment 10YR 6/3
coarse red with large (c. 0.2) dark grey inclusions; plain bowl rim (d. 40) with beginnings of round handle emerging from top, width 1.8; thick matt cream slip (2.5Y 8/2) inside and out; cf. Fossey 1969: 66 bowl 2.
- 159 AII (17) 36 bowl: rim fragment 7.5YR 6/4
coarse red with small dark red and grey inclusions; incurving rim, d. 32, with applied "piecrust" decoration outside along edge; thick matt cream slip (2.5-5Y 8/2) inside and out; cf. Säflund 1965: 149 fig. 116, 8.

- 160 AII (17) 52 sauceboat: rim fragment 2.5Y 7/2
fine grey-pink mottled ware, very smooth surfaces,
varying in colour from 7.5YR 8/4 to N 8/0, th. 0.3-0.4;
for fabric cf. Caskey and Caskey 1960: 150 and 153.

Fragments of Mud-Brick (201-206)

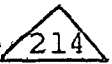
Six of the many pieces of sun-dried mud-brick were sampled, with colours varying from orange to green. Most were recorded as small-finds during excavation and so given numbers enclosed in triangles, but a couple were only separately recorded during study as "unaccessioned terra-cotta" or UTC.

- 201 AII (11)  mud-brick fragment 2.5Y 7/2

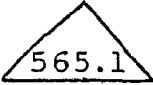
bright yellow with small black inclusions; 5.2 by 4.9 by 3.7.

- 202 AI (5E)  mud-brick fragment 7.5YR 7/4

pale orange, quite pure; 6.0 by 4.5 by 2.8.

- 203 AII (7)  mud-brick fragment 10YR 8/3

pale orange-buff with light red inclusions, among others; 5.3 by 4.6 by 2.4.

- 204 AI (5E)  mud-brick fragment 2.5Y 7/2

pale yellow-green with fine stalk impressions; 4.5 by 3.5 by 3.0.

- 205 AII (18sq) UTC 8.1 mud-brick fragment 2.5Y 8/2

pale yellow with small black inclusions; a flat surface, with traces of burning; 5.7 by 4.6 by 3.3.

- 206 AII (18sq) UTC 8.2 mud-brick fragment 7.5YR 7/4
semifine orange-brown; a flat surface; 3.2 by 3.2
by 2.7.

Vases from Area "B" (301-304)

The four outstanding objects from the small excavation (designated "B"), on the hilltop just north-west of the main excavation ("A") were also sampled. They are EH II in date, though their chronological relationship with the three phases of occupation of the main excavation is not yet clear.

- 301 BII/III (3) 51: B Vase no. 4 jug: rim to belly
preserved at handle
10YR 7/4

semifine buff-brown, with a red slip (5YR 4/3) outside; globular upper body, constricted neck, conical rim, possibly a spout, strap handle fragments at rim and shoulder; preserved h. 7.0; cf. Goldman 1931: 103 fig. 136.

- 302 BII/III (2) B Vase no. 1, saucer (mended):
only chips missing
10YR 7/3

fine pale yellow-buff (2.5Y 8/2 to 7.5YR 8/4) with flakey worn black(?) slip inside; d. 13.6, h. 6.0; cf. Caskey and Caskey 1960: pl. 50, VIII.22.

- 303 BII baulk, (1) 1: B Vase no. 3 sauceboat: rim to
base preserved at back
7.5YR 7/4

semifine buff with a few small (c. 0.1) light red and red-brown angular inclusions; thin matt slip inside and out, dark red to dark brown (5YR 6/6 to 5YR 4/4), with brush marks; quite squat, ring base, high horizontal handle; roughly shaped outside, smoother inside; preserved h. 11.0; cf. Caskey 1960: 291, fig. 1, intermediate between types II and IV.

304 BIII (3) 37: B Vase no. 2 askos: rim with
handle
10YR 7/3

semifine orange with a few small (0.5-1.5) white and grey inclusions; dull orange slip (10YR 8/3) inside and out; handle round in section leaving horizontally from edge of rim; d. of opening 9.0, th. 0.45; cf. Caskey and Caskey 1960: pl. 51, VIII.28.

Representative Sherds from the Pottery Dump (401-422)

Sherds from pots of typical shape and fabric were selected for sampling. Among the most common shapes were plates (401-407), bowls with "piecrust" applied decoration (408-413), and jars (415, 416), in fabrics ranging from buff to green.

401 AI (12) 707 plate: rim fragment 7.5YR 6/4
coarse red with many inclusions up to 0.1 in size; unslipped; flat or slightly concave shape, with plain rim: cf. Caskey 1972: 364 fig. 3, B28; d. 60; th. 0.9.

402 AI (12) 711 plate: rim fragment 7.5YR 7/6
semicoarse orange-red with several inclusions up to 0.06 in size; unslipped; plain rim, as 401; d. 30, th. 0.6.

403 AI (12) 713 plate: rim fragment 10YR 7/4
semifine buff with a few inclusions up to 0.02 in size; unslipped; plain rim, as 401; d. 22, th. 0.6.

404 AI (12) 747 plate: rim fragment 10YR 7/4
semifine buff with a few inclusions up to 0.02 in size; unslipped; plain rim, as 401; d. 35, th. 0.7.

- 405 AI (12) 753 plate: rim fragment 2.5Y 7/2
coarse green with several inclusions up to 0.08 in size; unslipped; plain rim, as 401, possibly from a large bowl; d. 60, th. 0.8.
- 406 AI (12) 507 plate: rim fragment 10YR 7/3
semicoarse buff with some small dark red inclusions; unslipped; thickened, rounded rim: cf. Caskey 1972: 371 fig. 6, C34; d. 50, th. 0.6.
- 407 AI (12) 545 plate: rim fragment 10YR 7/3
semicoarse buff with some inclusions up to 0.1 in size; unslipped; slightly incurving, rounded rim: cf. Caskey 1972: 371 fig. 6, C5; d. 24, th. 0.7.
- 408 AI (12) 706 large bowl: rim fragment 10YR 5/2
semifine reddish (with a grey core) with a few inclusions up to 0.1 in size; unslipped; thickened, incurving rim with scalloped "piecrust" outside; cf. Siedentopf 1973: 10 fig. 8; d. 30, th. 0.8.
- 409 AI (12) 719 large bowl: rim fragment 7.5YR 7/6
semicoarse orange with a few inclusions up to 0.1 in size; unslipped; smoothly inturning rim with "piecrust" decoration applied below lip, outside; cf. Fossey 1969: 58 fig. 3, 2 (top); d. 30, th. 0.5.
- 410 AI (12) 733 large bowl: rim fragment 10YR 8/2
semicoarse yellow with many inclusions up to 0.2 in size; unslipped; thickened rim with "piecrust" decoration outside below lip; cf. Säflund 1965: 147 fig. 112, 22; d. 40, th. 1.2.
- 411 AI (12) 756 large bowl: rim fragment 7.5YR 6/2
coarse pale green with many inclusions up to 0.2 in size; unslipped; thickened rim with "piecrust" decoration applied outside; cf. Säflund 1965: 149 fig. 117, 5; d. 35, th. 2.5.

412 AI (12) 558 large bowl: rim fragment 7.5YR 6/4

coarse red with many large (c. 0.2) inclusions and a thick green slip inside and out; "piecrust" decoration along outside of lip; cf. Säflund 1965: 149 fig. 116, 8 (but yet more incurving than his); d. 30, th. 1.0.

413 AI (12) 563 large bowl: rim fragment 7.5YR 8/2

semifine buff with only a few very small (c. 0.05) inclusions; unslipped; "piecrust" decoration outside below gently inturned, thickened rim; cf. Siedentopf 1973: 9 fig. 7, 76 (but deeper than his); d. 60, th. 1.8.

414 AI (12) 567 thick pan: rim fragment 7.5YR 7/4

semicoarse dull orange with many small (c. 0.1) dark red inclusions; unslipped; very shallow, with thick rounded vertical rim; cf. Caskey 1972: 367 fig. 4, B66 (but a little more upright than his); d. 30, h. 4.5, th. 1.5.

415 AI (12) 547 jar: fragment of rim with handle 10YR 7/2

semicoarse yellow with many small black inclusions; unslipped; base of vertical handle of twisted-rope type attached to slightly outturned, rounded rim; cf. Goldman 1931: 113 fig. 151, 3; d. 8, th. 0.6.

416 AI (12) 569 jar: fragment of rim with handle 10YR 7/2

semicoarse yellow with many small black inclusions; unslipped; base of vertical handle of twisted-rope type attached to slightly outturned, rounded rim; cf. Goldman 1931: 113 fig. 151, 3; almost identical in form and fabric to 415; d. 10, th. 0.5.

417 AI (12) 576 saucer: rim fragment 2.5Y 7/2

fine yellow-green; unslipped; pointed, sharply inturned rim; cf. Siedentopf 1973: 4 fig. 2, 7; d. 15, th. 0.3.

- 418 AI (12) 579 jar: rim fragment 5Y 8/1
fine yellow-green; unslipped; rounded, smoothly
outturned rim; cf. Caskey and Caskey 1960: 141
fig. 7, IV.6; d. 9, th. 0.4.
- 419 AI (12) 542 large bowl: rim fragment 7.5YR 7/4
semicoarse red-orange, with some medium (c. 0.15)
inclusions; dark red slip inside; gently inturned,
flattened rim; cf. Säflund 1965: 151 fig. 120, 10;
d. 30, th. 1.0.
- 420 AI (13) 1604 bowl: rim fragment 7.5YR 7/4
semifine orange, with a few small dark red inclusions;
red slip inside and over lip; flat, smoothly inturned
rim with lug handle below lip; cf. Caskey and Caskey
1960: 141 fig. 7, IV.2; d. 42, th. 0.6.
- 421 AI (12) 609 bowl: rim fragment 10YR 6/1
fine grey, slipped inside in red and outside in
mottled shades of orange, brown, grey and black;
hard clay, outer surface pitted, also showing
burnishing marks; plain rim, but twisted (due to
a kiln accident?).
- 422 AI (12) 843 bowl: rim fragment 10YR 7/4
semicoarse buff, with many small black inclusions;
unslipped; flat inturned rim, with uneven "piecrust"
along outside of lip; twisted shape, scarred inside
(due to a kiln accident?); d. 20?, th. 1.5.

Late Helladic ("Mycenaean") and Archaic ("Corinthian")

Pottery (501-526)

These sherds were found in the upper levels of the
excavation more or less associated with the Mycenaean wall

and the post-holes of the Archaic period. The dates and attributions given were kindly supplied by the excavator.

In this section, FM stands for the Furumark Motive Number (see Arne Furumark, The Mycenaean Pottery: Analysis and Classification; Stockholm 1941). Sample 510 is an EH II sherd of unusual nature which had found its way into an upper level.

501 AI (4) 1 Corinthian skyphos: base fragment 2.5Y 7/1

fine grey, with traces of black and red-orange paint on the bottom inside and on the wall outside.

502 AI (4) 2 Corinthian bowl or skyphos: base fragment 10YR 8/3

fine buff, with thin flakey black glaze inside and out.

503 AI (4) 3 Corinthian miniature bowl: rim fragment 7.5YR 7/7

fine orange, unslipped; apparently hand-made; d.8.

504 AI (4) 19 Corinthian skyphos: base fragment 10YR 8/4

fine buff with orange surface; smooth shiny black glaze inside and out.

505 AI (4) 20 Corinthian pyxis lid: rim fragment 10YR 8/3

fine yellow-buff; painted design on upper surface: red bands bordering a band of black checkerboard; Middle or Late Protocorinthian (c. 700-640 BC).

506 AI (4) 30 Corinthian skyphos: base fragment 7.5YR 7/5

fine orange, with red paint in the "radiating base lines" pattern, and red circle underneath base.

- 507 AI (5A) 25 Mycenaean vessel: fragment of spout
5Y 7/1

fine green ("Minyan"); a matt brown horizontal stripe of paint around the rim, with attached brown vertical stripes.

- 508 AI (5C) 6 Mycenaean closed vessel(?): wall fragment
10YR 8/3

fine buff, with one wide and three narrow bands of red lustrous paint (5YR 6/8) on the outside; th. 0.5; LH IIIA or IIIB.

- 509 AI (6) 1 Mycenaean kylix: base fragment 7.5YR 7/4

fine yellow-orange, with black paint on upper surface; LH IIIA or IIIB.

- 510 AI (7) 277 EH II vessel: wall fragment 10YR 7/1

fine grey, with mottled dull red, brown, yellow and grey surfaces, slipped and polished (cf. Caskey and Caskey 1960: 153); possibly from sauceboat; th. 0.3-0.4.

- 511 AII (2) 1 Corinthian skyphos: base fragment 2.5Y 8/2

fine beige; interior dull black glaze; exterior dull black glaze under base ring inside which two concentric circles and filled centre in red paint; d. 4.0.

- 512 AIII (1) 5 Corinthian large closed vessel: base fragment
7.5YR 8/4

heavy base ring (d. 8.0) in fine buff, with red paint on outside.

- 513 AIII (1) 12 Corinthian pyxis lid: rim fragment 10YR 7/3

fine buff with traces of white or pale pink slip on upper surface; d. 12.0.

- 514 AIII (3) 8 Corinthian pyxis lid: fragment 7.5YR 7/4
fine buff-orange, with filled centre and compass-drawn concentric circles in dark red paint on upper surface; Late- or Subgeometric (c. 750-650 BC).
- 515 AIII (3) 37
This sample was taken but not analysed. The number remains in the catalogue to simplify the coordination of analytical and archaeological records.
- 516 AIII (4B) 7 Mycenaean kylix: base fragment 7.5YR 7/4
fine orange-brown, with traces of red paint on upper surface; LH IIIA or IIIB; d. 9.0.
- 517 AIII (5) 2 Mycenaean conical bowl: rim fragment 10YR 8/4
fine buff with yellowish slip inside and out; painted with a black band on the inside and a broad red band on outside of rim and top of shoulder; LH IIIA or IIIB; d. 56.
- 518 AIII (5) 6 Mycenaean deep bowl(?): rim fragment 7.5YR 8/5
possibly rather an amphōra; uplifted horizontal handle attached at rim; fine buff with traces of black and red paint on outside; LH III.
- 519 AIIIS (4) 1 Mycenaean vessel: wall fragment 2.5Y 7/3
pale grey with tiny black inclusions; unslipped; a single band of dull brown paint 0.6 broad; th. 0.4-0.6; LH IIIC?
- 520 AIIIS (4) 3 Mycenaean deep bowl: rim fragment 10YR 8/3
fine pale yellow, with high-quality black lustrous paint inside and out; d. 18, th. 0.4-0.5; LH IIIA or IIIB.

521 AI (3) 51 Corinthian lamp: spout fragment 7.5YR 7/4
fine buff, with black glaze inside body and spout;
semi-open type; 5th century BC?

522 AII (6B) 1 Mycenaean open vessel: wall fragment
7.5YR 8/4

fine buff, with a cream slip inside and out; a black
band of paint inside, and a black band with red cross-
hatching outside (FM 78); LH I or II.

523 AII (6B) 6 Mycenaean vessel: wall fragment 7.5YR 8/4

fine buff, with a cream slip inside and out; on the out-
side, two parallel wavy red lines painted between
two parallel straight horizontal red lines (FM 53.9);
LH I or II.

524 AII (6B) 11 Mycenaean open vessel: handle fragment
7.5YR 7/4

fine buff, with a cream slip inside and out; a stripe
of brown paint on the inside and a stripe of black on
the outside; lower junction of high-swung handle.

525 AII (6B) 14 Mycenaean deep bowl: handle fragment
7.5YR 8/3

fine buff, with a cream slip inside and out; cracked
black paint on the inside, and black vertical stripes
under the handle on the outside; rim and beginning of
vertical strap handle; probably LH IIIC.

526 AII (6B) 36 Mycenaean bowl(?): rim fragment 2.5Y 8/2

fine buff, with a thin dull line around the outside
of the rim; possibly from a shallow, carinated bowl;
LH II or III.

Early Helladic I Pottery from the 1965 Excavation (601-623)

Most, though not all, of this material was published in the Annual of the British School at Athens for 1969. The descriptions given here may differ slightly from the published ones as a result of further examination of the pottery.

601 VP65 YZ pot 4 "frying pan": rim fragment 10YR 6/2

coarse grey-brown with burnished black slip inside; incised with simple strokes, spirals, and connecting tangents; of mainland type as opposed to Cycladic (Renfrew 1972: 536); ill. Fossey 1969: 68 top right.

602 VP65 Z J1 jar: rim fragment 5YR 7/3

fine dark red, unslipped but burnished; thick flaring rim; ill. Fossey 1969: 66 top left.

603 VP65 Z J10 jar: shoulder fragment 7.5YR 7/6

fine orange-buff; pattern of small stamped triangles on shoulder, combined with deep incised lines and smaller, shallower incisions; ill. Fossey 1969: 66 top centre.

604 VP65 Z J11 jug: fragment of neck and shoulder 10YR 6/1

coarse grey with small black inclusions (similar to 608); incised lines in groups of three on shoulder; ill. Fossey 1969: 66 centre.

605 VP65 Z B2 bowl: rim fragment 10YR 7/4

fine buff, with traces of smoothing lines on outside; heavy loop handle rising above rim; ill. Fossey 1969: 66 top right.

606 VP65 Z B3 bowl: rim fragment 10YR 7/3

fine buff, with thin red slip (5YR 6/6) inside and out, burnished; flat-rimmed shallow bowl with a hole pierced a little below the rim; ill. Fossey 1969: 66 top right.

607 VP65 Z P1 "frying pan"?: rim fragment.
10YR 7/3

coarse orange, unslipped, with a few black and dark red inclusions; decorated with impressed spirals and joining tangents, together with stamped triangles; possibly a bowl or pyxis rim, but if a "frying pan" it is of Syros type (Renfrew 1972: 528); ill. Fossey 1969: 66 bottom right.

608 VP65 Z P2 "frying pan": rim fragment 2.5Y 6/2

coarse grey with small black or dark grey inclusions (similar to 604); decorated with impressed spirals, joining lines, and tiny stamped triangles; ill. Fossey 1969: 66 bottom right.

609 VP65 Z M1 ladle(?): bowl fragment 7.5YR 7/4

fine pink, with good-quality dark red slip (2.5YR 4/6) covering the outer surface; d. 6; cf. Blegen 1928: 96 fig. 84.

610 VP65 Y B27 bowl: rim fragment 7.5YR 6/8

semifine red with a few tiny black and white inclusions; a dull, dark red slip inside (2.5YR 7/6) and out (10R 6/6); a disorderly double row of deep point impressions along the flattened rim; d. 32, th. 0.9; cf. Goldman 1931: 111 fig. 146, 8.

611 VP65 Y P2 "frying pan": rim fragment 10YR 6/2

coarse grey-brown, neither slipped nor burnished; decorated with radial strokes, deeply incised, on upper surface and along edge; of mainland type, as 601 (Renfrew 1972: 536); ill. Fossey 1969: 63 bottom right.

612 VP65 Y P1 "frying pan": rim fragment 2.5Y 6/2

coarse grey-brown, with grey burnished slip outside; on the upper surface, incision forming three concentric circles, the inner and outer in zig-zag form, the middle of short radial strokes; of mainland type (Renfrew 1972: 536); ill. Fossey 1969: 63 bottom right.

613 VP65 Y M1 "scoop" (?): complete profile preserved.
10YR 6/2

coarse red with large (c. 0.2) grey-brown inclusions;
burnished inside and out; possibly rather a narrow-
mouthed jug; ill. Fossey 1969: 63 bottom left
(restored as a scoop).

614 VP65 Y J6 jar: rim fragment 10YR 7/3

fine buff, neither slipped nor burnished; outturned
lip; knob decoration applied on outside at constriction
of neck; ill. Fossey 1969: 61 top right.

615 VP65 Y J1 small jar: rim fragment 7.5YR 8/4

fine buff, with dark red burnished slip on the outside
and over the lip to the inside of the rim; ill. Fossey
1969: 61 top left

616 VP65 X B20 bowl: rim fragment 2.5Y 8/1

fine buff, with burnished slip; dark red (2.5YR 4/6)
inside and red-brown (5YR 5/6) outside; wide bowl
with flattened rim and trumpet-ended handle; ill.
Fossey 1969: 58 middle right.

617 VP65 X J19 small jar: profile preserved from rim
to belly
10YR 6/4

fine buff-orange, unslipped but fire-blackened outside;
high collar neck; ill. Fossey 1969: 56 lower left.

618 VP65 X J20 small jar: complete from neck down
10YR 6/4

fine buff-pink, with thin dark orange (2.5YR 6/8)
matt slip outside; attachment for handle preserved
on belly; ill. Fossey 1969: 56 lower middle.

619 VP65 X J21 small jar: complete from shoulder down
2.5Y 8/2

fine pale green, without slip or burnish; ill. Fossey
1969: 56 lower right.

- 620 VP65 X J22 small jar: complete from base of neck down
5YR 8/1

fine pale pink, varying to pale green, without slip or burnish; traces of shaping marks on lower exterior; ill. Fossey 1969: 56 lower right.
- 621 VP65 X M3 small "spoon": complete profile preserved
7.5YR 7/4

fine pink, with red slip (2.5YR 6/6) inside and out; beginning of vertical ring handle preserved on rim; ill. Fossey 1969: 58 bottom left.
- 622 VP65 X M5 "fruitstand" (?): central portion
7.5YR 7/5

semifine orange with a few tiny dark red, and white (calcareous) inclusions; red matt slip (2.5YR 5/8) on the inner surface of the shallow side; vessel flares both upwards and downwards, with a double horizontal strap handle and incised slashes around constriction; probably six bored holes spaced around vessel on shallow side; ill. Fossey 1969: 58 bottom right.
- 623 VP65 X M4 lentoid pyxis: most of body preserved
10YR 7/2

coarse grey-brown with some light-coloured inclusions; slightly flattened base, d. 8; traces of burning on outside; ill. Fossey 1969: 58 bottom middle.

5. THE ANALYSES: NEUTRON ACTIVATION PROCEDURES

5.1 Choice of method

Neutron activation has several advantages over other techniques for this set of analyses. Some of these advantages are intrinsic to the method, whereas others depend more on the particular circumstances of this project. There are also a few disadvantages which must be taken into account. This section discusses the factors leading to the choice of analytical technique.

First proposed as an analytical method soon after the discovery of the neutron (von Hevesy and Levi 1936), neutron activation became a routine method for trace analysis with the development of nuclear reactors in the 1940's. The basic principle is simple, though many refinements have been developed. These are covered in several reference works (e.g., Lyon 1964; De Soete et al. 1972; Coomber 1975), so only a brief summary will be presented here.

When material to be analyzed is placed in a flux of neutrons, some of the neutrons will be absorbed by nuclei in the sample. If the resulting nuclei are unstable, the sample will give off radiations for some time following the irradiation. The nature of these radiations can be used to identify the radioactive nuclei, and the intensity can be used to calculate the quantity of the stable precursor element in the sample. Most analytical determinations are made relative to

a standard of known composition subjected to the same treatment as the sample, making the calculations quite simple (see below, section 5.2.6).

Unlike most analytical methods, neutron activation relies on properties of the atomic nucleus for its sensitivity and discrimination. These properties include the activation cross-section, or the ease with which a nucleus can absorb a neutron; the half-life of the transformed nucleus, which in most cases remains unstable even after the prompt emission of a gamma ray; and the mode of decay of that nucleus, usually by the emission of a beta particle (and an antineutrino) immediately followed by one or more gamma rays. The great sensitivity of the technique (for some elements) arises from the fact that one can count these emerging gamma rays directly and relate their number to the number of activated nuclei. Even though a very small proportion of the nuclei of a given element are activated, their total number can be very large. If their half-life and gamma-ray energies are suitable, many disintegrations can be counted in a short time, and the number of those nuclei estimated with some precision.

The multielement capability of neutron activation analysis arises from the very narrow bandwidth of the gamma rays. Analysts could not take full advantage of their monoenergetic nature, however, until the development of the semiconductor gamma-ray spectrometer in the early 1960's (see reviews by Goulding 1966; Hollander and Perlman 1966). With this

instrument, hundreds of gamma rays can be resolved, allowing the concentrations of many elements to be determined from a single spectrum.

The high resolution of the semiconductor spectrometer also enables measurements to be made without any chemical treatment of the sample. In the case of a detector having low resolution, the intense gamma rays from an abundant, easily-activated element can mask those of interest, requiring that this element be removed either before or after irradiation. With the newer spectrometers this is not usually necessary. Instrumental neutron activation analysis (INAA) is the term used for measurement of irradiated samples without chemical separations. Doing away with chemical treatment is not just a convenience, but also eliminates the possibility of incomplete separations and imprecision in measuring the chemical yield. Nor need the sample be dissolved, ashed, melted, or otherwise transformed chemically prior to analysis, as would be the case, for example, for atomic absorption or electrochemical methods. In fact the chemical form of the elements is irrelevant to their determination by INAA. Thus there is a reduced risk of contamination; that is, of inadvertent additions to the sample before irradiation (but see section 5.2.7.5, on contamination during sampling).

INAA also has, of course, several disadvantages. In order to determine the concentrations of as many elements as possible, measurements must be made of radionuclides with

half-lives ranging from minutes to years. In practice this means performing several irradiations and measurements on each sample (two and three respectively for this work). The wait between the last irradiation and the last measurement can amount to several weeks. The full analytical cycle for a given sample can require more than a month, though as a batch process INAA can be quite efficient.

Exposure to radiation was not found to be excessive in this research. In fact, the irradiation dose accumulated by this author over the two years of experiments amounted to about 35 mrem, much less than that received from environmental sources. Under different experimental conditions, however, accumulated dose may be a significant factor in the choice of analytical method.

Unfortunately, the cost of the irradiations and measurements must also be assessed. Access to a source of neutrons (reactor or generator) can be expensive, but may be reduced by packing irradiation vessels with many samples at once. The cost of a gamma-ray spectrometer is of the same order of magnitude as that of other modern analytical instruments. Obviously, availability of instrumentation will be one of the most important practical factors in the choice of analytical method. For the present research all the equipment was at hand, and irradiation could be performed conveniently (but not without charge) at a nearby facility.

The final practical consideration has to do with previous research in the same archaeological domain. Provenance determinations of Greek pottery have been carried out by analytical means for a quarter-century now, yielding a large quantity of compositional data. Some of these analyses would be directly relevant to the present study, as they concern pottery of the same period or from the same area as is treated here. Analyses carried out by a different technique, however, are not easily comparable to INAA data, for usually there are few elements analyzed in common. Even when there are several elements in common, questions of standardization and calibration often make comparisons very difficult. (For discussion of INAA comparisons between laboratories, see Yellin et al. 1978; Harbottle 1980; Yeh and Harbottle 1981; for problems in long-term reproducibility of analyses from a single lab, see Catling et al. 1980, pp. 61-63.) For this study, it was most important to be able to include data from two earlier phases of Early Bronze Age provenance analysis: the examination of pottery production at Lake Vouliagmeni (Attas 1975) and at Lerna (Attas 1980). Neutron activation analyses of Greek Late Bronze Age pottery have been carried out at the Lawrence Berkeley Laboratory (Karageorghis et al. 1972; Asaro and Perlman 1973) and at Brookhaven National Laboratory (Bieber et al. 1976a). The desirability of making comparisons with these large banks of data was the last factor in the choice of instrumental neutron activa-

tion analysis as the preferred method for this study.

5.2 Experimental procedure

5.2.1 Introduction

The procedure used for the analyses performed at McGill University has been adapted from those in use at other establishments performing routine instrumental neutron activations. Features of several laboratories have been combined to suit the archaeological and technical requirements of the McGill research. Each section below treats one step in the analysis and compares it to equivalent steps in use elsewhere. A final section discusses the validity of intercomparisons between the data of several laboratories, in the context of estimating the accuracy of the McGill results. The following abbreviations are used to denote archaeometric laboratories:

BNL=Brookhaven National Laboratory, U.S.A.
principal researchers: G. Harbottle and E.V. Sayre,
Department of Chemistry

LBL=Lawrence Berkeley Laboratory, University of
California, U.S.A.
principal researchers: F. Asaro and I. Perlman
(the latter now at HU)

HU=Hebrew University of Jerusalem, Israel
principal researchers: I. Perlman and J. Yellin,
Laboratory for Archaeometry

GANOS=Groupe d'Archéologie Nucléaire d'Orsay-Saclay
Laboratoire Pierre Sûe, Centre d'Etudes Nucléaires
de Saclay, France, and Laboratoire de Spectrométrie
Nucléaire, Orsay, France
principal researcher: F. Widemann

U of T=SLOWPOKE Reactor facility, University of Toronto,
Canada
principal researcher: R.G.V. Hancock

Poly=Institut de Génie Nucléaire, Installation SLOWPOKE
Ecole Polytechnique de Montréal, Canada
(archaeometric work is carried out primarily by
external researchers)

5.2.2 Sampling

Sampling was carried out in August and September of 1977 in the Archaeological Museums at ancient Corinth (material from Keramīdhāki, Korákou, Phlious, and Zygouriés), at Árgos (Lerna material), and in the Lionárdho at Návpليون (Asine material). The latter storehouse was visited again in October, 1980, to sample Tiryns material and supplementary objects from Asine.

Finely-powdered pottery was extracted from a broken edge of each sherd using an ordinary hand drill fitted with a solid tungsten-carbide bit and fixed to a table. The edge of the sherd was first cleaned by scraping it with the side of the turning bit; the bit was wiped before the actual sample was taken. Bit diameters were 2.4 mm (3/32 inch) for most sherds, but 1.6 mm (1/16 inch) for the thinnest ones. In order to extract several hundred mg of powder, two or three larger holes or half a dozen smaller ones were drilled parallel to the original surfaces of the pot. The powder was collected on a fresh sheet of paper and immediately transferred to a polyethylene vial.

Larger quantities of powder were required from sherds with a heterogeneous paste (i.e., coarse wares, containing bits of tempering material or other inclusions), in order to

ensure that the sample be representative of the sherd as a whole. (The aim of the analysis is to determine the overall paste composition rather than that of the clay fraction alone; these approaches are contrasted in section 2.3.) A theoretical treatment indicating the amount of sample required to ensure a given degree of representativity, based on the size and abundance of inclusions, has been published by Bromund et al. (1976). Their graph indicates that for most of our potsherds, sample sizes of the order of tenths of a cubic centimetre are ample. As the thinnest pottery usually has the finest paste, restricted sample size is not a problem, even in cases where only a few small holes can be drilled. The representativity of the sampling is further discussed below (section 5.3), where its contribution to the overall analytical reproducibility is estimated. Consideration of the effects of sample contamination from the drill bit, a problem more serious than previously estimated (Attas et al. 1977, p. 36; Attas 1980, pp. 51-52) is also discussed separately (section 5.2.7.5).

This method of sampling, also used by the BNL team (Abascal-M. et al. 1974, p. 86), was chosen because it causes less obvious damage to the sherd than others. That the archaeological usefulness of the sherd be unchanged after sampling was a standard prerequisite to obtaining permission to sample in most Greek museums. Other methods currently employed include drilling shallow holes into the sherd's

abraded surface using a synthetic-sapphire bit of 1 cm diameter (Perlman and Asaro 1969, p. 21; also used by GANOS), and hammering an abraded sherd enclosed between heavy sheets of polyethylene (Birgül et al. 1977, p. 46). With these methods contamination is reduced, but the damage they cause to the sherd would have been unacceptable to the Greek authorities.

A few of the samples from very crumbly, poorly-fired objects contained lumps of various sorts. These were crushed to powder in a porcelain mortar.

5.2.3 Preparation and encapsulation

Once in powdered form, each sample was placed in a porcelain crucible and baked at 1000°C for thirty minutes. This procedure drove off trapped water, decomposed calcium carbonates, and oxidized iron to the +3 state. In this way the effect of variations in the original firing are reduced (see section 2.3). Baking is carried out by GANOS; a recent study at U of T (Franklin and Hancock 1979) reaffirms its value.

The standard container for irradiations in many reactors, including the SLOWPOKE, is a small polyethylene snap-top capsule (Hancock 1976, p. 1444). The SLOWPOKE capsule has an external diameter of 16 mm and a length of 54 mm. Usually it contains two polyethylene sample vials of external diameter 12 mm and length 24 mm (volume approximately 1.4 ml) placed

end-to-end. As 300 mg of powder only half-filled these vials, each vial was cut in half before filling, thereby enabling four of them to fit into each capsule. The packaging procedure was as follows: a stainless-steel scalpel was used to cut off the upper half of each vial, which was discarded, except for the cap. The lower half was filled with 250 to 300 mg of pottery powder, weighed to the nearest 0.02 mg. It was then capped, labelled with an indelible felt marker, heat-sealed with a copper-tipped soldering iron, and trimmed of protruding polyethylene with the scalpel. On several occasions empty vials handled in the same way were tested and found not to contribute significantly to the concentrations of any elements determined.

Two other methods of sample preparation are more common. The BNL group fills quartz tubes with 40 mg of pottery powder (Abascal-M. et al. 1974, p. 86); this was the procedure at McGill when the NRX reactor at Chalk River was used for the irradiations (Attas et al. 1977; Birgül et al. 1977). In fact, to maintain consistency, the McGill work on Turkish pottery is being carried out using quartz tubes packed eight into each polyethylene capsule for irradiation in the SLOWPOKE reactor (D. Dautet, personal communication 1981). It was felt that in order to compensate for the relatively low neutron flux of the SLOWPOKE, irradiation of a large sample was important to this study. Although each polyethylene capsule could contain more quartz tubes than half-

vials, the greater volume of the half-vials influenced the decision in their favour.

The LBL, HU, and GANOS groups irradiate pottery samples in the form of disks, made by compressing a mixture of 100 mg of pottery powder and 50 mg of cellulose in a hand-press (Perlman and Asaro 1969, p. 22; Yellin et al. 1978, p. 97; Attas et al. 1979). The advantage of this method is that the dimensions of the disks are extremely consistent, allowing the samples to be positioned automatically, very close to the surface of the detector can, for high-efficiency gamma-ray measurements. Its disadvantages are the long preparation time and the extra opportunities for contamination of the sample. A practised technician at GANOS required over two hours to prepare a set of twelve sample disks (J. Sturton, personal communication 1978), whereas at McGill the same number of vials could be prepared in an hour.

5.2.4 Irradiation and measurement schedules

Three measurements were made of the gamma-ray emissions of each sample (Table 5-I). A short irradiation at Poly, lasting two minutes at a flux of 10^{11} neutrons per square centimetre per second, was followed after a delay of ten minutes by a measurement period of ten minutes. This measurement served to determine elements whose activated forms have half-lives on the order of minutes or hours. The samples were irradiated one at a time. Their gamma-ray

TABLE 5-I: Irradiation and Measurement Schedules

	Neutron flux ($\text{cm}^{-2} \text{s}^{-1}$)	Duration		of	Elements determined
		Irradiation (t_i)	Decay (t_d)	Measurement (t_c)	
Short irradiation	10^{11}	120 s	600 s	600 s	Na, Mg, Ca, Al, Ti, V, Mn
Long irradiation	10^{12}	0.25 day			
first measurement			4-6 days	0.0463 day	Na, K, Sc, La, (Sm), Yb, (Lu), (U), W, As, (Sb)
second measurement			20-40 days	0.1157 day	Rb, Cs, (Ba), Sc, Ce, Eu, Th, Hf, (Ta), Cr, Fe, Co, (Ni), (Sb)

Note: elements listed in parentheses are determined with very poor precision.

spectra were acquired using either a large-volume or a medium-volume lithium-drifted-germanium detector. These detectors each had a resolution of just over 2 keV full width at half maximum (FWHM) at 1332 keV. In both cases the signal was fed through standard preamplifier and amplifier modules to a Canberra 4096-channel pulse-height analyzer. A linear energy calibration of the analyzer (usually 0 to 4 keV over the 4096-channel range) allowed peaks corresponding to activated elements of interest to be readily identified on the cathode-ray display. The areas under these peaks and under nearby background regions (selected by the user) were calculated by the analyzer and printed.

The second irradiation was performed several weeks after the first, on batches of twelve half-vials. These occupied three sites of the Poly SLOWPOKE, packed four to a capsule. The irradiation time was 6 hours at a flux of 10^{12} neutrons $\text{cm}^{-2} \text{ s}^{-1}$, which was the maximum available at the SLOWPOKE. After four days, the samples were returned to the McGill University Radiochemistry Laboratory for a sequence of two measurements. The same gamma-ray spectrometer was used for both: a vertically-mounted lithium-drifted-germanium detector of medium volume linked through standard preamplifier and amplifier modules to a Nuclear Data Model 2200 multichannel analyzer. (Resolution of the system was relatively poor, usually 3-4 keV FWHM at 1332 keV, owing to difficulties in keeping the crystal cool.) In these

cases, however, spectrum data were not printed, but transferred to magnetic tape for subsequent processing at the McGill University Computing Centre. Energy calibration was achieved by recording the spectrum of a standard source (^{226}Ra) before the measurements of each batch of samples.

The first measurement at McGill took place four to six days after the long irradiation. This served to determine elements whose activated forms have half-lives on the order of a few days. Each half-vial was placed in a holder mounted coaxially with a distance of 48 mm ("shelf 4") between the bottom of the vial and the top of the detector can. The gamma spectrum was acquired for a live time of 4000 seconds (about 70 minutes including the average 5% dead time).

After a further wait of two to three weeks, each sample was measured again for 10 000 seconds (just under 3 hours) or more. This measurement served to determine elements whose activated forms have half-lives of several weeks or more. The distance from sample to detector can was 19 mm for this measurement ("shelf 2").

This schedule of irradiations and gamma-ray measurements is designed to determine the concentrations of as many elements as possible within the limitations of the availability of the instruments. It is quite similar to those in use at other laboratories since most of them determine the same elements. There are variations in the intervals and

the counting durations, and some laboratories perform more measurements in all. A significant advance has been implemented at LBL and HU with the use of small-volume detectors of extremely high resolution to measure low-energy gamma rays (Yellin et al. 1977). At least 4 measurements are performed, but more elements can be determined, and the determinations are much more precise than they would have been with a larger detector of lower resolution. Discussion of the choice of elements determined and factors affecting their precision is reserved until after the sections on standardization and on calculations.

5.2.5 Standardization

5.2.5.1 Selection of standard

Most activation analyses are carried out using a "relative" technique and the present work is no exception. In addition to being simpler than absolute methods, it is more accurate, since a number of physical and experimental parameters need not be included in the calculations (Lukens 1972). Instead, a standard of known composition is irradiated under the same conditions as the sample. If their activities are also measured under identical conditions, the activity ratio for each element is equal to the ratio of the mass of that element present in the sample and in the standard. (The relevant equations are presented in section 5.2.6.2.)

Clearly, accurate determinations of elements in samples depend on having a standard whose composition is well-known. Single-element standards are not difficult to prepare, but for best efficiency of operations a multi-element standard is preferred. For pottery analysis, many archaeometric laboratories use either a set of rock standards from the United States Geological Service (BNL), or a single pottery standard prepared by Perlman and Asaro (LBL, HU, GANOS). Slight discrepancies exist in analyses conducted using these two standards, but these are gradually being resolved (Harbottle 1980; Yeh and Harbottle 1981). Since previous analyses of Greek Early Bronze Age pottery had used the Perlman-Asaro standard (Attas et al. 1977; 1979), direct comparisons were simplified by using it for the present work as well. The major difficulty in using this standard, whose composition is given in Table 5-II, is that the supply is almost exhausted. Had we been required to include one or more units of standard with every irradiation, as is commonly done in most activation analysis laboratories, these analyses could not have been carried out using this standard. Fortunately, an unusual design feature of the SLOWPOKE reactor, described below, permitted us to use up only a very small quantity of standard pottery.

5.2.5.2 SLOWPOKE reactor stability

The SLOWPOKE reactor was designed by Atomic Energy of Canada Limited to be a safe, extremely stable source of

**TABLE 5-II: Composition of Perlman-Asaro
Standard Pottery***

Element	Species Studied	Technique†	Composition		Chemical Symbol
			Diff. Techniques	Best Value	
Aluminum	²⁶ Al	neut act 1		$(15.3 \pm 0.2) \times 10^{-4}$	Al
Antimony	¹²³ Sb	neut act 3	$(1.88 \pm 0.12) \times 10^{-4}$		
	¹²⁴ Sb	neut act 4	$(1.73 \pm 0.06) \times 10^{-4}$	$(1.71 \pm 0.05) \times 10^{-4}$	Sb
Arsenic	⁷⁶ As	neut act 3		$(3.08 \pm 0.22) \times 10^{-5}$	As
Barium	¹³⁸ Ba	neut act 2	$(7.13 \pm 0.32) \times 10^{-4}$		
	¹³⁴ Ba	neut act 4	$(7.0 \pm 1.1) \times 10^{-4}$	$(7.12 \pm 0.32) \times 10^{-4}$	Ba
Bromine	⁸¹ Br	neut act 3		$(2.3 \pm 0.9) \times 10^{-4}$	Br
Calcium	⁴⁷ Ca	neut act 3	$<1 \times 10^{-3}$		
		opt spec	$<1 \times 10^{-3}$		
		wet chem	$<2 \times 10^{-4}$	$<2 \times 10^{-4}$	Ca
Carbon	CO ₂	C-H anal		$(3 \pm 3) \times 10^{-4}$	C
Cerium	¹⁴⁰ Ce	neut act 4		$(8.03 \pm 0.39) \times 10^{-5}$	Ce
Cesium	¹³⁴ Cs	neut act 4		$(8.31 \pm 0.88) \times 10^{-6}$	Cs
Chlorine	³⁶ Cl	neut act 1		$<1.3 \times 10^{-4}$	Cl
Chromium	⁵² Cr	neut act 4		$(1.151 \pm 0.038) \times 10^{-4}$	Cr
Cobalt	⁶⁰ Co	neut act 4		$(1.406 \pm 0.016) \times 10^{-3}$	Co
Copper	⁶⁴ Cu	neut act 2	$(6.0 \pm 0.8) \times 10^{-5}$		
	Cu	wet chem	$(5.8 \pm 0.5) \times 10^{-5}$	$(5.9 \pm 0.5) \times 10^{-5}$	Cu
Dysprosium	¹⁶³ Dy	neut act 2		$(4.79 \pm 0.19) \times 10^{-6}$	Dy
Europium	¹⁵¹ Eu	neut act 2	$(1.288 \pm 0.048) \times 10^{-4}$		
	¹⁵² Eu	neut act 4	$(1.298 \pm 0.047) \times 10^{-4}$	$(1.291 \pm 0.034) \times 10^{-4}$	Eu
Gallium	⁷³ Ga	neut act 2		$(4.44 \pm 0.46) \times 10^{-5}$	Ga
Gold	¹⁹⁸ Au	neut act 3		$\leq 1 \times 10^{-4}$	Au
Hafnium	¹⁸¹ Hf	neut act 4		$(6.23 \pm 0.44) \times 10^{-6}$	Hf
Hydrogen	H ₂ O	C-H anal		$(6.4 \pm 0.0) \times 10^{-3}$	H
Indium	^{114m} In	neut act 2		$(1.09 \pm 0.08) \times 10^{-7}$	In
Iron	⁵⁷ Fe	neut act 4		$(1.017 \pm 0.012) \times 10^{-1}$	Fe
Lanthanum	¹³⁹ La	neut act 3		$(4.490 \pm 0.046) \times 10^{-5}$	La
Lutetium	¹⁷⁷ Lu	neut act 3		$(4.02 \pm 0.36) \times 10^{-7}$	Lu
Magnesium	²⁷ Mg	neut act 2	$(6 \pm 2) \times 10^{-3}$		
		opt spec	$(7 \pm 2) \times 10^{-3}$	$(6 \pm 2) \times 10^{-3}$	Mg
Manganese	⁵⁴ Mn	neut act 2		$(4.09 \pm 0.06) \times 10^{-3}$	Mn
Nickel	⁵⁸ Ni	neut act 4		$(2.79 \pm 0.20) \times 10^{-4}$	Ni
Potassium	⁴² K	neut act 2		$(1.35 \pm 0.04) \times 10^{-3}$	K
Rubidium	⁸⁶ Rb	neut act 4		$(7.00 \pm 0.83) \times 10^{-5}$	Rb
Samarium	¹⁵² Sm	neut act 3		$(5.78 \pm 0.12) \times 10^{-6}$	Sm
Scandium	⁴⁵ Sc	neut act 4		$(2.055 \pm 0.033) \times 10^{-5}$	Sc
		wet chem		$(6.04 \pm 0.03) \times 10^{-1}$	SiO ₂
Silicon dioxide	SiO ₂				
Sodium	²⁴ Na	neut act 2		$(2.58 \pm 0.04) \times 10^{-3}$	Na
Strontium	⁸⁷ Sr	neut act 2		$(1.45 \pm 0.22) \times 10^{-4}$	Sr
Tantalum	¹⁸² Ta	neut act 4		$(1.550 \pm 0.044) \times 10^{-6}$	Ta
Thorium	²³² Th	neut act 4		$(1.396 \pm 0.039) \times 10^{-5}$	Th
Titanium	⁴⁷ Ti	neut act 3		$(7.82 \pm 0.34) \times 10^{-1}$	Ti
Uranium	²³⁵ U	neut act 3		$(4.82 \pm 0.44) \times 10^{-6}$	U
Ytterbium	¹⁷³ Yb	neut act 3		$(2.80 \pm 0.38) \times 10^{-6}$	Yb
Zinc	⁶⁷ Zn	neut act 5		$(5.9 \pm 0.8) \times 10^{-5}$	Zn

*These compositions and all others in this paper refer to the elements unless otherwise noted.

†The entries in this column have the following meanings: neut act 1, neutron activation measurement with special irradiations for very short half-lives; neut act 2, usual neutron activation measurement for half-lives less than 1 day; neut act 3, usual neutron activation measurement for half-lives from 1 to 6 days; neut act 4, usual neutron activation measurement for half-lives longer than 6 days; neut act 5, special neutron activation measurement about 8 months after irradiation; opt spec, measurement with optical spectrography; wet chem, measurement by wet chemical analysis; C-H anal, measurement of carbon and hydrogen by combustion analysis.

*From Perlman and Asaro (1971, p. 187).

neutrons for activation analysis (AECL 1976; Ryan et al. 1978). The flux can be set to 0.1, 0.25, 0.5 or 1.0 times the maximum of 10^{12} neutrons $\text{cm}^2 \text{s}^{-1}$. There is a flux gradient of about $1\% \text{ cm}^{-1}$ along the axis of the capsule (and the reactor) at each of the five irradiation sites, and up to 5% difference from one site to another. These differences are very nearly constant in the long term, however, so that at any given position "the actual variation in the neutron flux is less than 2%" ($\pm 2\sigma$: Ryan et al. 1978, p. 89). At Poly, the consistency is maintained within $\pm 2\% (1\sigma)$ even through one of the periodic (approximately biannual) upgradings of the reactor, involving the addition of an extra beryllium plate to the upper reflector. In fact, for short irradiations, the variation is no more than $\pm 1\% (1\sigma$: Bergerioux et al. 1979, p. 234). This exceptional stability allows researchers to determine, for each element of interest, experimental activation constants for a given combination of sample irradiation and measurement positions. Thus the inclusion of a standard is not necessary for every irradiation.

5.2.5.3 Determination of activation constants

For the short-lived elements (those measured at Poly), the Poly values of the activation constants were used. These had been determined by irradiating pure compounds and measuring their activity at various distances from the Poly detectors (Saint-Pierre 1979, p. 39). For the longer-lived

elements, a capsule containing Perlman-Asaro standard pottery was irradiated for six hours at 10^{12} neutrons $\text{cm}^{-2} \text{s}^{-1}$ and taken to McGill for a series of measurements at the same sample-to-detector distances used for the pottery samples. Six measurements were averaged for the first (shelf 4) determination, and 13 measurements were averaged for the second (shelf 2) determination. The precision of these measurements is discussed in section 5.4.

5.2.6 Calculations

5.2.6.1 Spectrum processing

Spectra from the measurements made at McGill were processed at the McGill University Computing Centre using the computer program GAMMANAL (Gunnink et al. 1967). This program scans a spectrum to determine the position of each potential peak, evaluates its suitability in terms of breadth, height above background, and multiplicity, and calculates its net area above a straight-line background. This net area is accompanied by an uncertainty value based on the magnitude of the total peak and of the background. Doublets and triplets can be resolved if a valley is present between them. The energy of the gamma ray forming the peak is calculated from the channel number of its summit using a fit (almost linear) to reference peaks of known energy. The limits of detection are quite conservative, so that in a number of cases where GAMMANAL did not report a peak as significant its area could

be calculated by hand from the listing of the channel contents.

Many other laboratories use sophisticated large-computer programs for spectrum processing. At BNL, the program BRUTAL is a Control Data version of the code written by Gunnink, Levy, and Niday (1967), subsequently modified by B.R. Erdal (G. Harbottle, personal communication 1979). The LBL group has created an elaborate program quite specific to activation analysis of pottery (Perlman and Asaro 1969). Instead of searching for peaks wherever they might be found, the program integrates predetermined regions of the spectrum where peaks are known to exist. Experimental conditions such as amplifier gain and system resolution must be strictly controlled. A version of this program is used also by GANOS. At HU, Yellin (1980) has developed a more flexible program based on the same philosophy of processing spectra whose general characteristics are already known.

5.2.6.2 Formulae

The process of radioactive decay is such that the activity is proportional to the number of unstable atoms present, so that both quantities decrease exponentially with time:

$$A = A_0 e^{-\lambda t} \quad (1)$$

where A_0 is the activity at time $t=0$ and λ is the decay constant for the radioactive species in question. The half-life $t_{1/2}$ is

related to λ as

$$t_{1/2} = \frac{\ln 2}{\lambda} \approx \frac{.69315}{\lambda} \quad (2)$$

The process of activation is a linear one, if two factors are determined to be negligible. The first is that the decrease in N , the number of target nuclei during the period of irradiation t_i , is insignificant, so that N is effectively constant. This is true for almost all analytical activations. In the irradiation of materials to produce radioactive sources, however, often a substantial proportion of the target nuclei are transformed. Secondly, the number of activated nuclei which disintegrate during the irradiation period must not be significant with respect to the total number produced. If the half-life $t_{1/2}$ is much longer than t_i , this will be the case, but otherwise the decay during irradiation must be considered in calculating the total activity at $t=t_i$. (A further effect resulting from attenuation of the neutron flux in a thick sample, discussed by Friedlander et al. (1981, p. 116), is not relevant here.) With ϵ the proportion of decays actually detected, m the mass (in grams) in the sample of the element under analysis, M its atomic weight, K the relative abundance of the isotope to be activated, N_A Avogadro's number, σ the activation cross-section in cm^2 , ϕ the flux in neutrons $\text{cm}^{-2} \text{ s}^{-1}$, and t_i and $1/\lambda$ expressed in the same units of time, the measured activity in counts per

second at the end of bombardment is given by

$$A_0 = \epsilon \frac{mK}{M} N_A \sigma \phi (1 - e^{-\lambda t_i}) \quad (3)$$

(see Friedlander et al. 1981, p. 425).

After a time interval t_d following the end of the irradiation, the activity will have decreased to $e^{-\lambda t_d}$ times its former value. If the activity is then measured during a period of time t_c , the number of disintegrations detected is the integral of the activity over that period. The integral of $A_0 e^{-\lambda t}$ dt from $t = t_d$ to $t = t_d + t_c$ is $1/\lambda$ times the difference between the activities at the beginning and at the end of that period. This value, which corresponds to the observed peak area mentioned in the previous section, can be factored to yield

$$\text{Area} = A_0 e^{-\lambda t_d} (1 - e^{-\lambda t_c}) / \lambda \quad (4)$$

When $t_d \gg t_c$, the factor $1 - e^{-\lambda t_c}$ can be approximated by λt_c but it proved simpler in this work to use the same formula for the calculation of all elemental concentrations.

The activity equation can be solved for C , the concentration of the element of interest in the sample (expressed as a proportion). If we let w represent the total mass of the sample, then

$$C = \frac{\text{Area} \cdot \lambda}{\epsilon \frac{wK}{M} N_A \sigma \phi (1 - e^{-\lambda t_i}) (e^{-\lambda t_d}) (1 - e^{-\lambda t_c})} \quad (5)$$

The factors λ , K , M , N_A and σ are constant for a given element. The detection efficiency ϵ is constant for a given gamma-ray energy and measurement geometry, and as we have seen, so is the flux ϕ for a given reactor power level and irradiation position. Following Bergerioux et al. (1979), who term this the semi-absolute method, we can replace all these factors by an experimentally-determined irradiation constant, here called B :

$$C = \frac{\text{Area}}{Bw(1 - e^{-\lambda t_i}) (e^{-\lambda t_d}) (1 - e^{-\lambda t_c})} \quad (6)$$

This is the form of the activation equation actually used in the calculations. Values of the constants B for each element have been calculated by irradiating standards of known composition, and exchanging the factors C and B in the above equation (see section 5.2.5.3).

5.2.6.3 Refinements

A further simplification was made to the calculations of elemental concentrations based on the measurements of short-lived radioisotopes at Poly. For most of the samples the irradiation, decay, and measurement times were fixed at 2, 10, and a further 10 minutes respectively, so that the exponential factors of equation (6) remained constant.

Their product with B was calculated in advance for each element, making the rest of the calculation particularly simple. Even in cases where formula (6) was used, the calculation was simple enough that it could be most efficiently done with a programmable pocket calculator.

The short irradiations were all performed using the bottom position of irradiation site 1, which is the flux reference position for Poly's SLOWPOKE. As the long irradiations usually took place in three of the other four sites, the spatial variations of flux had to be taken into account. Measurements of these variations, made by Saint-Pierre (1979, pp. 24-26) and Kennedy (personal communication 1981), are summarized in Table 5-III. For the early irradiations using whole capsules, the values from Table 5-III were used as is; subsequently, when half-capsules were used, the lower, or "Bas" value for each site was multiplied by the half-capsule value at the corresponding position in site 1. In both cases the sample weights were multiplied by this flux correction factor as a separate step before formula (6) was applied. The calculations for the elements measured at McGill were done at the McGill University Computing Centre using punched-card data generated by GAMMANAL for the peak areas of interest. The short program BETACONC, written by J. Edward in 1980, was modified for the analysis of pottery to include several corrections for interferences due to overlapping gamma peaks.

TABLE 5-III: Spatial Variation of Neutron Flux in SLOWPOKE,
Relative to Site 1 Bas*

Site:	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>half-capsules</u> <u>in site 1</u>
Haut	0.972	0.988	0.981	0.945	0.987	0.943 0.981
Bas	1.000	1.017	1.004	0.968	1.010	0.997 1.003

* Data from Saint-Pierre (1979) and Kennedy (personal communication, 1981)

These are discussed in the following section.

5.2.7 Methods used to determine the concentrations of various elements

5.2.7.1 Introduction

In this section is presented detailed information on the determination of each chemical element. Factors affecting the precision are mentioned, as well as corrections which may have affected the accuracy of the determinations. Some notes on elements whose concentration is not reported are also included.

5.2.7.2 Short irradiation (see Table 5-IV)

Na: This element is easily measured at Poly, but the measurement at McGill is more precise. Both values have been calculated as a control on the accuracy of the determinations (see below, section 5.7.2.3).

Mg: A large proportion of the peak results from ^{27}Mg produced in the (n,p) reaction on ^{27}Al . There is an additional small contribution from the (n, α) reaction on ^{30}Si . Corrections have been applied using interference factors experimentally determined by Poly personnel (Galinier et al. 1980, p. 35). The uncertainty in these corrections, compounded by the fact that the Si concentration was not measured but instead estimated to be 20-30% in common earthenware ceramics (Picon 1973, pp. 122-129), means that the overall precision for Mg is low.

Ca: The ^{49}Ca peak lies in an energy region both free from interferences and of very low background, so it is well-

TABLE 5-IV: Elements Determined from the Short Irradiation

<u>Element</u>	<u>Determined from</u>	<u>Half-life[†]</u>	<u>Gamma-ray energy (keV)</u>	<u>Interfering reaction</u>	<u>Interference factor*</u>
Sodium	²⁴ Na	15.02 h	1369, 2754		
Magnesium	²⁷ Mg	9.45 min	1014	²⁷ Al(n,p) ²⁷ Mg ³⁰ Si(n,α) ²⁷ Mg	5.7 600
Calcium	⁴⁹ Ca	8.72 min	3084		
Aluminum	²⁸ Al	2.24 min	1779	²⁸ Si(n,p) ²⁸ Al	200
Titanium	⁵¹ Ti	5.75 min	320		
Vanadium	⁵² V	3.76 min	1434		
Manganese	⁵⁶ Mn	2.58 h	1811		

[†]Min = minutes, h = hours; data from Lederer and Shirley (1978).

*Interference factor: the ratio of the concentration of the interfering element to the apparent increase in concentration of the element being determined; e.g., if 5.7% Al results in an apparent extra 1% Mg, the interference factor is 5.7. These values were determined by Galinier et al. (1980, p. 35).

suites to the determination of percentage levels of calcium in pottery. The determination from the isotope ^{47}Ca gives less precise results, but its half-life of 4.54 days makes it more convenient for laboratories not set up for measurements immediately after irradiation.

Al: This element is the major contributor to the activity of the sample at the beginning of the measurement at Poly. By the end of the measurement, its contribution has diminished by 95%. Although the analyzer automatically increases the measurement time by about 8% to compensate for the average dead-time over the ten-minute period, this correction is best suited to elements with half-lives long compared to the measurement time. For Al, and to a lesser extent V, this results in a systematic underestimation of the concentration. The underestimation amounts to 4-6% of the reported concentration for most of the samples (with an increase of 1% (1σ) in the uncertainty), but may be lower for samples of lower mass which give rise to a lower dead-time. Since no Al concentration data are available for the earlier sets of Early Bronze Age pottery analyses, the Al values are used for internal comparison only, and no correction for the systematic error was made. (A small correction for ^{28}Al produced by the (n,p) reaction on ^{28}Si has been made routinely, even though it is negligible compared to the error arising from the dead-time correction.)

Ti: Although free from interferences, the ^{51}Ti peak is in a region of high background, which limits the precision of its determination.

V: Vanadium is quite sensitive to analysis by neutron activation, so that concentrations around 100 ppm are easily determined in pottery. Because the half-life of ^{52}V is only 3.76 minutes, the determination has a

systematic underestimation in the range of 2-3%, for reasons explained in the paragraph on Al, above. Just as in that case, no correction has been made.

Mn: The most intense peak of ^{56}Mn is the one at 847 keV, but this lies very close to a ^{27}Mg peak at 844 keV. The ^{56}Mn peak at 1811 keV is sufficiently distant from the large peak of ^{28}Al at 1779 keV that no interference corrections are required.

5.2.7.3 Long irradiation, first measurement

(see Table 5-V)

Na: The precision of this measurement is excellent. There is a small systematic error between this and the Poly measurement, since the McGill value is more often higher than lower. Although both values are reported, only the second is used for grouping. Different standards may be at the root of this discrepancy, though analysis of the standard pottery at Poly (Table 5-XI) gave results for Na in excellent agreement with those reported by Perlman and Asaro (1969).

K: Because of the relatively short half-life of ^{42}K (12.4 hours), the precision of the determination was dependent strongly on the interval between irradiation and measurement. Within a given batch of twelve samples, those measured last had the highest uncertainty associated with the K concentration.

Sc: The isotope ^{46}Sc is relatively long-lived, but its activity is so intense that a good estimate of the Sc concentration can be obtained from this first measurement. The value is used as a control of experimental conditions and calculations, being checked against the more precise.

TABLE 5-V: Elements Determined from the Long Irradiation,
First Measurement

<u>Element</u>	<u>Determined from</u>	<u>Half-life (days)</u>	<u>Gamma-ray energy (keV)</u>	<u>Interferences</u>
Sodium	²⁴ Na	0.626	1369	--
Potassium	⁴² K	0.515	1525	--
Scandium	⁴⁶ Sc	83.8	889	--
Lanthanum	¹⁴⁰ La	1.68	1596	--
(Samarium)	¹⁵³ Sm	1.95	103	²³⁹ Np
Ytterbium	¹⁷⁵ Yb	4.19	396	--
(Lutetium)	¹⁷⁷ Lu	6.71	208	²³⁹ Np, ¹⁸⁷ W
(Uranium)	²³⁹ Np	2.35	278	--
Tungsten	¹⁸⁷ W	0.996	479	--
Arsenic	⁷⁶ As	1.10	559	--
(Antimony)	¹²² Sb	2.72	564	--

Note: Elements listed in parentheses are determined with very poor precision.

value from the second measurement.

La: An intense peak free from interferences is used to determine this rare earth with high precision.

Sm: Although ^{153}Sm is the strongest activity in the pottery samples after a few days, the region of the gamma-ray spectrum around 103 keV is very complex. The isotope ^{239}Np , formed by beta decay from the activated species of uranium, ^{239}U , emits a gamma ray at 106 keV, and gives rise to Pu X-rays at 100 and 104 keV. In most cases at McGill, none of these is resolved from the much larger Sm gamma ray. An attempt has been made to estimate the Np and Pu contribution, using the ratios of the peaks in the region 99-106 keV to the peak at 277 keV in an irradiated sample of pure natural uranium. The scatter in the corrected Sm concentrations indicates that this correction was not very successful. Since at other laboratories (e.g., GANOS) where Sm is determined more precisely the correlation between Sm and La concentrations is exact to within experimental error (Laubenheimer and Widemann 1977, p. 75), the loss of Sm as a diagnostic element at McGill was not considered serious.

Yb: Although free of interferences, the ^{175}Yb peak at 396 keV is small and sits on a high background, so that the determination of Yb is not very precise.

Lu: This is one of the elements which is most sensitive to neutron activation, but interferences make it unsuitable at McGill for the determination of pottery provenance. An attempt was made to estimate the influence of the gamma ray from ^{239}Np at 209 keV and the one from ^{187}W at 207 keV, but these corrections were found to be unreliable. The BNL group have also had problems with Lu (Fillières 1978), but GANOS and other groups who do not

sample with tungsten carbide bits report results of good precision.

U: The concentration of U was measured (using ^{239}Np) only in order to make an approximate correction to the Sm and Lu concentrations. The determination was never precise, and occasionally uranium was not detected. This imprecision was the major contribution to the poor values for the Sm and Lu concentrations.

W: The precision of the measurement is excellent; however, most of the W has entered the sample by contamination from the drill bit (see section 5.2.7.5). Its concentration in standard pottery is very low, but an independent check of the irradiation constant with pure irradiated tungsten gave agreement within 6%. The GANOS values are consistent within each capsule (group of ten samples), but they seem to incorporate a systematic error varying from one capsule to another. Use of the GANOS values to correct the Co concentrations is discussed in section 6.3.2.

As: The determination of As presents no problems, as the peak at 559 keV is easily separated from those of ^{82}Br at 554 keV and ^{122}Sb at 564 keV.

Sb: An attempt was made to determine Sb using the ^{122}Sb peak at 564 keV, but in about one third of the measurements it was not detected, and agreement with the long-lived isotope ^{124}Sb was poor.

5.2.7.4 Long irradiation, second measurement

(see Table 5-VI)

Rb: Although the peak is small, it is free of interferences. The McGill determination is more precise than that of

TABLE 5-VI: Elements Determined from the Long Irradiation,
Second Measurement

<u>Element</u>	<u>Determined from</u>	<u>Half-life (days)</u>	<u>Gamma-ray energy (keV)</u>	<u>Interferences</u>
Rubidium	⁸⁶ Rb	18.65	1077	--
Cesium	¹³⁴ Cs	753	605, 796	¹²⁴ Sb at 603 keV
(Barium)	¹³¹ Ba	11.7	496	--
Scandium	⁴⁶ Sc	83.8	889, 1120	¹⁸² Ta at 1122 keV
Cerium	¹⁴¹ Ce	32.5	145	--
Europium	¹⁵² Eu	4894	1408	--
Thorium	²³³ Pa	27.0	312	--
Hafnium	¹⁸¹ Hf	42.4	482	--
Tantalum	¹⁸² Ta	115	1221	--
Chromium	⁵¹ Cr	27.7	320	--
Iron	⁵⁹ Fe	44.6	1099, 1292	¹⁸² Ta at 1289 keV
Cobalt	⁶⁰ Co	1925	1173, 1332	--
(Nickel)	⁵⁸ Co	70.8	811	--
(Antimony)	¹²⁴ Sb	60.2	1691	--

Note: Elements listed in parentheses are determined with very poor precision.

GANOS where the interval from irradiation to measurement was often more than twice the half-life of ^{86}Rb (18.65 days).

Cs: Each of the two main gamma rays of ^{134}Cs was used to determine the Cs concentration. The value from the higher-energy ray is more precise, as the other has an interference from ^{124}Sb , which has been taken into account in the calculation.

Ba: The 12-day half-life of ^{131}Ba is such that neither the first nor the second measurement is ideally suited to the determination of Ba. The second is slightly better, but even then the ^{131}Ba peak at 496 keV was not detected in many samples. The reservations expressed by other researchers with regard to the utility of Ba as a discriminating element (see section 2.3) imply that extra effort to determine it with precision would not be worthwhile.

Sc: The two most intense gamma rays in the pottery spectrum several weeks after irradiation are those of ^{46}Sc . The higher-energy peak gives a more precise value for Sc concentration, even after a small correction is made for a ^{182}Ta interference at 1122 keV.

Ce: The low energy (145 keV) of the main ^{141}Ce gamma ray places it in a region of the spectrum with high background. The potential interference from ^{59}Fe at 142 keV is usually resolved by GAMMANAL, and so does not require separate correction.

Eu: The determination of this rare earth is straightforward, and its precision is fair.

Th: There are no major interferences to the determination of Th, so that its precision is good. Results at GANOS

show systematic differences from those at McGill, but their nature is not clear (see section 5.4).

- Hf: Again, the straightforward integration of a medium-sized gamma-ray peak leads to results of medium precision.
- Ta: Low levels of this element in Greek pottery make the precision of its determination poor, both at McGill and by GANOS. There is a noticeable increase in concentration when the sample has been heavily contaminated by the drill bit (see section 5.2.7.5).
- Cr: The precision of the concentrations reported for Cr is good, since the large peak is free of interferences. Production of ^{51}Cr by (n,α) on ^{54}Fe in the Poly reactor is negligible for Cr and Fe concentrations in the ranges found in Greek pottery (interference factor = 2.7×10^4).
- Fe: This minor constituent of pottery can be determined through either of two strong gamma rays, the one at 1292 keV giving slightly more precise results, even after correction for a small interference from a ^{182}Ta gamma ray at 1289 keV.
- Co: Again, two strong gamma rays make precise determinations of Co in pottery straightforward. The one at 1332 keV has a lower background, giving more precise results. Samples contaminated by the drill bit contain extra Co (see section 5.2.7.5).
- Ni: The determination of this element can be accomplished by measuring the 810-keV gamma ray of ^{58}Co , produced by the (n,p) reaction on ^{58}Ni . This gamma ray, however, is very weak in these spectra, so that even when it was evident, the precision of the Ni determination was poor.

Sb: The background around 1691 keV is very low, but so is the detector efficiency and resolution. The ^{124}Sb peak is therefore weak, and spread over a large number of channels, so that GAMMANAL sometimes did not find it or integrate it properly. The peak integrations were checked by hand.

5.2.7.5 Drill-bit contamination

For the reasons mentioned in section 5.2.2, solid tungsten-carbide bits were used to drill out powdered samples of pottery for analysis. The effects of contamination of the sample by this procedure are more serious and more frequent than they appeared to be in earlier work (Attas et al. 1977, p. 36; Attas 1980, pp. 51-52). As mentioned in the previous section, the concentrations of the elements Co, Ta, and Lu are affected. (A Danish archaeometric group (Hansen et al. 1979, p. 128) has excluded Cr as well, but no justification for this has been observed in the present work.) An attempt was made to correct these concentrations using the tungsten peak area and concentration as a control of the degree of contamination.

A salesman from Arthur Balfour Ltd., the supplier of the bits, explained (1979) that although their actual composition is a trade secret, they consisted of about 70% tungsten carbide, with small quantities of titanium, niobium, and tantalum carbides acting as "body" (or mass, or fillers), and a binder of cobalt, with a very small percentage of nickel.

An analysis at Poly of a large (0.6925 g) fragment of drill bit gave the following concentrations: W, 52%; Co, 5.5%; Ta, 0.13%. The high activity from ^{187}W immediately after irradiation precluded the determination of Ti and Nb. (The concentration of Ti in pottery is in any case sufficiently high (c. 0.5%) that it would not be significantly affected by drill-bit contamination.)

A discrepancy exists, therefore, between the quoted and measured W concentration, even when the latter is expressed as a carbide (55%). The measurements of the drill-bit composition were used to correct the Co and Ta concentrations measured in the pottery samples, by subtracting from them a quantity proportional to the W concentration:

$$[\text{Co}]_{\text{corrected}} = [\text{Co}]_{\text{measured}} - 0.106[\text{W}]$$

$$[\text{Ta}]_{\text{corrected}} = [\text{Ta}]_{\text{measured}} - 0.0025[\text{W}]$$

where [] refers to the concentration of the element. The value of [W] in the samples was determined from the first measurement made at McGill, as detailed in section 5.2.7.3. An indication that the correction has been properly made, at least for Co, comes from analyses of duplicate samples from the same vases. As the degree of contamination differed from sample to sample, the Co concentrations are quite different. The data are discussed in detail in the following section, where Table 5-IX includes the variability of Co

concentrations before and after correction. In three out of the four cases, the match between the corrected values was much improved. (In the fourth case the values were already close.) In fact the pairs of analyses themselves could have been used to estimate the proper correction. The ratio of the difference in Co concentrations to the difference in W concentrations is again close to 0.1 in three out of the four cases.

One factor which could invalidate the corrections is the presence of significant quantities of W already in the ceramic. Although this cannot be directly tested in every case, geochemical and practical results both indicate natural abundances of no more than a few parts per million (ppm). In a table of abundances of elements in the igneous rocks of the upper continental crust, Wedepohl (1971, p. 65) quotes a value of 1.3 ppm for W. Perlman-Asaro standard pottery contains about 4.2 ppm (F. Widemann, personal communication 1978), and the clay VOU 01B about 2.2 ppm (Table 5-XII). Several samples taken from easily-drilled objects have concentrations below the limit of detection. If we assume the maximum natural concentration of W is 10 ppm, the corrected Co concentration may be up to 1 ppm too low. Adding an uncertainty of ± 0.5 ppm, or $\pm 1.7\%$ for an average 30 ppm Co concentration, may yet be generous.

For Ta the correction makes little difference to the scatter in the concentrations. The uncertainty of the

determination itself is so large that it masks the effect of drill-bit contamination. The correction has been made, but the data are not useful for provenance studies.

Finally, the unreliability of the Lu concentration results largely from imprecision in estimating the proper Np correction; the W correction is estimated as a fraction of the area of the main W gamma-ray peak, and does not depend on the drill-bit composition.

5.3 Precision

Two approaches have been taken to determining the precision of the measurements. The first of these is indirect, consisting of the summation of the errors attributable to each factor in the basic equation for activation analysis, (5) in section 5.2.6.2. The second is a direct evaluation of the variability evident in multiple measurements made on the same material.

Individual sources of uncertainty occur at every stage of the analysis. The estimation of some of these is simple, while others are more difficult to quantify. For instance, the representativeness of the sample with respect to the heterogeneity of pottery is best determined experimentally (but see section 2.3). On the other hand, imprecision in weighing the sample and in measuring elapsed times is negligible, amounting at the most to 0.2-0.3% in each case. This corresponds to a combined total of 0.4% (since only

squared errors can be directly summed), resulting in a standard deviation σ of $\pm 0.1\%$, if we take the maximum variation to be equivalent to $\pm 2\sigma$ (e.g., Baird 1962, p. 67). The half-lives are known with sufficient precision that the uncertainty in the exponential factors of equation (5) remains below a total of 1% (or $\pm 0.25\%$ as 1σ). Flux variations may amount to $\pm 2\%$ (1σ), or half as much in the short term, as explained in section 5.2.5.2.

Variation in positioning the sample with respect to the detector contributes to the uncertainty as well. Although the capsule can be positioned very precisely in its holder, the powder inside is free to move. The capsule was tapped to force the powder to one end, but a maximum uncertainty of ± 0.5 mm in the mean sample position may be expected. If the centre of the McGill detector is taken to be approximately 30 mm below the top surface of the can, the inverse square variations caused by a 1-mm shift at distances of 80 and 50 mm above the centre of the detector (section 5.2.4) would amount to 2.5% and 4% for the first and second measurements respectively. These correspond to uncertainties of $\pm 1.25\%$ and $\pm 2\%$ total, or $\pm 0.62\%$ and $\pm 1\%$ (1σ). These values may be slightly overestimated, since they disregard the fact that the sample and the detector are both extended objects rather than abstract points. This fact affects the measurements at Poly to the extent that the uncertainty must be determined experimentally. The maximum variation in the activity of a

half-filled capsule attributable to the arrangement of powder inside is 5% (G. Kennedy, personal communication 1981). For fuller capsules, the variation would be lower, to a minimum of less than 1% when the powder is immobilized. The half-capsules in this study were usually quite well filled, so the variation can be estimated at around 2% maximum, or $\pm 0.5\%$ (1 σ). Early stages of research using whole capsules may have had variations up to 5% maximum, or $\pm 1.2\%$ (1 σ).

Finally, the statistical uncertainty arising from the random nature of gamma-ray emission contributes to a greater or lesser extent depending on the number of gamma rays detected and on the background. This is the $\pm$ figure, representing 1 σ , associated with each value in the table of analytical results (Appendix A). An average σ for each element can be determined from these data, and is presented in Table 5-VII as column 6 (estimated from the Tiryns data). Column 7 has been calculated as the square root of the sum of the squared uncertainties in each of the other columns (Baird 1962, p. 65).

It was also possible to obtain direct information on analytical variability. Although practical considerations precluded conducting a dozen complete analyses of samples from a single sherd, multiple determinations of several types provided a good indication of the precision of the data. For the short irradiations, 11 analyses of a capsule containing clay from the Vouliagmeni site (VOU 01B) were performed

TABLE 5-VII: Contributions to Analytical Precision

<u>Element</u>	<u>Percent Uncertainty (1σ) Arising from Various Sources</u>					<u>Total Uncertainty (1σ)</u>
	<u>Weighing + Timing</u>	<u>Exponential factors</u>	<u>Flux variations</u>	<u>Sample positioning</u>	<u>Counting statistics</u>	<u>(excluding sampling)</u>
Na	0.1	0.25	1.0	0.5	3	3.2
Mg					13	13
Ca					3	3.2
Al					0.8 (+1.0)	1.7
Ti					4	4.2
V					3	3.2
Mn					2	2.3
Na	0.1	0.25	2.0	0.62	0.5	2.6
K					8	8.3
Sc					3	3.7
La					2	3.0
Sm					4 +	4.6 +
Yb					15	15
Lu					20 +	20 +
U					25 - 40	25 - 40
W					3	3.7
As					10	10
Sb					30 - 50	30 - 50

TABLE 5-VII - continued

Element	Percent Uncertainty (1σ) Arising from Various Sources					Total Uncertainty (1σ)
	Weighing + Timing	Exponential factors	Flux variations	Sample positioning	Counting statistics	(excluding sampling)
Rb	0.1	0.25	2.0	1.0	9	9.3
Cs					8	8.3
Ba					25	25
Sc					0.5	2.3
Ce					4	4.6
Eu					9	9.3
Th					6	6.4
Hf					10	10
Ta					20	20
Cr					4	4.6
Fe					1.0	2.5
Co					1.5 (+1.7)	3.3
Ni					20 - 40	20 - 40
Sb					15 - 40	15 - 40

Al: 1% has been added to the total uncertainty to take into account the uncertainty in the systematic underestimation of Al (see section 5.2.7.2). This is negligible in the case of V.

Sm, Lu: The + indicates the concentrations are unreliable (see section 5.2.7.3).

Co: The extra 1.7% uncertainty arises from the correction of the Co concentration for drill-bit contamination. This is negligible in the case of Ta.

over a period of six months. The results are presented in Table 5-VIII. They indicate that although counting statistics are a major source of uncertainty for some of the elements, even with very good statistics it was not possible to reduce the actual precision below 3.9% (1σ). It should be noted that for this set of analyses a half-filled whole capsule had been used, so that the error in positioning was greater than that quoted in Table 5-VII. Nevertheless these data provide independent estimates of the precision of the analyses as a whole.

In a number of instances a pair of samples could be attributed to the same vase on typological grounds with a high probability, and in one case with certainty (the vase was later reconstructed). A comparison of the composition of each member of the pair gives an idea of the overall analytical variability. Sampling variability forms part of this evaluation, but in all except one of the 4 cases, both members of the pair happened to be included in the same long irradiation (the exception being TIR 61 and 86), so that the effect of variations of flux with time is not taken into account. Table 5-IX shows the variation for each element in the 4 sample pairs, and the average variation, all expressed as a standard deviation in per cent. For the short-irradiation elements, differences between these values and those derived from the multiple analyses of VOU 01B (Table 5-VIII) and from consideration of individual contri-

TABLE 5-VIII: Multiple Analyses (Short Irradiation Only) of Vouliagmeni Clay VOU 01B

<u>Date</u>	<u>Na (%)</u>	<u>Mg (%)</u>	<u>Ca (%)</u>	<u>Al (%)</u>	<u>Ti (%)</u>	<u>V (ppm)</u>	<u>Mn (ppm)</u>
81.2.24	0.65	1.6	19.3	5.65	0.35	94	827
81.3.5	0.67	1.8	18.0	5.74	0.30	100	852
81.3.26	0.73	1.7	19.8	5.98	0.35	101	920
81.4.2	0.72	1.9	19.5	5.88	0.35	107	892
81.4.9	0.71	1.8	19.9	5.98	0.37	108	921
81.5.14	0.72	1.6	20.3	5.90	0.35	106	908
81.6.4	0.72	1.8	20.0	5.92	0.33	102	937
81.6.23	0.73	2.2	20.2	6.26	0.31	100	922
81.7.15	0.68	1.5	18.4	5.54	0.31	101	862
81.8.5	0.68	2.1	18.8	5.51	0.34	100	864
81.8.12	0.69	1.9	20.3	6.04	0.33	105	950
Counting Statistics (1σ)	±0.02	±0.24	±0.4	±0.05	±0.02	±3.5	±15
Counting Statistics (%)	2.9	13	2.0	0.9	5.9	3.4	1.7
Mean Concentration	0.700	1.81	19.50	5.85	0.336	102.2	896
Standard Deviation	0.027	0.21	0.79	0.23	0.022	4.0	39
Standard Deviation (%)	3.9	11.7	4.1	3.9	6.4	4.0	4.4
Uncertainty not due to Counting Statistics (%)	2.6	--	3.6	3.8	2.5	2.1	4.1

TABLE 5-IX: Variability of Duplicate Samples from the
Same Vases*

	<u>KER</u> <u>60 & 61</u>	<u>KER</u> <u>68 & 69</u>	<u>TIR</u> <u>61 & 86</u>	<u>TIR</u> <u>73 & 74</u>	<u>Mean</u> <u>σ</u>
Na	4.6	6.0	3.2	2.1	4.0
Mg	7.9	2.2	0.0	5.2	3.8
Ca	4.7	21.7	4.1	14.9	11.4
Al	2.7	1.4	0.1	1.8	1.5
Ti	11.6	5.0	3.3	3.0	5.7
V	0.9	0.4	1.1	1.1	0.9
Mn	3.5	1.9	0.2	4.0	2.4
Na	1.1	9.4	3.0	0.3	3.4
K	10.6	0.1	5.3	4.8	5.2
Sc	0.1	1.4	0.3	3.8	1.4
La	0.9	2.2	1.3	3.1	1.9
Sm	1.2	0.9	5.8	1.4	2.3
Yb	10.5	6.9	4.9	6.3	7.2
Lu	9.0	26.9	21.2	7.1	16.0
U	7.0	16.9	43.3	5.0	18.0
W	55.2	31.1	34.1	5.4	31.4
As	27.5	74.8	70.1	5.6	44.5
Sb	35.9	15.9	-	5.1	19.0

TABLE 5-IX - continued

	<u>KER</u> <u>60 & 61</u>	<u>KER</u> <u>68 & 69</u>	<u>TIR</u> <u>61 & 86</u>	<u>TIR</u> <u>73 & 74</u>	<u>Mean</u> <u>σ</u>
Rb	1.8	9.3	10.9	4.3	6.6
Cs	4.6	5.5	5.0	11.2	6.6
Ba	15.3	42.8	-	32.4	30.2
Sc	1.9	3.4	0.3	2.6	2.0
Ce	1.2	0.9	2.9	3.5	2.1
Eu	5.6	2.2	2.4	1.7	3.0
Th	0.2	3.5	1.3	8.2	3.3
Hf	7.9	20.5	10.6	3.8	10.7
Ta	16.7	1.5	23.8	14.1	14.0
Cr	4.8	3.3	1.7	10.5	5.1
Fe	0.7	3.8	1.2	2.4	2.0
Co	7.7	8.2	2.2	1.3	4.9
Ni	31.4	28.1	37.8	-	32.4
Sb	34.3	12.7	35.0	61.3	35.8
Co (corrected)	0.2	0.0	0.6	4.6	1.4
Ta (corrected)	29	11	22	26	22

* All figures represent one standard deviation, expressed in percent.

butions to the precision (Table 5-VII) exist for Mg, Al, V, and Ca. For the first three of these, the precision is better than expected, probably by chance. The larger variations in Ca concentration, on the other hand, must reflect heterogeneity of the ceramic paste. For almost all elements determined in the first measurement following the long irradiation, the standard deviations are again smaller than those of Table 5-VII. Constancy of flux accounts, to some extent at least, for these differences. The variations in tungsten are to be expected, since that element enters the sample largely through the drilling process. Arsenic, however, varies far more than expected on analytical grounds. It may be partially volatilized during the original firing of the pot or in the baking of the powdered sample, or it may simply be distributed very heterogeneously in clays, as Franklin and Hancock (1979) claimed. In any case, these large variations make it unsuitable for provenance studies. Among the elements determined from the second measurement, only the uncorrected Co shows variations larger than those predicted by Table 5-VII.

5.4 Accuracy

The accuracy of the analysis is an estimate of how close the reported concentrations are to their "true" values, or at least to those determined by a consensus of analytical methods. The accuracy is thus the relevant indicator of reliability to be used when comparing analytical data from

different laboratories. Like the precision, it can be estimated by combining the errors associated with the various experimental factors in the calculations, though a true test would involve interlaboratory comparisons. In this case, the total measurement precision, the precision of the activation constants (B values), and the accuracy of the quoted composition of the standard pottery must be taken into account. (It should be noted that this does not include the sampling uncertainty.) For comparisons with other work using the Perlman-Asaro pottery as a standard, however, the last factor need not be considered, as the same values for its composition (Table 5-II, taken from Perlman and Asaro 1971) would have been used at all the laboratories. In fact, laboratories (such as BNL) using other standards often perform intercalibrations, involving multiple high-precision analyses of one standard using the other as a reference, in order to determine correction factors which enable direct comparison of analytical data (see Table 7-X). Since all the comparisons of data from this work use either data calculated from the Perlman-Asaro standard or BNL data, for which a good intercalibration exists (Yeh and Harbottle 1981), the uncertainties in the standard pottery are not included in the estimate of the total accuracy. They can nevertheless be found in Table 5-II.

Table 5-X shows the results of combining the analytical precision with the precision of the activation constants.

TABLE 5-X: Precision of Activation Constants and Overall Accuracy

<u>Precision of Activation Constants (1σ, %)*</u>		<u>Experimental Precision (from Table 5-VII)</u>	<u>Overall Accuracy (1σ, %)[†]</u>
<u>Short irradiation</u>			
Na	2.5	2.3	3.4
Mg	2	13	13
Ca	3	3.2	4.4
Al	2	1.7	2.6 + 5 → 5.6
Ti	3	4.2	5.2
V	3	3.2	4.4 + 2.5 → 5.0
Mn	3	2.3	3.8
<u>Long irradiation, first measurement</u>			
Na	0.8	2.6	2.7
K	1.0	8.3	8.4
Sc	1.8	3.7	4.1
La	1.0	3.0	3.2
Sm	1.5	4.6 +	4.8 +
Yb	7.6	15	17
Lu	5.5	20 +	20 +
U	6.0	25 - 40	25 - 40
W	4.9	3.7	6.1
As	1.6	10	10
Sb	3.9	30 - 50	30 - 50

TABLE 5-X - continued

Precision of Activation Constants (1σ, %) *		Experimental Precision (from Table 5-VII)	Overall Accuracy (1σ, %) [†]
<u>Long irradiation, second measurement</u>			
Rb	7.7	9.3	12
Cs	2.8	8.3	8.8
Ba	9.5	25	27
Sc	1.1	2.3	2.6
Ce	3.4	4.6	5.7
Eu	4.0	9.3	10.1
Th	4.0	6.4	7.6
Hf	4.6	10	11
Ta	10.1	20	22
Cr	2.6	4.6	5.3
Fe	1.8	2.5	3.1
Co	2.0	3.2	3.8
Ni	13.2	20 - 40	25 - 40
Sb	13.0	15 - 40	20 - 40

* For the short irradiation, these data were provided by G. Kennedy (personal communication 1981). For the long irradiation, the first set represents the standard deviations of 6 measurements of the standard pottery, and the second set represents the standard deviations of 13 such measurements.

[†] Relative to standard pottery for long irradiation data.

Al, V: The inaccuracy arising from the systematic underestimation of these concentrations has been added.

Sm, Lu: The + indicates that the reported concentrations are unreliable owing to interferences which have not received adequate correction.

For the short irradiation the activation constants were determined from irradiations of pure compounds, so that the quoted accuracy should be valid for any comparisons. The rest of the data are valid for comparison with other standard-pottery-based data.

As was the case for precision, direct evidence for measurement accuracy is also available from several sources. First of all, the standard pottery itself has been analyzed at Poly for elements whose activated forms are short-lived. The results of this analysis are compared in Table 5-XI to the Perlman-Asaro (1971) determination and to a U of T analysis (Hancock 1976). Agreement is excellent for all elements except Mg, where the precision is very poor, and Ca, which may be non-uniformly distributed in the standard pottery. (The low sample mass of the Poly analysis resulted in a reduction of the systematic underestimation of Al and V.)

A second material has been analyzed at BNL and GANOS as well as several times at McGill. This is the fired clay VOU 01. Agreement is in general very good (Table 5-XII). The BNL results, converted to the Perlman-Asaro standard using the intercalibration of Yeh and Harbottle (1981), stand a little apart for some elements (Na, K, La) but are otherwise perfectly acceptable. Among the elements whose determination presents difficulties, Lu at McGill is significantly low, though Sm is consistent from laboratory to laboratory. The McGill Th value is also lower than the others.

TABLE 5-XI: Partial Analyses of Perlman-Asaro StandardPottery

	<u>Perlman and Asaro (1971)</u>	<u>This work</u>	<u>Hancock (1976)</u>
Na (%)	0.258 ± 0.004	0.25 ± 0.02	0.274 ± 0.006
Mg (%)	0.5 ± 0.2	0.74 ± 0.46	1.32 ± 0.16
Ca (%)	< 0.02	0.4 ± 0.1	0.2 ± 0.1
Al (%)	15.3 ± 0.2	15.5 ± 0.1	13.6 ± 0.4
Ti (%)	0.782 ± 0.034	0.86 ± 0.04	0.844 ± 0.074
V (ppm)	---	168 ± 6.	150 ± 10.
Mn (ppm)	40.9 ± 0.5	41 ± 6.	37.6 ± 1.9

* The ± terms accompanying the Perlman-Asaro data are indications of accuracy, whereas those accompanying the other data represent ±1σ counting statistics only.

TABLE 5-XII: Multiple Analyses of Vouliagmeni Clay

<u>Element</u>	Mean of <u>VOU 012, 013, 014</u> (Attas <u>et</u> <u>al.</u> 1977)	<u>VP 13</u> BNL * 1976-77	Mean of <u>VOU 001, 002</u> GANOS (Attas 1980)	<u>VOU 01B</u> (this work)
Mg	-	-	-	1.8
Ca	20.4	20.2	20.4	19.5
Al	-	-	-	5.85
Ti	-	-	-	0.34
V	-	-	-	102
Mn	-	911	816	896
Na	-	0.93	0.68	0.71
K	-	1.46	1.78	1.73
La	24.9	20.2	24.7	23.4
Sm	4.47	-	4.30	4.37
Yb	2.45	-	2.16	1.96
Lu	0.33	0.32	0.32	0.26
U	-	-	-	1.2
W	-	-	-	2.2
As	8.8	-	11.6	6.2
Sb	0.88	0.93	-	0.52
Rb	81	87	-	73
Cs	6.6	7.5	10.6	9.5
Ba	234	282	-	-
Sc	15.7	14.7	16.2	15.5
Ce	47.0	43.0	-	45.1
Eu	1.04	0.92	1.22	1.01
Th	8.2	6.8	7.8	5.2
Hf	3.41	3.38	3.6	3.0
Ta	0.56	0.43	-	0.48
Cr	212	209	190	178
Fe	3.92	3.60	4.08	3.77
Co	24.6	23.5	25.3	23.3

* Converted using factors from Table 9 of Yeh and Harbottle (1981).

Finally, a set of samples whose analysis at GANOS had been incomplete was re-analyzed in full at McGill. These were the samples KER 9-18 and KRK 5-14. The partial GANOS data (Attas 1980) have been compared with the McGill values (appendix A) both as group means, the sets each being archaeologically homogeneous, and on a sample-by-sample basis. Agreement was satisfactory (indeed, within the limits of experimental precision) for all elements except the following:

- W: GANOS values are a factor of 10 lower, but follow the same trends as the McGill values. GANOS had difficulty in measuring the very small W peak in the standard pottery. The activation constant used in the McGill work was checked against that derived from a pure W compound and was found to agree within 5%.
- Lu: The McGill values are 25-30% higher than those at GANOS. Difficulties in correcting for the Np and the W contributions may exist at both laboratories.
- As: Large random deviations exist between the two sets of measurements. As no technical difficulties are evident, perhaps natural variations in the clays are the cause (see also section 5.3).
- Rb: The GANOS values have measurement uncertainties of 50% or more, and are therefore not useful.
- Ce: The McGill values are systematically 10% higher than those at GANOS.
- Th: The GANOS values are 40% higher than those at McGill. Again, the McGill activation constant was checked using

a Th standard and found to agree within 16%. Comparison of pottery groups from other sites (that is, similar, though not identical samples) shows good agreement for Vouliagméni, Asine, and Zygouriés, but again a 40% discrepancy for Phlious. Since at GANOS the samples from each site were irradiated as a group, each group with its own pottery standard, it is likely that in some cases the measurement of ^{233}Pa in the standard pottery at GANOS presented problems.

Ta: Neither determination is very precise.

Cr: The McGill values are systematically 9% lower than those at GANOS.

With these few discrepancies in mind, it is therefore possible to combine McGill and GANOS data with confidence, knowing that the accuracy of both is sufficient to ensure the success of direct comparisons.

6. FORMATION OF REFERENCE GROUPS

6.1 Introduction

The result of the chemical analyses is a large data table presented, for ease of consultation, in Appendix A. This mass of data is not easily interpreted by eye, but there are several means of condensing or otherwise transforming it to make it more tractable. The aims of data analysis in this study are the following:

- 1) to establish chemical groups, each with a single provenance (but possibly more than one with the same provenance);
- 2) to assign other samples to these groups, if they had been excluded from the analysis in the first stage;
- 3) to distinguish or conflate archaeological groups.

An archaeological group is here taken to mean a set of sherds of similar form/paste/decoration and findspot. A chemical group, for the purposes of this chapter, is a collection of samples from a single site whose composition is similar. Since the chemical attributes of a sample (the concentration values) are all numerical ones, a mathematical approach to the definition of "similarity" is straightforward. The constitution of chemical groups then becomes a problem in numerical taxonomy (Sneath and Sokal 1973). Since many

works describing the application of taxonomic and multivariate statistical techniques to provenance analysis have recently appeared (Ward 1974; Doran and Hodson 1975; Bieber et al. 1976a; Harbottle 1976; Sayre 1977; Wilson 1978; Catling et al. 1980), the theory behind these techniques is not described in detail here. Instead, the first part of this chapter demonstrates the use of these techniques with material from a typical site, Keramidhaki. In the second part are presented results of group formation for the other sites. The approach whereby the material from each site is first handled on its own is recommended by Wilson (1978, p. 230) on grounds of clarity and flexibility. Once one or more tentative groups have been established for each site, they can be compared between sites both as groups and on a sample-by-sample basis. This procedure may lead to adjustments of the group constitutions, and possibly to the merging of groups from separate sites.

6.2 Procedure, exemplified with Keramidhaki material

6.2.1 Histograms and scatter plots

The examination of data from a single site can result in the isolation of single samples with unusual compositions ("outliers") as well as the subdivision of the majority of the samples into subgroups, each of relatively uniform composition. Several techniques exist for identifying outliers, some of which are useful also for subdividing groups. Perhaps the simplest is the examination of histograms and

scatter plots, visual representations of the distributions of elemental concentrations for one and two elements respectively (Picon et al. 1971; 1975; Brooks et al. 1974). Samples with extreme values for one or more elemental concentrations are easily identified, and can be set aside for consideration at a later stage of the data analysis. Occasionally a bimodal (two-humped) distribution of concentrations can be observed, providing grounds for a preliminary subdivision of the samples from a single site into two groups.

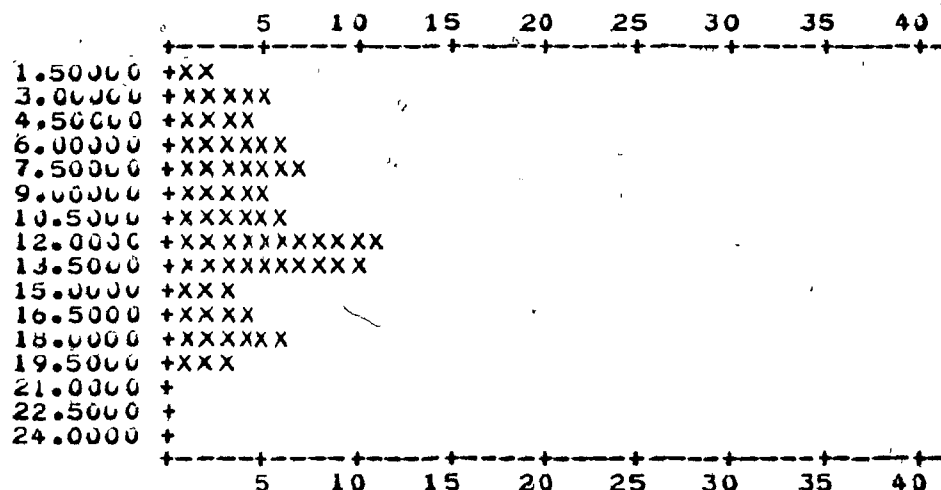
The usual form of an elemental distribution for a chemical group is a matter currently under discussion, some researchers claiming to have found normal (Gaussian) distributions and others log-normal ones. Catling et al. (1980, p. 68) point out that a rigorous decision in each case may be made only on the basis of statistical tests for properties known as skewness and kurtosis. Unfortunately, these tests require numbers of samples greater than those used in most provenance studies. Moreover, these authors found "by extensive experimentation that where strong structure is latent in the composition data the form of the probability distributions employed has relatively little effect on the results obtained". In the present study, as in theirs, a logarithmic transformation was not routinely performed in preparation for the multivariate analyses; where occasional comparison checks have been made, the transformed data gave groupings similar to those found using untransformed data.

The effect of other transformations is discussed in the next section.

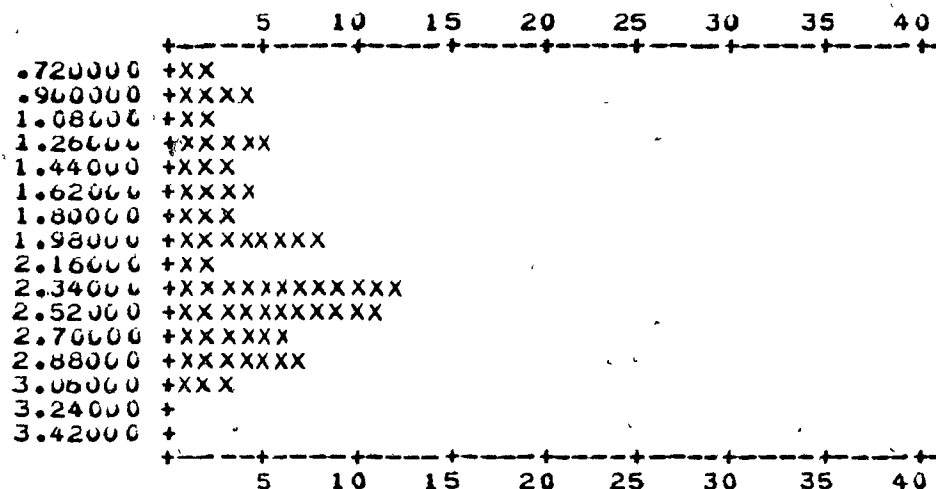
Histograms of elemental concentrations for the Keramidhaki analyses, including the four KOR samples from other excavations at ancient Corinth, immediately enabled certain samples to be identified as outliers (see, e.g., Fig. 6-i; others not shown). For instance, KER 63 stands out with extremely high Mg, V, Cr, and Fe concentrations; KOR 3 with the highest Al, Ti, La, Yb, Ce, and Hf values; KER 62 (low Al, La, Yb, Sc; high Cr); KER 24 (low Mn; high Th, Hf); KER 26 (high Mn); KER 29 (high Cs); KOR 2 (low Sc, Fe); KER 20 (high Co); and so on. The shape of the distribution for most elements is unimodal, but is not clearly enough defined to be called either normal or log-normal. The distributions for a few elements are unusual: that of Ca is very broad, and may be multimodal; that of K appears to have a valley around 2%; and that of La has one around 32 ppm (Fig. 6-i). Scatter plots of the Keramidhaki data reveal other interesting features. There is a negative correlation between Na and K (correlation coefficient $r = -0.64$), indicating that an ionic substitution may have taken place (Fig. 6-ii). Such an effect has been noticed for these elements by Asaro *et al.* (1975, p. 227) and by Fillières (1978, p. 119). Widemann (personal communication, 1979) has postulated that when substitution has occurred, the molar sum of these concentrations, namely $[Na]/23.0 + [K]/39.1$, should

FIGURE 6-1: Histograms of Ca, K, and La concentrations
for the Keramidhaki samples.

Ca
(%)



K
(%)



La
(%)

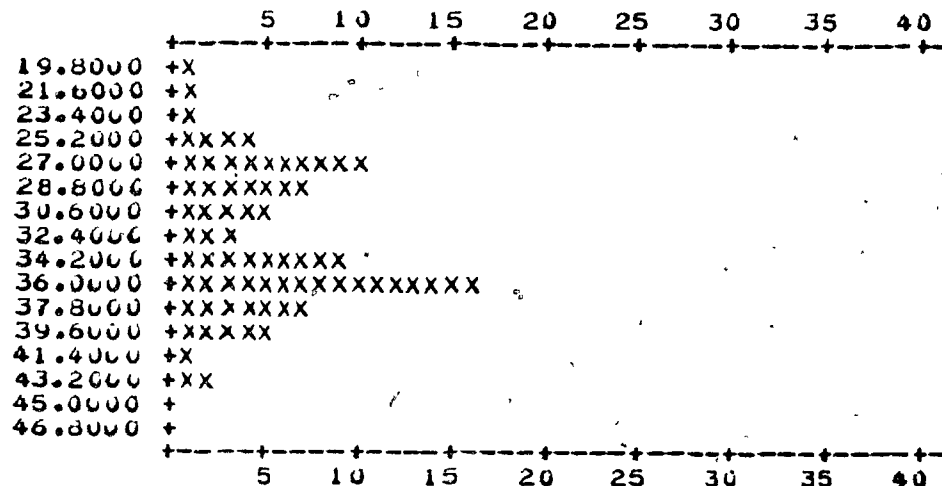
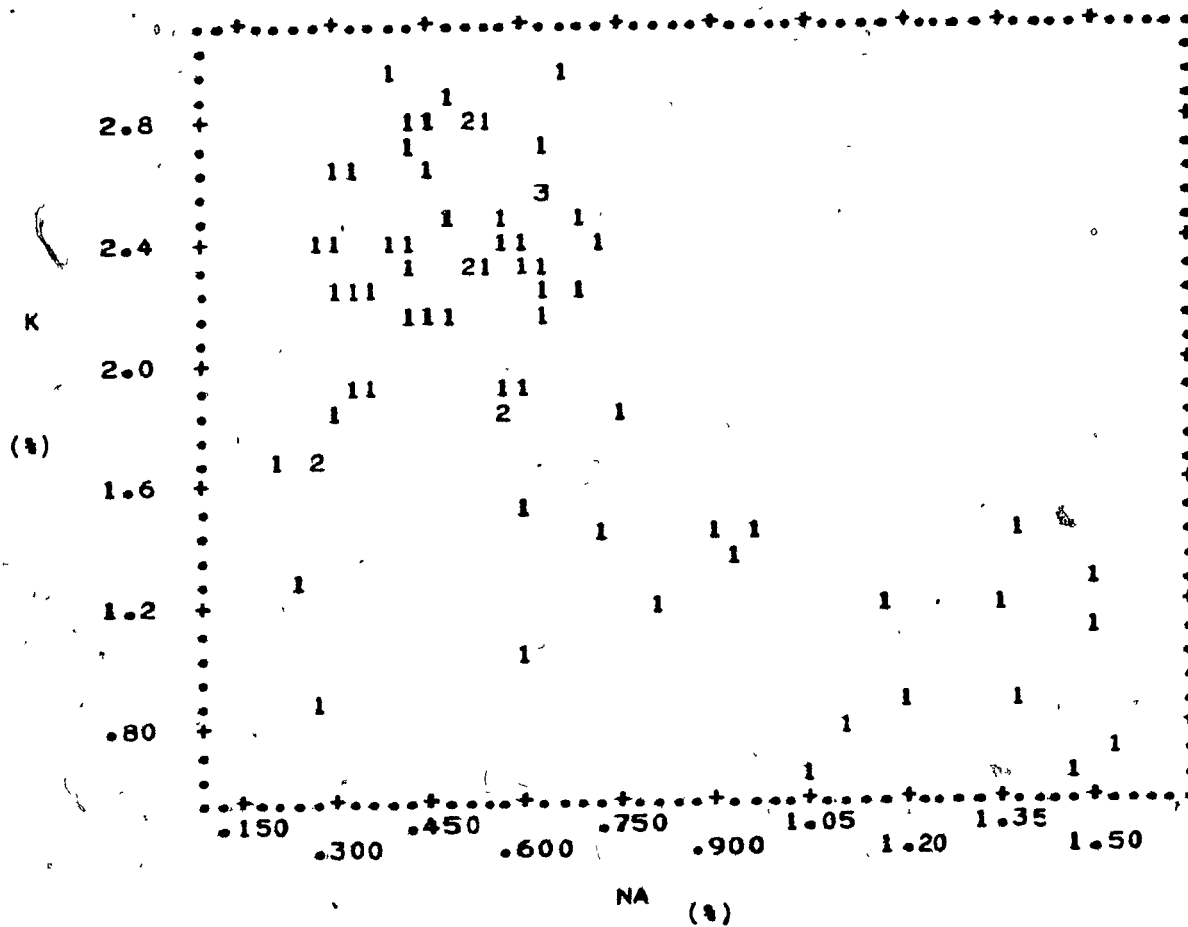


FIGURE 6-ii: Scatter plot of Na and K concentrations for the Keramidhaki samples.



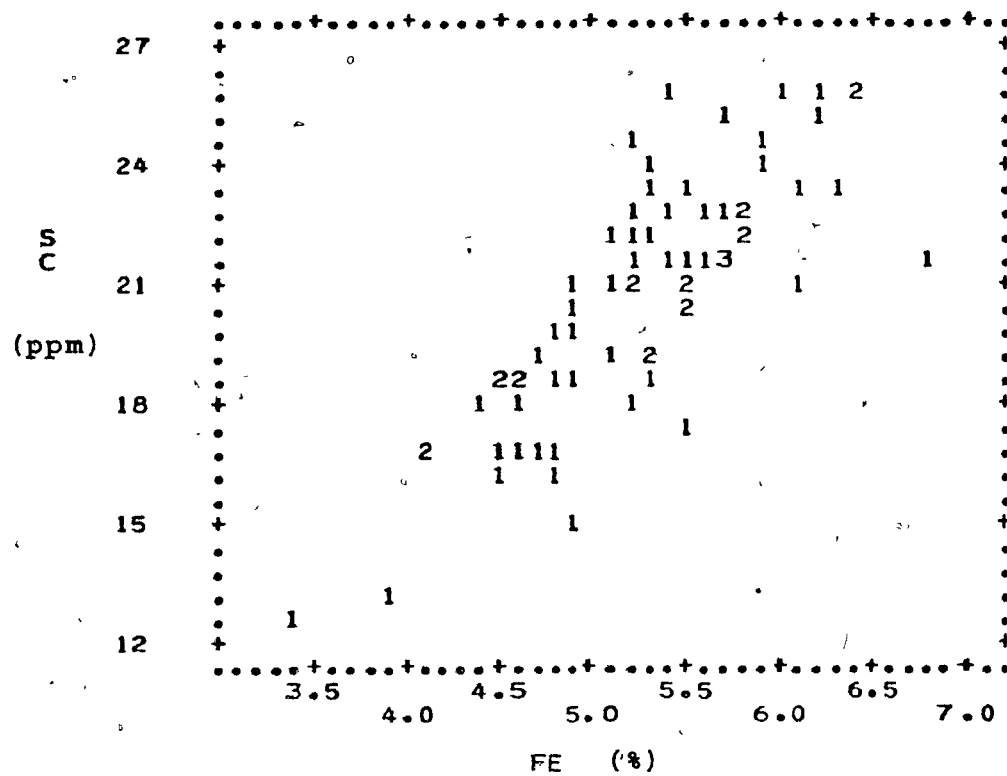
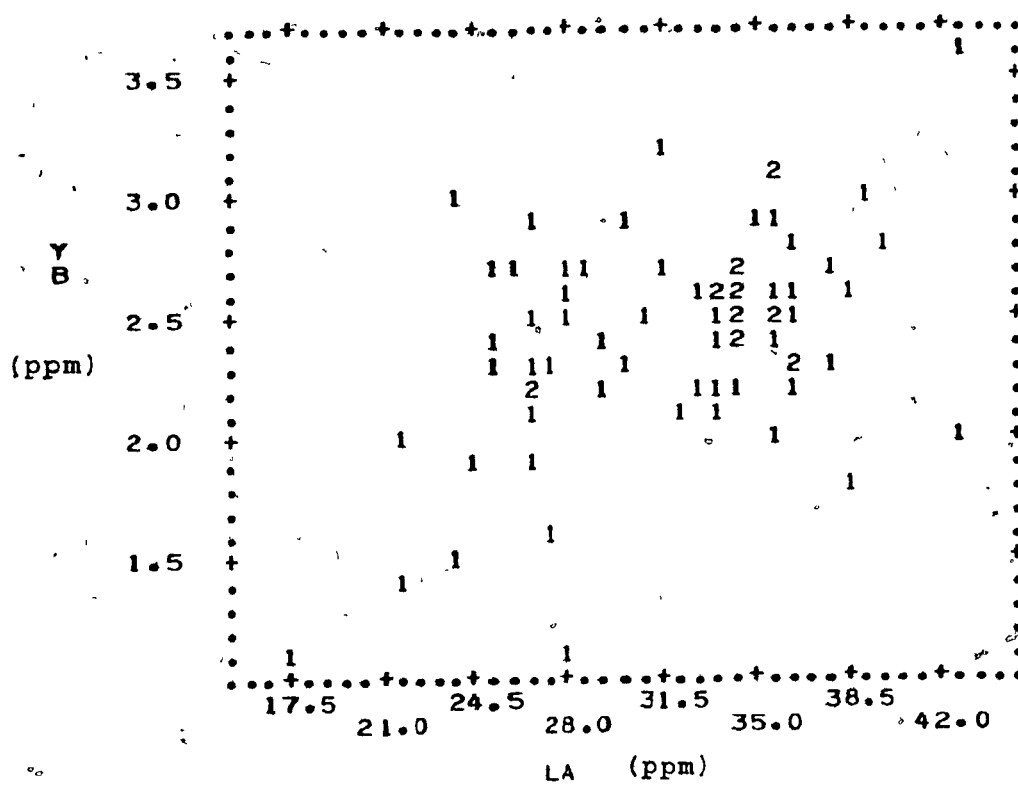
remain approximately constant. The relative standard deviation of this sum over the whole Keramidhaki data set is indeed lower than that of either element alone (18% vs. 53% for Na and 32% for K). The plot of Yb vs. La (Fig. 6-iii) seems to show two groups divided on the basis of La concentration. The Fe vs. Sc plot (Fig. 6-iv) does not show a correlation as strong as that observed by Brooks et al. (1974), indicating that the KER samples as a whole do not form a homogeneous group. Information of this sort is intriguing, but its interpretation can be made more explicit by the results of multivariate data treatments.

6.2.2 Cluster analysis

One of the most useful techniques for examining the interrelationships of samples is cluster analysis (Sneath and Sokal 1973; Doran and Hodson 1975; Bieber et al. 1976a). This is a procedure, almost inevitably performed by computer, whereby samples are linked one at a time, on the basis of compositional similarity, to form clusters of ever-increasing size. Depending on the nature of the data under study and on the desired form of the results, several options are available to the user of a cluster-analysis program. First of all, there are many ways to calculate the similarity of two samples. For numerical data, the most common is a form of Euclidean distance, based on the sum taken over all the elements of squared differences between elemental concen-

FIGURE 6-iii: Scatter plot of Yb and La concentrations for the Keramidháki samples.

FIGURE 6-iv: Scatter plot of Fe and Sc concentrations for the Keramidháki samples.



trations. Squared Euclidean distance (SED) is calculated between samples A and B as follows (Sneath and Sokal 1973, p. 124):

$$SED_{A,B} = \sum_{i=1}^n (A_i - B_i)^2$$

where A_i and B_i are the concentrations of the i 'th element in samples A and B, and n is the number of elements considered. When $n=2$ or 3 the sum corresponds to the familiar Pythagorean formula for distance in a plane or in space. For any number of dimensions (elements), a small value of SED indicates a pair of very similar samples. Before the actual clustering this value must be calculated for all possible pairs of samples. (To facilitate comparisons between sets of data where different numbers of elements are being considered, the mean squared Euclidean distance (MSED) is occasionally determined, by dividing the sum by the number of elements in each case [Bieber et al. 1976a].)

Using the SED or MSED values arranged in a table, or "distance matrix", the cluster analysis proceeds in steps. At the first step⁰, each sample constitutes its own single-member cluster; the last results in the fusion of all the samples into a single cluster. A choice of criteria exists for determining which two clusters at any stage are "most similar", and hence are the next to be joined. Frequently used for archaeological applications are the single-linkage, average-linkage, and centroid methods (Doran and Hodson 1975,

pp. 176-177). The first of these uses as the distance between two clusters the smallest distance between two samples chosen one from each cluster; in the second, the average distance between all such pairs is used; and in the third, the distance between the centroids (multivariate means) of the two clusters is calculated. Single-linkage clustering tends to produce "chained" clusters, with many single samples being joined in preference to multi-sample clusters. Although superior on theoretical and computational grounds (Doran and Hodson 1975, p. 176), single-linkage clustering has been found by archaeologists to be less useful for forming meaningful groups than the other two methods. Average-linkage is one of the most popular methods for forming unchained, or relatively homogeneous, clusters (Wilson 1978, p. 230). The centroid method produces almost identical results but requires less computer memory than the average-linkage method (Dixon 1981, p. 459). Its main peculiarity is that the sequence of amalgamation distances need not be strictly monotonic (see, e.g., Fig. 6-v).

Although raw concentration values could be used to calculate the distance matrix for cluster analysis, in most cases these data are first standardized. By subtracting from each concentration value the mean value for that element within the archaeological group being considered and dividing by its standard deviation, the concentrations are normalized so that all have the same basic statistical parameters

(zero mean and unit variance). In this way the effect of different units of measurement and different concentration ranges for each element is eliminated. All elements contribute equally to the calculated distances. (This can also be achieved to a certain extent through a logarithmic transformation.)

The presence of outliers can distort the normalizing effect of the standardization procedure. If one sample has a very different concentration value for a certain element, then the standard deviation for that element will be greatly increased. After standardization, the concentration range for that element will be much smaller (except for the aberrant sample's value) than the ranges for the other elements. That element will therefore play a smaller role in clustering.

To avoid this eventuality, outliers should be removed before a definitive cluster analysis is performed. Which samples are to be considered outliers can be determined from histograms, as described above, or from a preliminary cluster analysis. The latter choice has the advantage that, if the analysis is performed several times in succession each time after the removal of a few more outliers, the changes in the remaining clusters can be examined. Their eventual stability is an indication that the effect of any remaining samples with slightly aberrant compositions is negligible.

The results of a cluster analysis are most conveniently represented in the form of a dendrogram, or tree-like struc-

ture, with a single sample at the tip of each branch. The vertical axis shows the distances between samples and clusters; similar ones join at low distances (near the branch tips) and very different ones at large distances. If there are outliers, they often appear as a set of single-sample branches joining only towards the end of the clustering procedure.

The computer program BMDP2M (Dixon 1981) was found to be convenient for cluster analysis. Iterative clustering was applied to the Keramidhaki data under the following conditions: the elements taken into account (based on the information in section 5.2.7) were Ca, Al, Ti, V, Mn, Na, K, La, Yb, Rb, Cs, Sc, Ce, Eu, Th, Hf, Cr, Fe, and Co; the elemental concentrations were standardized; centroid clustering was performed on a Euclidean distance matrix. The first attempt, using all 72 KER and KOR samples, gave a dendrogram (Fig. 6-v) with one small cluster, two large ones, and these outliers (listed in decreasing order of linkage distance): KER 63, KER 45 and 62, KER 20, KOR 3, KOR 2, KER 24, KER 29 and 46, KER 47 and 49, KER 23 and 26, KER 22, 25, and 28. A second clustering which included all samples except the eight farthest outliers produced two large clusters, several small ones, and fourteen outliers, either singly or in pairs. Removing five of these and repeating the analysis produced a dendrogram of similar overall structure, with seven outliers. The five most extreme of

FIGURE 6-v: Cluster-analysis dendrogram for 72 Keramidhaki samples.

1.268
1.388
1.595
1.623
1.698
1.596
1.697
1.718
1.725
1.697
1.731
1.520
1.791
2.006
2.007
1.956
1.998
2.013
2.025
2.073
1.127
1.171
2.219
2.261
2.324
2.325
2.354
2.381
2.164
2.297
2.469
2.479
2.542
2.508
2.510
2.591
2.674
2.695
2.732
2.901
2.842
2.978
2.988
2.989
3.067
3.181
3.195
3.422
3.402
3.398
3.432
3.463
3.571
3.589
4.185
3.874
4.277
4.889
4.235
5.394
6.336
6.540
7.231
7.655
8.331
10.069

these were removed for the next clustering, after which three more were removed in preparation for an attempt with 51 samples in all. By this point, although a few outliers were still present, the structure of the rest of the dendrogram remained unchanged (Fig. 6-vi). At the dissimilarity level of 4.0, it comprised the following clusters:

- A. KER 1, 2, 6, 7, 14, 15, and KOR 1;
- B. KER 43 and 57;
- C. KER 4, 9, 10, 12, 16, 17, 21, 34, 35, 41, 55, 59, 60, 61, and 66;
- D⁺ (i.e. associated with D) KER 53;
- D. KER 3, 5, 8, 13, 19, 32, 36, 39, 40, 48, 51, 52, 56, and 67;
- E. KER 22, 27, 44, 58, 65, and KOR 4;

and the outliers KER 25, 33, 38, 54, and the pair (F.) KER 37 and 42.

6.2.3 Interpretation of cluster-analysis dendrograms

If one chooses a different dissimilarity level at which to examine the dendrogram's structure, this would naturally result in a different set of clusters. A higher level would yield a smaller number of larger, more dispersed clusters, and a lower level would have the opposite effect. Several indications can guide the user in selecting the most suitable dissimilarity cut-off, and hence the most suitable number of

FIGURE 6-vi: Cluster-analysis dendrogram for 51 Keramidhaki samples.

clusters (Wilson 1978, p. 231). The first of these comes from the dendrogram itself. Doran and Hodson (1975, p. 182) have suggested examining the sequence of dissimilarity-level values through the later steps of the clustering procedure. Abrupt changes in the values indicate that very dissimilar clusters are being joined; those clusters would best be kept separate. The dissimilarity levels of the final Keramidhaki dendrogram show several "jumps" in the last steps, but the first of these occurs between the values of 3.940 and 4.118. Prior to that step, moreover, single samples are being added to clusters, whereas in the steps immediately following it, the clusters themselves are being combined. Therefore this arrangement seems to be the earliest one in which the clusters might be significant.

A second form of evidence often helpful to the interpretation of cluster analysis results is chemical. A lower limit on the level of dissimilarity which is significant can be determined by estimating the greatest distance value which could arise between identical samples as a result of analytical imprecision (Wilson 1978, p. 232). This may not be a simple calculation, and when the data are standardized, the result depends on the particular data set being studied. For this 51-sample Keramidhaki cluster analysis, the minimum significant distance is approximately 1.9. Perhaps a more meaningful figure can be determined from the analysis of duplicate samples from the same vase. Table 5-IX lists two such KER

pairs, but only KER 60 and 61 are included in the cluster analysis (KER 68 and 69 being outliers). They join at a dissimilarity level of 2.4. We may therefore assume that differences smaller than this value are not significant. This result has no bearing, however, on the significance of clusters separated by greater distances. Natural geochemical variations in clay composition within a given chemical group certainly account for at least part of the larger observable differences.

Finally, the nature of the samples themselves can aid in selecting meaningful clusters from the dendrogram. As Wilson (1978, pp. 231-232) pointed out by way of example,

if the individual specimens from each of the different styles of pottery examined were scattered more or less evenly over the complete dendrogram, it would be reasonable to conclude that composition types are not correlated with the nature of the pottery from that site. One large cluster might then be a satisfactory interpretation of the dendrogram. If, on the other hand, the different pottery styles were systematically ordered within the dendrogram, at least two composition types would certainly be appropriate.

When all three sources of evidence, the mathematical, the chemical, and the archaeological, indicate the same arrangement of clusters, this arrangement can be considered significant, if not definitive. If the indications are conflicting, however, tentative judgments can be made, subject to later testing by comparison with groups from other sites and open to subsequent changes.

Let us take a closer look at the nature of the samples in each of the Keramidhaki clusters. The first cluster comprises 5 samples of fabric 1 and 2 of fabric 2 (of Cherry's classification; see section 4.5.4). All are common shapes in medium or fine paste except KOR 1, a coarse-paste animal figurine. The second comprises the two samples of fabric 3b, coarse fragments of wall and of jar rim. The third is a large cluster of 15 samples mostly from common vase shapes in fabrics 2, 3, and 4. The other large cluster has 14 members of various forms and finenesses, in fabrics 1, 2, and 3. Quite distant from these clusters is one consisting of 6 relatively coarse samples from unusual objects fashioned in pastes 2, 4, 5, and 7 (misc.).

There is clearly some correlation between the chemical nature of the clusters and the forms and fabrics of their members. The correlation is far from perfect, however, particularly for the largest cluster. If one interprets the dendrogram in the light of Wilson's remarks, quoted above, the most that can be said is that the first 39 samples (clusters A to D) may form one large Keramidhaki group.

6.2.4 Including descriptive information

There are several approaches by which the relationship between the appearance (form, paste, fabric) and the chemical composition of pottery can be further explored. Some of these may be useful also for testing the single-group hy-

pothesis just mentioned. They have in common the prior arrangement of the samples into archaeological groups, whose chemical nature is then examined by a computer-statistical routine. This examination can be univariate, using histograms, or multivariate, using stepwise discriminant analysis. The first archaeological grouping to be investigated was the arrangement of the KER samples into Cherry's fabric groups. There are nine of these, including miscellaneous (no. 7) but excluding the rare fabric 3c, of which no sherds were sampled.

The program BMDP7D in the University of California package of Statistical Software (Dixon 1981) produces side-by-side histograms of elemental concentrations for samples in several preassigned groups. These can then be compared visually and with the aid of t-tests for evaluating possible differences in the means. When the analytical data for all 72 Keramikhaki samples (including the 4 more precisely from the Agora area of ancient Corinth) were displayed in this way, several trends were evident. The histograms for several elements are shown here (Fig. 6-vii). The concentrations of calcium vary extensively between groups: they are high for sherds of fabrics 4, 5, and 6, and intermediate for the two sherds of fabric 3b. Scandium concentrations are relatively low for sherds of fabrics 4, 6, and particularly 5. Also relatively low in samples from fabric category 5 are aluminum and vanadium concentrations. High concentrations of sodium occur only in sherds of fabrics 1 and 2, where low concen-

FIGURE 6-vii: Histograms of Ca, Sc, Al, V, and Na concentrations for the Keramidhaki samples arranged by fabric group.

MIDPOINTS	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12
Ca (g)	21.500	21.500	21.500	21.500	21.500	21.500	21.500	21.500	21.500	21.500	21.500	21.500
MEAN	21.500	21.500	21.500	21.500	21.500	21.500	21.500	21.500	21.500	21.500	21.500	21.500
STD.DEV.	21.500	21.500	21.500	21.500	21.500	21.500	21.500	21.500	21.500	21.500	21.500	21.500

GROUP MEANS ARE DENOTED BY M'S IF THEY COINCIDE WITH M'S. N'S OTHERWISE

MEAN	12.969	11.390	10.982	10.982	10.982	10.982	10.982	10.982	10.982	10.982	10.982	10.982
STD.DEV.	2.728	2.546	4.476	4.476	4.476	4.476	4.476	4.476	4.476	4.476	4.476	4.476

MIDPOINTS	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12
SC (ppm)	26.000	26.000	26.000	26.000	26.000	26.000	26.000	26.000	26.000	26.000	26.000	26.000
MEAN	26.000	26.000	26.000	26.000	26.000	26.000	26.000	26.000	26.000	26.000	26.000	26.000
STD.DEV.	26.000	26.000	26.000	26.000	26.000	26.000	26.000	26.000	26.000	26.000	26.000	26.000

GROUP MEANS ARE DENOTED BY M'S IF THEY COINCIDE WITH M'S. N'S OTHERWISE

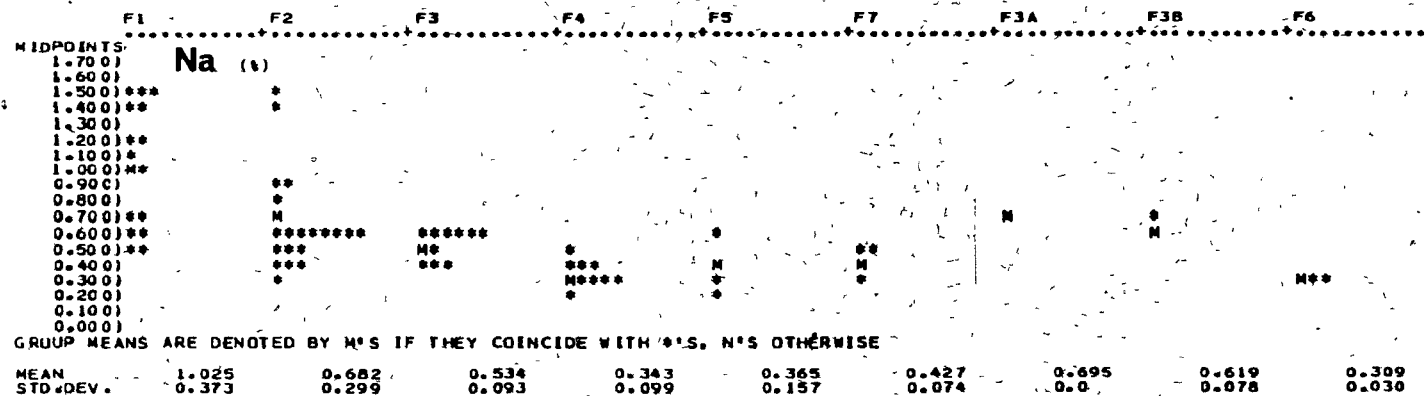
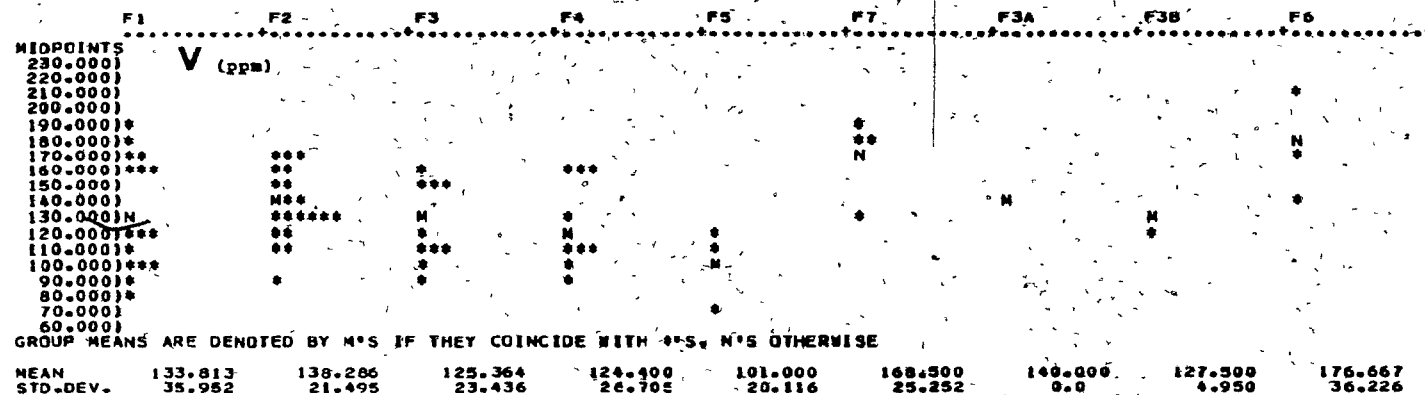
MEAN	21.956	21.833	19.717	19.717	19.717	19.717	19.717	19.717	19.717	19.717	19.717	19.717
STD.DEV.	2.223	3.053	1.825	1.825	1.825	1.825	1.825	1.825	1.825	1.825	1.825	1.825

MIDPOINTS	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12
Al (g)	16.000	16.000	16.000	16.000	16.000	16.000	16.000	16.000	16.000	16.000	16.000	16.000
MEAN	16.000	16.000	16.000	16.000	16.000	16.000	16.000	16.000	16.000	16.000	16.000	16.000
STD.DEV.	16.000	16.000	16.000	16.000	16.000	16.000	16.000	16.000	16.000	16.000	16.000	16.000

GROUP MEANS ARE DENOTED BY M'S IF THEY COINCIDE WITH M'S. N'S OTHERWISE

MEAN	7.826	6.145	7.137	7.137	7.137	7.137	7.137	7.137	7.137	7.137	7.137	7.137
STD.DEV.	0.809	1.088	0.813	0.813	0.813	0.813	0.813	0.813	0.813	0.813	0.813	0.813

2



trations occur as well. These trends indicate that fabrics 1, 2, 3, and 3a may be chemically very similar. They differ from the rest of the fabric groups, among which only fabrics 3b and 5 can be distinguished.

6.2.5 Discriminant analysis

Discriminant analysis is another technique for visualizing and testing differences between groups in multivariate space. The version known as "stepwise discriminant analysis", implemented as program BMDP7M in the University of California package of Statistical Software (Dixon 1981), uses preassigned groups of samples to select elements useful for discriminating among the groups. The method is termed "stepwise" because the elements are selected one at a time. Linear classification functions are established, one for each group, using these elements as variables. When applied to concentration data for a given sample, each function calculates the squared Mahalanobis distance D^2 between the sample and the centroid of the corresponding group. (The squared Mahalanobis distance is the squared Euclidean distance divided by the group variance along the line passing through the group centroid and the sample [Bieber et al. 1976a, p. 67; Doran and Hodson 1975, p. 210]. It is a useful measure of distance when variables show high correlations, since these are taken into account in the calculation of D^2 .) Probabilities of membership in each group are calculated on the basis of the

Mahalanobis distance. The probabilities are normalized so that they sum to 100% over all the groups. A sample is thus assigned to the group giving the greatest probability, even if the absolute D^2 value is very high (the sample being distant from all group centroids). Caution must therefore be exercised in using discriminant analysis to assign samples to groups in this way. A further complication ensues if, as is often the case, discriminant functions do not include all the elements measured. A sample's composition may then match that of a group very closely for some elements but not for others, and it may be incorrectly or unjustifiably assigned by the program.

Certain options of BMDP7M allow these difficulties to be overcome at least partially. It is possible to force the program to use all the elements in constructing the discriminant functions, rather than only those showing the greatest differences between groups. Those elements still dominate the functions, but the others are included as well. An unusual concentration of any element in a sample would then increase the value of D^2 for that sample with respect to a group to which it would otherwise belong. A further option of the program permits the user to offer a list of samples for consideration as possible members of the groups dealt with in the discriminant analysis. They are entered as a final "group" not to be included in the construction of the discriminant functions. The program nevertheless

calculates their Mahalanobis distances from each of the group centroids, and prints those distances as well as the normalized probabilities of membership. Used in conjunction with the forcing option, this procedure allows samples to be attributed with some confidence to previously-established reference groups.

One very valuable feature of the discriminant analysis program BMDP7M is the bivariate plot of samples in discriminant space. The axes of this plot are the first two canonical variables; that is, "the linear combination of variables entered that best discriminates among the groups... [and] the next best linear combination orthogonal to the first one" (Dixon 1981, p. 523). Each sample of a group is represented on the plot as a letter in the plane which best shows the separation of the groups. An example is shown in Fig. 6-viii.

This plot is useful for visualizing the similarities and differences among groups, their minimum overlap and their maximum separation. In particular, the validity of clusters devised from dendrograms can be examined in two dimensions. The clusters will not normally overlap, but unless there is a clear gap between them, they may actually be two parts of a single, larger group.

When the total number of samples is only slightly greater than the number of elements used in the analysis, the bivariate plot may give the illusion of well-separated groups when in fact the groups differ only slightly or not at all.

This occurs because in a hyperspace with a sufficient number of dimensions, it is always possible to select a hyperplane which divides a small collection of points (samples) into any two parts desired (K. Worsley, personal communication 1982). In order to enable significance tests for group differences to be made, the program prints an overall F-statistic as well as individual ones for each pair of groups, with indications of the number of degrees of freedom in each case. The significance of these statistics can be tested by comparisons with tables of critical values of F.

Stepwise discriminant analysis was applied to 68 Keramidhaki samples divided into eight fabric groups (samples of fabric 7 - miscellaneous - were omitted). The program succeeded in separating the samples of fabrics, 1, 2, 3, 3a, and 3b from those of fabrics 4, 5, and 6, on the basis of Ca, Ti, and Na concentrations. No distinctions of a finer nature were evident. In an effort to bring such distinctions to light, BMDP7M was next tried on the four groups resulting from merging the samples of fabric groups 1, 2, 3, 3a, and 3b. A larger set of elements was chosen by the program (Al, Ca, Ti, Ca, Cr), but 6 of the 7 sherds belonging to the fabric groups 5 and 6 were once again reassigned. The relatively small size of these groups probably accounts for this apparent instability. Efforts to separate samples of fabrics 1, 2, and 3 were no more successful, as the classification functions assigned only 71% of those 48 samples to their

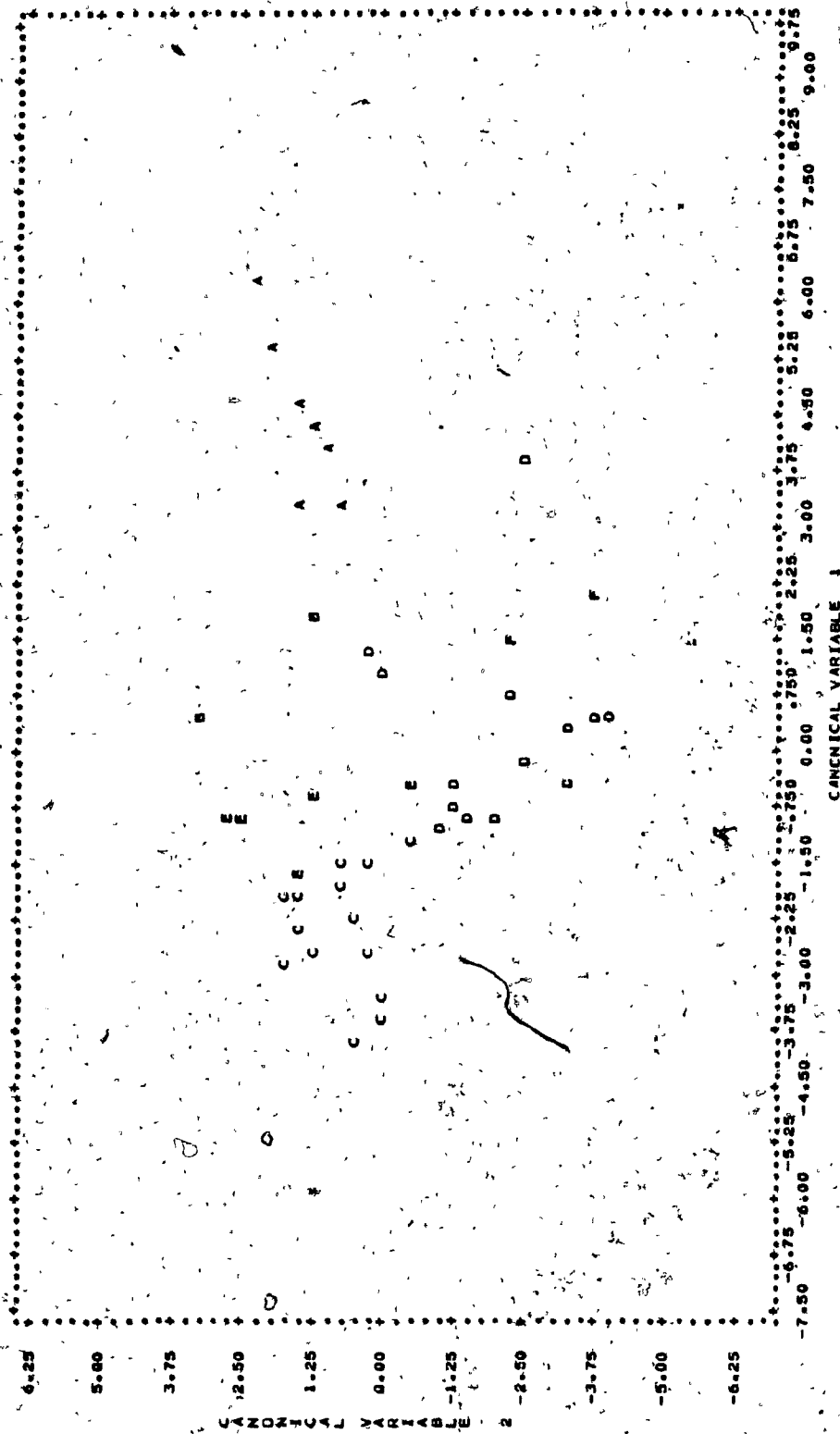
fabrics correctly on the basis of Na and Th concentrations. We are led to conclude that the fabric categories are only approximate indications of chemical groupings. In particular, three of the most prevalent fabrics at Keramidhaki (1, 2, and 3), accounting for over half of a sample of 1170 sherds in Cherry's study (1973, p. 73), are indistinguishable by chemical means. The other fabrics are quite different, but their composition ranges overlap in some cases.

Returning to the examination of the cluster-analysis results described in section 6.2.2, we next applied discriminant analysis to the tentative clusters. The six clusters A to F consisting of more than one sample each were used as input to BMDP7M. This arrangement included 46 of the 51 samples in the dendrogram of Fig. 6-vi. The discriminant-analysis program succeeded very well in distinguishing them, assigning every sample to its own group. Moreover, the plot (Fig. 6-viii) of the first two canonical coordinates shows the clusters to be reasonably well-separated. The ones appearing to be the closest, C and E, are in fact quite distant along the third and fourth canonical coordinates, not shown in the bivariate plot. The six elements Na, Th, Sc, Cr, Mn, and Yb were selected by BMDP7M as useful for this discrimination.

6.2.6. The Keramidhaki reference group

Before settling on a quasi-definitive arrangement of the Keramidhaki samples, a further test was made. This was the

FIGURE 6-viii: Bivariate plot of the samples in 6
Keramidhaki clusters, using the first
two canonical coordinates as calculated
by stepwise discriminant analysis.



isolation and examination of those sherds among the Keramidhaki material which satisfy the criteria for a reference group, as discussed in section 4.4. Rims of sauceboats and small bowls in fine and semifine pastes make up 11 of the objects sampled from Keramidhaki. (This low fraction, 16%, results from the decision to include examples from all fabric groups in the Keramidhaki collection.) Seven more base sherds, from either sauceboats or bowls, could be added to this reference collection, giving a total of 18 samples: KER 6 to 18, 35, 36, 51, 52, and 67. The pastes of all of these belong to one of Cherry's fabric types 1 or 2. More significant is the fact that almost all were distributed among the three clusters A, C, and D (the exceptions being the two outliers KER 11 and 18). No typological criteria are immediately evident which discriminate among members belonging to each of these clusters. From an archaeological point of view, then, they may best be considered as one larger group. Whether the chemical subdivisions imply any subtle distinctions of provenance, such as separate workshops in the Corinth area, is a problem best discussed in the context of inter-group comparisons (Chapter 7).

The requirement that the chemical reference group for Keramidhaki include these 16 samples led us to merge the clusters A, C, and D of the dendrogram. The small bowl KER 53 was included as well, since cluster D absorbs it before merging with the other large clusters. The pair of samples KER 43 and 57, however, which form cluster B, could be excluded on the

TABLE 6-I: Keramidhaki Chemical Reference Group and Outliers

KERCORE (37 samples)*						KEROUT (35 samples)*					
KER 1	A	1	34	C	2	KER 11	2	45	5		
2	A	1	35	C	2	18	2	46	6		
3	D	1	36	D	2	20	3	47	1		
4	C	1	39	D	3	22	E 4	49	1		
5	D	1	40	D	3	23	4	50	1		
6	A	1	41	C	3	24	4	54	3		
7	A	1	48	D	1	25	4	57	B	3b	
8	D	2	51	D	2	26	4	58	E	4	
9	C	2	52	D	2	27	E 5	62	5		
10	C	2	53	D	2	28	5	63	6		
12	C	2	55	C	3	29	7	64	6		
13	D	2	56	D	3	31	1	65	E	2	
14	A	2	59	C	4	33	1	68	7		
15	A	2	60	C	4	37	F 3	69	7		
16	C	2	61	C	4	38	3	KOR 2	2		
17	C	2	66	C	2	42	F 3a	3	2		
19	D	3	67	D	1	43	B 3b	4	E	7	
21	C	3	KOR 1	A	1	44	E 4				
32	D	1									

* The letter accompanying the sample number refers to the cluster to which that sample belongs (see section 6.2.2). The number which follows is the fabric classification of the sampled sherd (see section 6.2.3). KER 30 does not appear on this table because it was too hard to sample.

grounds that the two make up the separate fabric group 3b. The large group so formed has 37 members, or just over half of the total number of sherds sampled. It can be used as it is to represent the Keramidhaki reference composition (Table 6-I).

6.2.7 Keramidhaki outliers

Just under half of the Keramidhaki samples, then, have "atypical" compositions. Six of these form the cluster E, a varied group of relatively coarse objects. In fact, many of the outliers are made of coarse pastes, and perhaps their origins can be more precisely determined by mineralogical methods than by activation analysis. Such investigations are in progress, in collaboration with John Riley (University of Southampton) and John Cherry (Cambridge University). Pending the results of that study, indications of the provenance of these sherds arising from the activation analyses are used to assign them tentative origins. The lack of reference material similar to these objects in form and paste hinders such assignments, although any chemical similarity to the Keramidhaki reference group would constitute evidence of local origin. Let us examine the outliers individually.

KER 11: ring base; high Cs

KER 18: sauceboat spout; high Co

KER 20: large, coarse bowl; very high Co

- KER 23
and 26: coarse fragments, perhaps both from fire
dogs; low concentrations of many elements,
but high Mn
- KER 24: coarse wall sherd; low concentrations of many
elements, but high Th
- KER 25: coarse wall sherd; concentrations generally
low, especially Eu
- KER 28: coarse wall sherd; concentrations quite low,
but high Hf
- KER 29: coarse wall sherd; high Cs
- KER 31: ?bowl base; high Cr
- KER 33: jar handle; low Ti
- KER 37
and 42: bowls of form VI.6 in fabrics 3 and 3a; low
rare earths and particularly Th; high As
(not used for grouping)
- KER 38: large, coarse bowl; low Al, Ce, Eu
- KER 43
and 57: coarse jar and wall sherd in fabric 3b; dif-
ferent composition pattern although no few
elements stand out in particular
- KER 45
and 62: sandy baking pans; low Al, Ti, rare earths;
high Cr, Co. Could sandy temper be of
particular importance to this type of ceramic?
Preliminary petrographic examination indicates
that these sherds have "abundant glass"
(J. Riley, personal communication, 1980).
- KER 46: large, coarse ?bowl; high Cs
- KER 47
and 49: jar sherds in fabric 1; high Na, Mn, Sc; high
As (not used for grouping)
- KER 50: coarse wall sherd; low K; high Cr, Co
- KER 54: coarse jar; high Co
- KER 63: large bowl; extremely high Cr and Mg (not used
for grouping); high V, Fe; low Ti, Eu. Pre-

liminary petrographic examination shows this sherd to be "serpentine-rich" (J. Riley, personal communication, 1980)

KER 64: large bowl; high Cr

KER 68
and 69: high base and handle of (a single?) fine grey (mottled) sauceboat; low Mn; high V, Ti, Cr

KOR 2: large animal figurine; low Al, Yb, Fe, Sc; high Ca

KOR 3: painted sauceboat rim; high Al, Ti, rare earths; low Cr

The nature of several of these objects is unusual. It can be argued on grounds of rareness as well as on chemical grounds that the grey mottled sauceboat KER 68 and 69, the animal figurine KOR 2, and the painted sauceboat KOR 3 had been brought to Corinth from other centres of manufacture. The origin of the 6 objects belonging to cluster E may also not be local. The animal figurines KER 66 and KOR 1, the sherds with applied rope decoration KER 60 and 61, and the painted sauceboat KER 67, on the other hand, may be products of Keramidhaki artisans.

6.3 Reference groups and outliers at other sites

6.3.1 Korá kou

The same procedure as for Keramidhaki has been followed in order to establish a reference group for Korá kou. Outliers could have been picked out from histograms, but since iterative cluster analysis was so effective with the

Keramidhaki data, it was the main method used to define a tentative reference group for Korakou as well. The program BMDP2M was again used for centroid clustering of a Euclidean-distance matrix, the 19 elemental concentrations having first been standardized. Although a large core of similar samples was evident from the first dendrogram (Fig. 6-ix), clustering was performed repeatedly after the removal of the following outliers, in turn: KRK 29, 33, 35, 37, and 48; KRK 4, 26, and 34, KRK 3, 8, and 47; KRK 25; KRK 11, 12, 23, and 30; KRK 9 and 31; KRK 32 and 44; KRK 17; KRK 16; and KRK 22 and 38.

Once again, some external information was used to determine the best point at which to stop removing outliers. The archaeological reference consists of the sauceboat sherds, KRK 5-14 and the bowl sherds KRK 19-23, 38, and 39. A few of these are among the outliers just listed. The compositions of the last two outliers, KRK 22 and 38, differ only slightly from the group average (see appendix A). As well, the sequence of amalgamation distances does not show large discontinuities at any point (Fig. 6-x). These two samples were therefore left in the group for the time being. The samples KRK 9 (high Cs), KRK 8 (very high La, Th, Hf, but low Ca, Mn), and the cluster KRK 11, 12, and 23 (high Ca), however, are more distant. They were provisionally excluded. So were KRK 16, 17, and more distant samples not belonging to the archaeological reference group. We were left with 22 samples, or half of the total number analyzed, forming

FIGURE 6-ix: Cluster-analysis dendrogram for 44 Koráhou samples.



[illegible]

FIGURE 6-x: Cluster-analysis dendrogram for 22 Korákov samples.

AMALG!
DISTANCE

1.963
2.425
2.842
2.905
3.046
3.220
3.412
3.697
3.722
3.894
3.908
4.088
4.209
4.088
4.497
4.502
4.451
4.754
4.399
4.741
5.510

The diagram is a 16x16 grid. The top row contains 16 asterisks (*). The second row contains 16 vertical bars (I). The third row contains 16 vertical bars (I). The fourth row contains 16 vertical bars (I). The fifth row contains 16 vertical bars (I). The sixth row contains 16 vertical bars (I). The seventh row contains 16 vertical bars (I). The eighth row contains 16 vertical bars (I). The ninth row contains 16 vertical bars (I). The tenth row contains 16 vertical bars (I). The eleventh row contains 16 vertical bars (I). The twelfth row contains 16 vertical bars (I). The thirteenth row contains 16 vertical bars (I). The fourteenth row contains 16 vertical bars (I). The fifteenth row contains 16 vertical bars (I). The sixteenth row contains 16 vertical bars (I). The grid is filled with various symbols and lines, including asterisks, vertical bars, horizontal bars, and plus signs, arranged in a complex pattern. The symbols are distributed across the grid, with some appearing in specific rows and others in specific columns. The lines are drawn horizontally and vertically, connecting different parts of the grid. The plus signs are placed at various intersections and along the lines. The overall pattern is highly structured and symmetrical.

the chemical reference group (Table 6-II). Besides the sauceboats and small bowls, these include a cross-section of other EH II forms in fine or semifine pastes, as well as four of the six EH III sherds sampled.

Let us examine the nature of the outliers from this group. The ordinary sauceboats and bowls have already been mentioned. KRK 3 and 4 are high bases, uncommon forms whose compositions are not similar. KRK 16 and 17 are fine sherds (the first definitely from a sauceboat) which bear a burnished, mottled slip. They resemble each other in composition, but are quite different from a third mottled sherd, KRK 18, included in the chemical reference (or "core") group. This is analogous to the situation of KRK 25 and 26 vis-à-vis KRK 28; all three are closed forms in green pastes, but only the last belongs to the core group. The ladle shaft KRK 30 has been excluded from the core group primarily because of its high Cs content. The other sample from a ladle, KRK 29, is of coarse paste, as are KRK 31-37. Among these, only KRK 36, a jar sherd with applied rope decoration, belongs to the core group. KRK 29 has a very unusual composition, including 7% Mg. In many respects it resembles KER 63, perhaps sharing a common origin. The weight KRK 37 and the sample of earth from its holes KRK 48 resemble each other quite strongly; they are the most calcareous of the Korakou samples. Probably the weight was fashioned from local earth unsuitable for pottery manufacture. Finally, two of the

TABLE 6-II: Korákov Chemical Reference Group and OutliersKRKCORE (22 samples)

KRK 5

6

7

10

13

14

15

18

19

20

21

22

28

36

38

39

40

41

42

43

45

46

KRKOUT (22 samples)

KRK 3

4

8

9

11

12

16

17

23

25

26

29

30

31

32

33

34

35

37

44

47

48

EH III sherds, KRK 44 and 47, have unusual compositions, the latter (almost no Ca) much more extreme than the former (low Co). One of these, KRK 47, also bears unusual decoration in light paint on a dark slip, as does KRK 46, a member of the chemical reference group.

6.3.2 Zygouries

With the Zygouries samples, a new complication had to be accommodated. This was the merging of the data from GANOS (Attas 1980) with that generated at McGill. Analysis of nine ZYG samples in France did not include determination of the elements measured at Poly (section 5.2.7.2) and values reported for Rb and Ce concentrations are unreliable. Tungsten concentrations were reported to be in the 10-24 ppm range, low enough that even if they are in error by a factor of 2, the inaccuracy in correcting the Co concentration amounts to no more than 2.5 ppm. This is an acceptable, though far from ideal, degree of imprecision. Because the cluster analysis program BMDP2M cannot manipulate data with missing values, two sequences of computer treatments were performed. One included all the ZYG samples but only the 14 elements common to both the GANOS and the McGill measurements (Ca, Na, K, Mn, La, Yb, Cs, Sc, Eu, Th, Hf, Cr, Fe, Co), and the other included the 20 samples measured at McGill with their full complement of concentration data.

The first clustering of 28 of the 29 ZYG samples (ZYG 13 being excluded as its Ca value was missing) revealed ZYG 2, 17, and 27 to be most distant from the remainder (Fig. 6-xi). The next dendrogram, produced after their removal from the analysis, showed ZYG 14 and 15 to be clear outliers. An element-by-element comparison determined that ZYG 13 and 14 are quite similar in composition, so that ZYG 13 could be safely excluded from the reference group as well. A cluster analysis of the 23 remaining samples left the joining of ZYG 1, 20, and 4 (in that order) to high amalgamation distances. A further analysis without these samples showed a smoother rise in the amalgamation distances, with a slight gap at the four-cluster level (Fig. 6-xii). These clusters are:

- A. ZYG 3, 6, 21, 22, 26, 28, 29, 30
- B. ZYG 8, 9, 10, 11, 12, 16, 23, 24, 25
- C. ZYG 7, 19
- D. ZYG 18.

This arrangement is similar to that obtained by clustering only the 20 McGill samples. In three passes, the following outliers were isolated from the McGill samples and successively removed: ZYG 15, 17, and 27; ZYG 4; ZYG 19 and 20. A discontinuity in the sequence of amalgamation distances at the 5-cluster level suggest the following arrangement:

FIGURE 6-xi: Cluster-analysis dendrogram for 28 Zygouriés samples.

FIGURE 6-xii: Cluster-analysis dendrogram for 20 Zygouriés samples.

[illegible]

ZYG 3, 6, 21, 22, 25, 26, 28, 29, 30

ZYG 12, 16, 23, 24

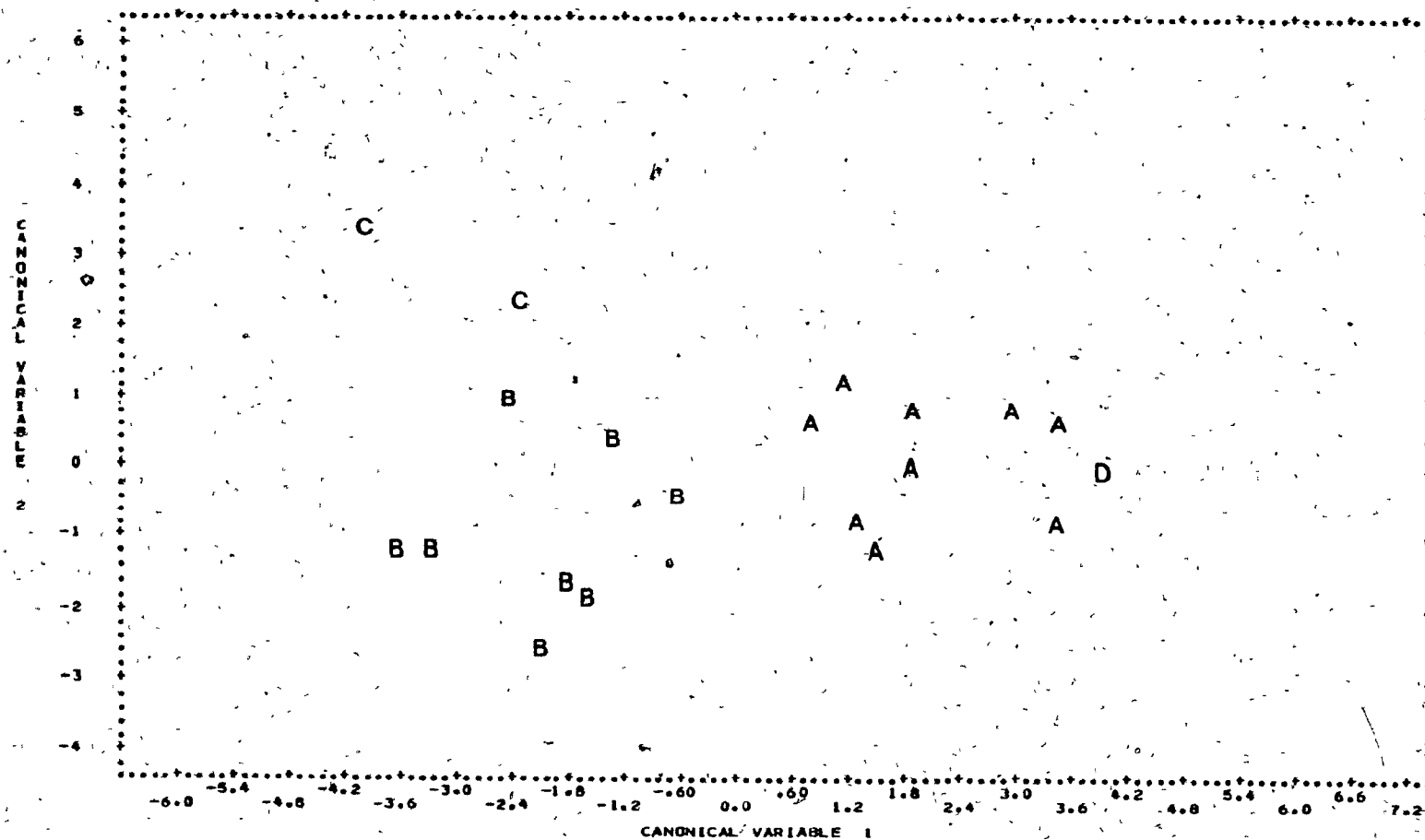
ZYG 18; ZYG 19; ZYG 20.

The only substantial differences between these two arrangements is the position of ZYG 25. Its chemical resemblance to ZYG 9 puts it in cluster B of the first arrangement; without ZYG 9, it most resembles ZYG 22, ZYG 28, and ZYG 30. Since more elements are included in the calculations in the latter instance, assignment of ZYG 25 as above was preferred.

A discriminant analysis was performed on the 4 clusters described above (with ZYG 25 re-assigned to A), in order to see how well they are separated and which elements account for the separations. The bivariate plot of the first two canonical variables, produced by the program BMDP7M, shows the clusters to be quite distinct, with a clear gap between A and B (Fig. 6-xiii). ZYG 25 is the member of cluster A closest to cluster B. These clusters differ in Fe and Sc concentrations, those of the samples in B being higher. Cobalt concentrations are also slightly higher in samples from that cluster. The other, smaller clusters are distinguished on the basis of high Ca concentrations (C) and a high Yb concentration (D).

The chemical significance of a chronological distinction was also tested by discriminant analysis. The samples ZYG 21-30 come from a deposit dated to the early part of the EH II phase, whereas ZYG 7-20 are sherds typical of the

FIGURE 6-xiii: Bivariate plot of the samples in 4 Zygouriés clusters, using the first two canonical coordinates as calculated by stepwise discriminant analysis.



late part of that phase. (ZYG 1-4 and 6 are unusual objects from various deposits.) The program BMDP7M was used to test the differences between these two archaeological groups. Discrimination is not so clear as in the previous instance, but the elements Mn and to a lesser extent Cs appear useful in distinguishing the groups. The early group has higher concentrations of these and other elements than the late group.

This division of the Zygouries samples resembles the one produced in the cluster analysis. In the latter case, however, two members of the early group, ZYG 23 and 24, are found in cluster B, which also includes six members of the late group. All the members of cluster A whose context is known (i.e., all but ZYG 3 and 6) come from the earlier deposit. The archaeological significance of these distinctions becomes clearer when the ZYG samples are compared to those from other sites (chapter 7); at this point the chemical reference group was conservatively taken to consist of the 20 samples making up the 4 clusters listed above (Table 6-III).

We may now consider the nature of the ZYG outliers with respect to this reference group. First of all, neither of the two ram's headed sauceboats, ZYG 1 and 2, matches the Zygouries reference composition. ZYG 2 has the more unusual composition, with only 2.5% Ca, twice the Hf of the other samples, and very low Mn and Cs concentrations. ZYG 1

TABLE 6-FII: Zygouries Chemical Reference Group and Outliers

ZYGCORE (20 samples)*

ZYGOUT (9 samples)

	ZYG 3	A		ZYG 1
	6	A		2
	7	C		4
	8	B		13
	9	B		14
	10	B		15
later	11	B		17
EH II	12	B		20
	16	B		27
	18	D		
	19	C		
	21	A		
	22	A		
	23	B		
earlier	24	B		
EH II	25	A		
	26	A		
	28	A		
	29	A		
	30	A		

*The letter A, B, C, or D following the sample number refers to the cluster to which that sample belongs (see text).

has high concentrations of Ca and Cr. The curious jug neck ZYG 4 has very low Ca and Cs concentrations, but a value for Cr well above the average for Zygouries. The pair of sauceboat spouts ZYG 13 and 14, although ordinary in appearance, have low concentrations of many elements, particularly Na, K, La, Sc, Fe, and Eu, but high ones of As, and for ZYG 14 at least, Ca as well. ZYG 15 is another ordinary-looking sherd, a ring base in this case, with unusually high Cr, Cs, and Ca values but low V, Ti, Sc, Fe, and rare-earth ones. The bowl rim ZYG 17 has the highest concentrations of Al, V, Ti, Rb, Cs, Sc, and Co. The composition of ZYG 27 is even more extreme, with very high concentrations of Na, La, Ce, Eu, Th, and Hf, but low concentrations of Ca and Co.

We are left with the borderline cases ZYG 7, 18, 19, and 20. The first and third of these make up cluster C, a pair of samples with high concentrations of Ca but low ones of La and Hf. ZYG 18 is notable for its high Yb content, as mentioned above, but also contains above-average concentrations of Na and Mn. Finally, ZYG 20 is unusual only in its alkali-metal composition: high in Na and Cs, but low in K and Rb. The clay (or the ceramic) may have undergone a transformation involving substitution of these ions, a possibility mentioned in section 6.2.1. In that case ZYG 20 would have the same origin as the Zygouries reference group.

6.3.3 Phlious

Only a small collection of Early Helladic material was preserved from the excavations at Phlious. This limited the selection of material for the archaeological reference group. The provisional chemical group established on the basis of 10 analyses at GANOS (Attas 1980, p. 90) was bolstered by the inclusion of 5 ladle fragments and a loomweight, analyzed at McGill. Cluster analysis of the McGill samples alone served only to indicate that PHL 4 (a coarse ladle handle) and PHL 14 (the loomweight) differ strongly in composition from the other 4 samples.

The treatment of all 16 samples together required limiting the number of elements considered to those common to both laboratories, in this case, Na, K, Mn, La, Yb, Cs, Sc, Ce, Eu, Hf, Cr, Fe, and Co. (Ca was not measured in this irradiation at GANOS, the GANOS Rb values are unreliable, and there appears to be a systematic difference in Th concentrations. The GANOS W values seem reasonable enough to allow the Co concentrations to be approximately corrected.) In the first cluster analysis (not shown), the pair of samples PHL 11 and 12 appeared to have the most extreme compositions, with high Mn, La, Ce, Eu, and Co concentrations but a low value for Na. These are two sauceboat sherds, ordinary in appearance, of greenish paste with a medium quantity of dark gray (PHL 11) or black and gray (PHL 12) inclusions. The loomweight PHL 14 also has an unusual

composition, with high rare-earth concentrations but low Al, Mg, V, Na, Rb, Cs, Sc, and Fe ones. The animal-head figurine PHL 1 is the fourth object of very distinctive composition, high in La but low in most of the other elemental concentrations. The compositions of a further 4 samples differ from the group average to a lesser extent (Fig. 6-xiv). These are PHL 4 (high Cr, Cs, Co); PHL 7 (high La, Sc, Fe); PHL 8 (low K; high Eu, Hf, Cr); and PHL 23 (high Na; low La, Ce, Cr). All these sherds come from ordinary-looking objects. Since the amalgamation distances rise smoothly through the steps of the cluster analysis where the samples join the core cluster, it was difficult to decide whether or not to include some or all of them in the chemical core group. Since the PHL group based on the GANOS data was unusually broad (Attas 1980, p. 90), these 4 samples were omitted for the moment (Table 6-IV), put aside for possible re-attribution to Phlious on the basis of inter-site comparisons.

6.3.4 Asine

The condition of the Asine data is similar to that of the Zygouries and Phlious data: ten samples analyzed by GANOS, and a further 21 analyzed at McGill. No Ca measurements were taken for this irradiation at GANOS, and once again the GANOS Rb values have very large measurement uncertainties, but at least the Th concentration ranges seem to agree between the two laboratories. The elimination of



FIGURE 6-xiv: Cluster-analysis dendrogram for 12 Phlious samples.

FIGURE 6-xv: Cluster-analysis dendrogram for 26 Asine samples.

2 5 3 8 3 4 0 9 8 3 4 7

2.265
2.085
2.295
2.373
2.957
3.134
3.673
4.338
4.523
4.846
4.811

[illegible][illegible]

1.449
1.826
2.097
2.054
2.257
2.275
2.405
2.548
2.660
2.712
2.853
2.941
2.937
2.981
3.257
3.394
3.408
3.349
3.446
3.757
3.848
4.123
4.138
4.509
4.560

The diagram is a 16x16 grid. The top row contains 16 asterisks (*). The grid is filled with vertical and horizontal lines, some of which are dashed. There are several '+' and '-' signs placed at various intersections. The lines and signs form a complex pattern that resembles a stylized letter 'I' or a similar shape. The overall appearance is that of a technical drawing or a diagram from a patent document.

TABLE 6-IV: Phlious Chemical Reference Group and OutliersPHLCORE (8 samples)

PHL 2

3

5

9

10

13

18

24

PHLOUT (8 samples)

PHL 1

4

7

8

11

12

14

23

outliers proceeded in a manner similar to that for other sites.

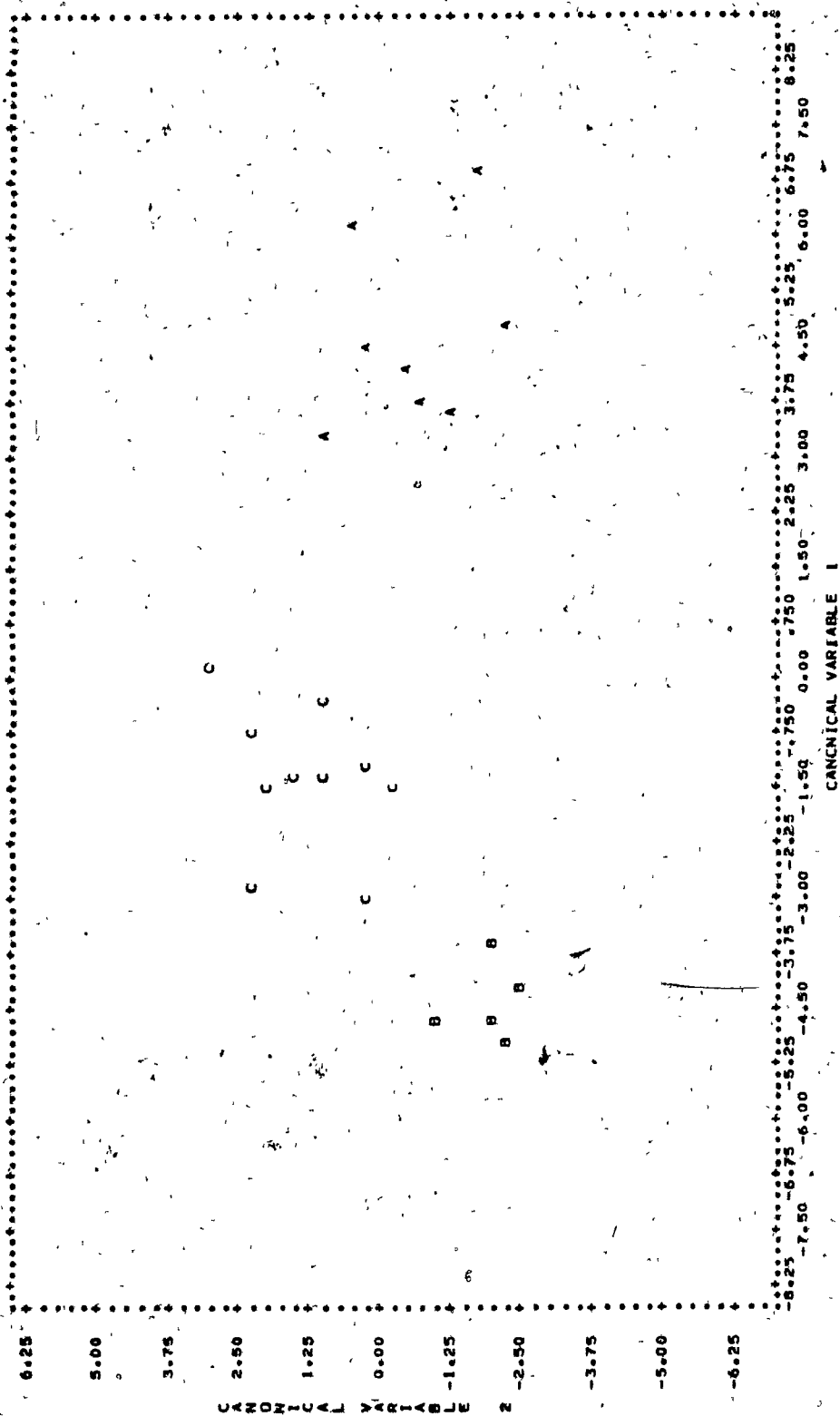
Separate cluster analyses were performed for the samples analyzed at McGill and for the entire data set, using in each case the maximum number of reliable elements. Successive dendrograms for the McGill data alone (not shown) have the following samples as outliers, in order from most to least extreme: ASI 7, ASI 12 and 27, ASI 31, ASI 8, ASI 6 and 16, ASI 9, and ASI 18. At smaller values of the amalgamation distance, multi-sample clusters are linked. The same iterative process performed using the 14 elements Na, K, Mn, La, Yb, Cs, Sc, Ce, Eu, Th, Hf, Cr, Fe, and Co, and all 31 samples to begin with, gives these outliers: ASI 7, ASI 12, ASI 27, ASI 31, ASI 8. The dendrogram produced after their removal has no outliers, but is made up of several multi-sample clusters (Fig. 6-xv). The amalgamation distances increase rather smoothly, making the choice of the best interpretation difficult. The nature of the objects in each cluster and the chemical differences between clusters help in the interpretation of this dendrogram.

Of the six samples of mud brick, five fall into the most extreme cluster (i.e., the one joining the rest of the samples at the highest amalgamation distance). This cluster ("A") also contains two pottery samples, ASI 16 (a large bowl) and ASI 17 (base of bowl or sauceboat). The clay sample ASI 22 joins the cluster last. These samples have

lower concentrations of most elements than the rest from Asine. Since they stand apart so clearly, they cannot be used to deduce the local origin of the rest of the Asine samples. Certainly ASI 16 and 17 can be considered local, but for the others we lack such definite indications. It should be noted at this point that since most of these objects were found out of context, all evidence for their date is typological. The mud bricks in particular may belong to any period in Asine's history (Guest-Papamanoli 1978). This, of course, does not invalidate their use as local reference material, but their connection with the Early Helladic period is tenuous.

Since we wished to include ASI 4 and ASI 22 in this first group, but to keep the group apart from the rest of the samples, the cut off point of amalgamation distance was chosen to lie between 3.8 and 4.5. At the lower of these two values, two other clusters plus two single samples are distinct. The smaller of these clusters ("B") is made up of the samples ASI 10, 20, 24, 25, and 33, all with high Na and K concentrations. The third cluster ("C") contains the other mud-brick sample, ASI 5, and the sherds ASI 9, 11, 14, 15, 18, 19, 21, 26, 34, and 35. Of these, ASI 14 joins last, ASI 13 joins that cluster at an amalgamation distance of 4.1, just before cluster B and the sample ASI 32. These two single samples might best be kept aside. A discriminant analysis shows the three clusters to be well-separated

FIGURE 6-xvi: Bivariate plot of the samples in 3 Asine clusters, using the first two canonical coordinates as calculated by stepwise discriminant analysis.



(Fig. 6-xvi). The program BMDP7M used Mn, Cr, Fe, and Co to distinguish them, though K, La, and Yb also vary consistently among them.

The samples most suitable for constituting an archaeological reference group are ASI 13, 14, 17, 19, 24, 25, 26, 32, 33, 34, and 35, all sauceboat or bowl sherds. These are divided up between clusters B and C, except for ASI 13, close to cluster C, and ASI 17, a member of cluster A. There is no evident typological distinction between the objects in cluster B and those in cluster C. It was therefore tempting, when comparing Asine material to objects from other sites, to merge clusters B and C, or even to treat the 26 samples of the dendrogram as a single large group (Table 6-V). As long as this does not cause the Asine samples to overlap groups from other sites, it is acceptable, but otherwise the three clusters should be kept separate. Samples from other sites attributed to the large Asine group should be tested against the three clusters separately in any case. At least two of these clusters, A and C, are probably local, since both contain mud-brick samples.

Among the outliers are several sherds with unusual paste or decoration. ASI 7 (low rare earths, Cr, Co; high Al, V, Fe, Sc) bears a burnished exterior, as does ASI 27 (low Mg; high Mn, rare earths). ASI 31 (high K, Rb, Cs, La, Eu, Sc, Fe, Co) is a small sauceboat in slipped-and-polished, mottled ware. ASI 8 (low K; high Na, Cs, V, Mn) and ASI 12

TABLE 6-V: Asine Chemical Reference Group and OutliersASICORE (26 samples)*ASIOUT (5 samples)

ASI 1	A
2	A
3	A
4	A
5	C
6	A
9	C
10	B
11	C
13	
14	C
15	C
16	A
17	A
18	C
19	C
20	B
21	C
22	A
24	B
25	B
26	C
32	
33	B
34	C
35	C

ASI 7
8
12
27
31

*The letter A, B, or C following the sample number refers to the cluster to which that sample belongs (see text).

(low Na; high rare earths, Mn, Fe, Co) contain quantities of rock inclusions. The appearances of ASI 13 and ASI 32 are not unusual, but the samples are set apart by high Yb and Cr concentrations respectively.

6.3.5 Tiryns

The larger number of samples from Tiryns and the more explicit strategy followed in selecting them give the Tiryns material an increased potential for interesting chemical groupings. Before these groupings were investigated, a few outliers were found and eliminated using histograms and cluster analysis as described above. Since all the Tiryns samples had been analyzed at McGill (and Poly for the short-lived radioelements), the full suite of 19 reliable elements was used in the computer work. The samples TIR 26, TIR 70, TIR 76, and TIR 83 could immediately be set aside for later consideration, on the basis of extreme concentrations of many elements. The dendrogram with 55 samples (Fig. 6-xvii) shows that a twelve-sample cluster is more distant from the majority of the samples than the remaining outliers. The only abrupt increase in the sequence of amalgamation distances occurs at the 9-cluster level, all but two of these clusters having four or fewer members. At this point, where the amalgamation distance jumps from 3.8 to 4.2, the second-largest cluster has ten samples: TIR 38, 56, 57, 59, 60, 61, 62, 77, 86, and 88. Setting this group aside as

FIGURE 6-xvii: Cluster-analysis dendrogram for 55 Tiryns samples.

TIRCORE-B, we continued to refine the main Tiryns compositional group. The next outliers to be removed were TIR 11, 58, and 87, leaving 42 samples. Two very loose clusters could be removed at this point: TIR 7, 10, 20, and 84; and TIR 79, 80, 81, and 82. (In Figure 6-xvii, these clusters form at amalgamation distances of 4.2 and 4.3 respectively.) All these samples have high Ca concentrations, but those in the second cluster have high Mn, Eu, Fe, and Sc ones as well. A number of pairs and single samples then became the farthest samples: TIR 1, TIR 33, TIR 42, TIR 6 and 19, TIR 39 and 44, and TIR 36. There is a gap in the sequence of amalgamation distances after the first three samples of this list (Fig. 6-xviii). The other 5 join the core cluster of TIR samples soon after it forms, indicating that they perhaps should remain in that core. Those 31 samples form the tentative group henceforth called TIRCORE-A (Table 6-VI).

Information concerning the nature of the samples in the two tentative groups TIRCORE-A and TIRCORE-B sheds some light on their significance. Material was sampled from three Early Helladic phases at Tiryns. TIR 1-20 are sauceboats and bowl fragments from an EH II deposit, TIR 31-45 are similar sherds from the transitional EH II/III phase, and TIR 56-62, 75-77, and 79-88 are various sherds from an EH III level. The group TIRCORE-A contains 15 sherds from the first set and 14 from the second, but only two, TIR 75 and 85, from the third. Furthermore, the sherds from the

FIGURE 6-xviii: Cluster-analysis dendrogram for 34 Tiryns samples.

2	2	2	2	3	1	1	1	1	1	2	2	1	2	3	1	1	1	2	1	2	2	3	3	3
1	5	4	9	8	1	4	7	6	1	0	6	2	5	5	8	1	6	3	4	5	0	9	8	7
T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	
R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	
4	4	7	7	8	1	3	3	1	1	4	3	1	1	3	1	7	3	3	1	4	1	4	3	
2	3	1	4	3	5	8	2	1	5	4	4	9	6	9	2	7	8	4	5	3	5	5	4	

ANALG.
DISTANCE

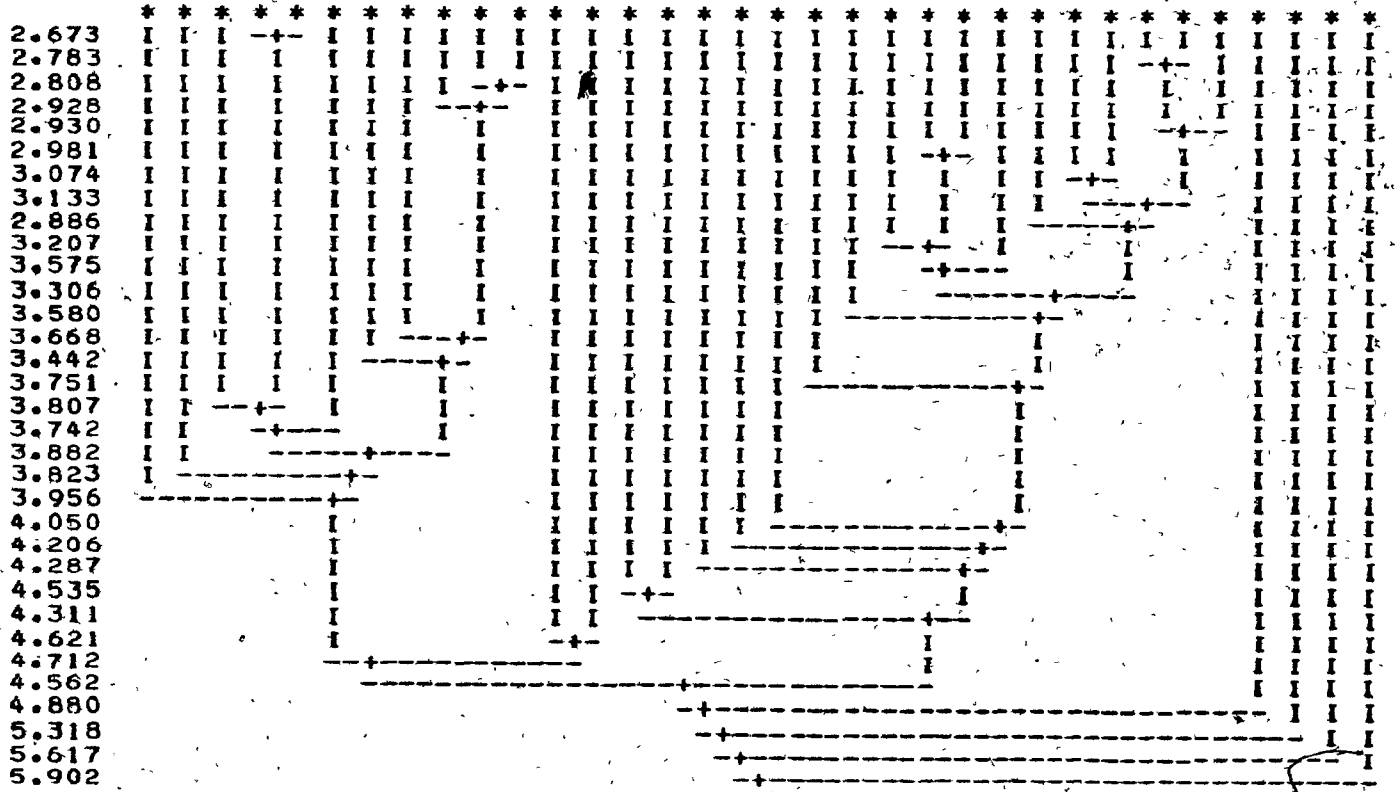


TABLE 6-VI: Tiryns Chemical Reference Groups and OutliersTIRCORE-A (31 samples)

TIR 2 32
 3 34
 4 35
 5 36
 6 37
 8 39
 9 40
 12 41
 13 43
 14 44
 15 45
 16 73
 17 74
 18 75
 19 85
 31

TIROUT (18 samples)*

TIR 1 A
 7 C
 10 C
 11
 20 C
 26
 33 A
 42 A
 58
 70
 76
 79 D
 80 D
 81 D
 82 D
 83
 84 C
 87

TIRCORE-B (10 samples)

TIR 38
 56
 57
 59
 60
 61
 62
 77
 86
 88

* The letter A accompanies samples similar to TIRCORE-A; the letters C and D identify other loosely-linked clusters of samples (see text).

first two sets are thoroughly mixed in the last dendrogram, indicating that they have the same origin. On the other hand, all but one (TIR 38) of the ten sherds of TIRCORE-B belong to the EH III phase. It appears that clear chemical differences reflect the chronological and typological differences between the EH III phase and the two preceding ones.

The nature of the chemical differences could be explored with the aid of histograms and discriminant analysis. Certain distinctions are even evident from the data table itself. For instance, the members of TIRCORE-B contain much more calcium than other Tiryns samples (averages of 10% vs. 2%). As these sherds have, on the average, a coarser paste than the others, it was suggested that limestone or calcite tempering of the same clay might account for the differences in composition (U. Franklin, personal communication, 1981). A rough calculation suggests that the addition of sufficient temper to raise the Ca concentration from a value around 2% to one around 10% would lower the concentrations of the other elements by 11% or so, assuming that the calcium was added as pure CaCO_3 but was transformed to CaO by baking the powdered sample prior to analysis. Indeed, the 9% drop in Al concentration between the earlier and later phases is reasonably close to this value. It is, in theory, possible that the increases in the concentrations of a few elements (in this case Mn and Co) might be caused by an impure lime temper, but the drastic decrease in Na and Hf concentrations from

sherds of TIRCORE-A to that of TIRCORE-B (roughly from 1.0% to 0.4% and from 5-6 ppm to 2.7 ppm respectively) cannot. A clay of different composition must have been used for the TIRCORE-B objects.

Most of the 20 EH III objects are in fact made of calcareous clay. Differences in concentrations of other elements indicate that several groups are involved, TIRCORE-B being the largest. Which, if any, of these are local products might become clearer on comparison with the reference groups from other sites (chapter 7).

The only member of TIRCORE-B not belonging to the EH III phase is TIR 38. It is an ordinary-looking rim sherd from a shallow bowl, but its composition is slightly unusual for that chemical group. It has high concentrations of Mn, Ca, Mg, and As (the last two elements not used for clustering), but low Al and La concentrations.

Sherds of several very different EH III wares make up the group TIRCORE-B. The samples TIR 56, 57, 59-62, and 86 are fragments of flat-based, thinly-slipped jars mostly in medium pastes. TIR 77 is a horizontal sauceboat handle in semifine paste, and TIR 88 is a rim sherd from a large, flat-rimmed bowl coated with cream and black slips and decorated on the lip with lines of black paint. (For sauceboats in EH III levels at Tiryns, see section 4.2 and Kilián et al. [1981].) The polished deep bowls also characteristic of EH III are not part of TIRCORE-B. Four of them (TIR 79-82)

form a loose cluster, TIR 84 is part of another loose cluster, and TIR 83 is an extreme outlier, low in many elements. This chemical diversity is surprising considering the uniformity of decorative technique and form among the deep bowls. Other outliers among the EH III sherds include TIR 76, a ring base from a fine-paste sauceboat or bowl, with a lustrous, polished white slip on the outer surface, reminiscent of the fine slipped-and-polished mottled ware of EH II. It has high concentrations of Al, Ti, and the rare earths, but low ones of Mg and Ca. TIR 58 resembles the other jar bases in appearance, but is rather unusual in composition, with high Cs, V, Sc, Fe, and Co concentrations but a low Hf one. The decorated bowl rim TIR 87 also has high V, Sc, Fe and Co concentrations, but very low Na and Ti ones as well.

Two sherds from the EH III level are members of TIRCORE-A. TIR 75 is a ring base, from a sauceboat or bowl, in a fabric common in the earlier phases. Since its thin brown slip is worn, it may be an EH II or Transitional sherd found out of context. On the other hand, the bowl rim TIR 85 is not such a common EH II or III form; if anything, the shape is reminiscent of EH I forms. The paste and slip, however, are similar to those of the other EH III sherds.

The group TIRCORE-A, with very low concentrations of calcium, is certainly the main compositional group for Tiryns table ware during the EH II and Transitional phases. Although

no direct evidence such as clay or mud-brick analyses is yet available to link it conclusively to production at Tiryns, the predominance of this chemical group among the TIR samples make an origin near to Tiryns very likely.

Since within the cluster TIRCORE-A the EH II and Transitional sherds are mixed, it was felt that any attempt to distinguish them chemically would be unsuccessful. As a check on this hypothesis, and as a test of the discriminant-analysis program, the analytical data for the 15 EH II and 14 Transitional sherds of TIRCORE-A were submitted to BMDP7M.* Using only La as a discriminating element, the program produced a pair of overlapping histograms for the groups supplied, and discriminant functions which were not very effective. (When only 2 groups are supplied, BMDP7M prints histograms rather than a scatter plot.) With the program constrained by the "Force" option to use all the variables, however, the samples from the two groups did not overlap at all. Although their histograms were adjacent, EH II samples had positive values of the canonical variable whereas Transitional ones scored negatively. In geometrical terms, this means that in 19-dimensional space, the hyperplane defined by the coefficients for the canonical variable splits the sample points into the two chronological groups.

It appears that here the effect of having too few samples in relation to the number of elements is being felt. The univariate F-statistic is significant at the 0.01 level

only for La; with all elements included the groups are not significantly different even at the 0.05 level (approximate F-statistic of 1.68 against a critical value of 2.9 for 19 and 9 degrees of freedom). The small difference in La concentrations may be most simply interpreted as a slight change in the place (location or depth) where clay was extracted, or a slight change in the procedure of preparing clay to make pottery, paralleling the results obtained by Attas et al. (1982) for Lakonian pottery of more recent date.

Among the sherds from the EH II and Transitional phases which do not belong to TIRCORE-A are several ordinary and a few unusual objects. The sauceboat sherds TIR 1, 7, 10, and 42, and the bowl rims TIR 11, 20, and 33 do not show any obvious anomalies of form, surface treatment, or paste, but their compositions each have some peculiarity. High Ca concentrations exclude TIR 7, 10, and 20 from the TIRCORE-A group, while TIR 1 has high Mn and Eu but low K and Cs concentrations, and TIR 11 has high Ti, La, Ce, Th, Hf, and particularly Cr concentrations. TIR 33 has a very high Mn value but a low Na one, and TIR 42 has low concentrations of many elements, the most extreme being Co. TIR 26 is a slipped-and-polished sherd from a fine-paste sauceboat, a ceramic type often found to have an unusual composition, in this case involving high concentrations of Al, Mg, V, and Sc (see section 8.3.1). The composition of TIR 70 is quite bizarre, with high concentrations of Cs, Mg, Ca, Co, As, and

particularly Cr. An origin far from Tiryns is in keeping with its form, a pyxis of Cycladic type.

Finally, the two Transitional sherds TIR 73 and 74 come from "ouzo cups", simple cylindrical vessels characteristic of the EH III phase at the nearby site of Lerna. Both are bona fide members of TIRCORE-A, indicating that this reference group is not limited to sauceboats and bowls even though the sampling strategy was biased in that direction.

6.3.6. Lake Vouliagmeni

The analyses presented in the writer's M.Sc. thesis (Attas 1975) form a strong basis for Lake Vouliagmeni reference groups. Elemental means and standard deviations for the local composition pattern, calculated from a 40-sample group, have been published as well (Attas et al. 1977). This group (Table 6-VII) suitably represents the range of composition characteristic of Lake Vouliagmeni pottery. Although it may actually consist of two or three subgroups (Attas 1975, p. 81), these internal variations do not affect the attribution to Lake Vouliagmeni of samples found at other sites, since the Vouliagmeni composition is quite distinctive within the Argolis and Korinthia (Attas 1980, p. 93; this work, Table 7-II).

A few mud-brick and clay samples from Lake Vouliagmeni had been analyzed by GANOS in 1978 in order to answer some questions specific to the mud bricks (Cohen 1979) and as

TABLE 6-VII: Lake Vouliagmeni Chemical Reference Groups and Outliers

<u>VOUCORE-L (40 samples)</u>		<u>VOU-F (45 samples)</u>	<u>VOU-R (12 samples)</u>
VOU 010	302	VOU 106	VOU 155
011	402	301	156
012	403	304	157
013	404	418	158
014	406	421	159
101	407	501-514	411
102	408	516-526	602
105	409	603	604
107	410	605	608
108	413	606	611
112	414	607	612
113	415	609	623
114	416	610	
115	417	614-622	
151	419		
153	420		<u>VOUOUT (14 samples)</u>
201	422		015
202	613		016
203			103
204			104
205			111
206			116
			152
			154
			160
			303
			401
			405
			412
			601

a check on inter-laboratory consistency. Overall, they matched the local Vouliagmeni group extremely well (Attas 1980, p. 91), but they contribute little to the Vouliagmeni reference group, already quite sound. Technical problems with some of the GANOS data were further encouragement not to include them in the main reference group. They nevertheless give an indication of typical concentrations for the elements Na, K, and Mn, not measured in the earlier McGill work. The Vouliagmeni clay has been analyzed in several laboratories (see Table 5-XII), so that more complete data are available for that single sample, if required. The rest of the Vouliagmeni samples have been included individually in the inter-site computer work (chapter 7) in order to determine which reference group each resembles most closely. A large number of these (VOU-F in Table 6-VII) had been attributed to the north-east Peloponnese (Corinth/Mycenae area) by their style and by comparison with other laboratories' data. Direct comparisons are now possible. A further, smaller cluster, VOU-R in Table 6-VII, was not assigned an origin in the earlier work.

6.3.7 Lerna

Two compositional reference groups for Lerna had been established at GANOS (Attas et al. 1979; Attas 1980, p. 69). The computer program GROUP had been used to isolate a major group, LERNA-A, with 20 samples, and a minor group, LERNA-B,

with 8, both with a few "associated" samples. The validity of this arrangement can be tested by forming reference groups from the Lerna data in the same manner as for the other sites. Four more samples from Lerna were analyzed at McGill in 1979 (LER 8, 9, 10, and 40); these have been included in the calculations.

All the Co values have been affected by contamination from the drill bit. Although the absolute measurements of W by GANOS for this set of samples were erratic, the values common to each irradiation are consistent. Within each irradiation, the Co and W concentrations of chemically-similar samples from the same archaeological group were compared, and a correction factor determined by taking the ratio of their differences (see section 5.2.7.5). The corrected Co concentrations, although not as accurate as those from McGill, were still useful for forming reference groups. Lu and As were excluded, however, the first because of interferences and the second because it varies unpredictably, as demonstrated in section 5.3. The Th concentrations appear to be internally consistent, and so should be suitable for group formation, but it is not clear whether or not a systematic overestimation exists for the Lerna samples (see section 5.4). Th concentrations were therefore not used for the inter-group comparisons in chapter 7.

Even though a different method of group formation (cluster analysis) was used at McGill, with fewer elements

taken into consideration, the resulting reference groups are almost identical to those already presented (Attas 1980). After successive removals of outliers, a dendrogram was produced (Fig. 6-xix) which has a large jump in the amalgamation distance from 2.9 to 3.3. At that point there is only one large cluster, containing 16 samples. If the element Ca is excluded from the cluster analysis, several more samples, whose Ca concentration had not been measured, can take part. A similar dendrogram (not shown) nevertheless resulted, with a discontinuity in the amalgamation distance from 2.8 to 3.2. In this case the large cluster included 3 additional samples. This 19-sample reference group will henceforth be called LERCORE. It contains pottery from both the EH II and EH III phases at Lerna.

A smaller group at McGill has almost the same set of members as the one described previously (Attas 1980). Both are split into halves on the basis of Sc and Fe concentrations. The halves are here referred to as LEROUT-B1 and LEROUT-B2 (see Table 6-VIII). Actually, the first of these can be linked to local production, through the presence of the mud brick LER 6. A further pair, LER 51 and 52, are loosely related to LEROUT-B2 but probably do not share the same origin. They are denoted LEROUT-B3.

A triplet of samples from the Middle Neolithic period forms a cluster of unknown provenance, called LEROUT-C in Table 6-VIII.

FIGURE 6-xix: Cluster-analysis dendrogram for 27 Lerna samples.

0.766
1.428
1.942
2.015
2.085
2.090
2.222
2.427
2.498
2.551
2.627
2.530
2.809
2.932
2.968
2.918
3.340
3.667
3.824
3.480
4.149
4.052
4.240
4.326
4.538
4.759

TABLE 6-VIII: Lerna Chemical Reference Group and Outliers

<u>LERCORE (19 samples)</u>		<u>LEROUT (36 samples)*</u>	
LER 7		LER 1	40
12		2	45
13		3	46
14		4	48
15		5	51 B3
18		6 B1	52 B3
19		8	53
20		9	54
27		10	
29		11	
37		16	
41		17	
42		21	
43		22 B2	
44		23	
47		24 B2	
49		25 B2	
55		26 B2	
56		28	
		30	
		31 B1	
		32 B1	
		33	
		34 B1	
		35	
		36 C	
		38 C	
		39 C	

*The symbols accompanying some of the sample numbers identify four additional small clusters (see text).

7. INTER-SITE COMPARISONS

7.1 Aims and methods

In this chapter many of the samples not included in the reference groups for the eight sites under study are assigned to such reference groups. These assignments proceed on the basis of similarities in chemical composition between the single samples and the groups. An important prerequisite to valid assignments is that the groups themselves be distinguishable. Overlapping elemental distributions may be minor annoyances or insurmountable problems, depending on their severity. Section 7.2 is devoted to testing differences in group compositions and rearranging the reference groups, while attributions of samples are made in section 7.3.

The groups were modified in several stages. Minor changes were made to start with, but it soon became apparent that the modifications entailed a change of approach. As shown later (section 7.2.3), it could no longer be maintained that each core group represented the output of a single production centre or even of a single site. Reference groups each composed of similar samples from several sites were created by cluster analysis of the samples in the core groups. These were sufficiently distinct that many samples could be attributed to each of them unambiguously. At the same time, most of the groups could be attributed to sites or areas also unambiguously. The steps leading to this

reformulation are described in this chapter because they demonstrate the need for treating the samples from all the sites together. It may be that in studies of pottery exchange in other areas the single-site approach advocated by Wilson (1978, p. 230) would be more successful. In this study it was primarily useful in eliminating outliers and limiting the number of samples to be included in the multi-site analyses.

The procedures which were used to examine results from each site individually are also applicable to the inter-site phase of data analysis. Univariate techniques, involving examination of histograms as well as comparisons of means and standard deviations, give good preliminary information on resemblances and differences among groups. Discriminant analysis is designed specifically to pick out the significant differences between groups and to exploit them fully in representing the distribution of sample concentrations in two dimensions. With the "force" option in effect to ensure the consideration of all elements in its calculations (section 6.2.5), this program is also well-suited to assigning single samples to the group which they most closely resemble. It is therefore the main mathematical tool used in this chapter. Cluster analysis also finds a place in this chapter as a means of forming new groups based purely on chemical similarity between samples.

7.2 Revised reference groups

7.2.1 Group separations

The set of reference groups which were compared included the following: one each from Asine, Keramidhaki, Korakou, Lerna, Phlious, and Zygouries; two from Tiryns; and two from Vouliagmeni. (The third Vouliagmeni group, F, a mixture of sherds of different dates, was later attributed on a sample-by-sample basis to some of the sites in the region under study.) The 19 sets (one for each element) of side-by-side histograms (not shown) for these 10 groups revealed that some groups had very different compositions but others were difficult to distinguish. Some elements varied more consistently than others between groups. In order to summarize these trends, a table was drawn up of all possible pairs of reference groups (Table 7-II). The elemental means and standard deviations for these groups can be found in Table 7-I. For each pair of groups, the set of elements whose one-standard-deviation ranges (67% confidence intervals) do not overlap is listed at the intersection of the row and column of the table corresponding to the two groups. If an element appears there, assignment of a sample to one of the two groups on the basis of that element's concentration would be correct at least 83% of the time. If several elements are listed, the discrimination between the groups is much improved.

It will be immediately evident that several groups have at least two or three elements listed in their comparisons

TABLE 7-I: Means and Standard Deviations of the Elemental Concentrations for the 10 Reference Groups

<u>GROUP</u>	<u>Number of samples</u>	<u>Al (%)</u>	<u>Mg (%)</u>	<u>Ca (%)</u>	<u>V (ppm)</u>
ASICORE	26	* 7.6 ± 0.8	* 2.5 ± 0.3	* 5.6 ± 3.8	* 122 ± 19
KERCORE	37	8.0 ± 0.7	2.0 ± 0.3	11.1 ± 3.4	137 ± 25
KRKCORE	22	7.8 ± 0.5	2.2 ± 0.3	11.1 ± 2.0	130 ± 15
LERCORE	19	-	-	* 8.5 ± 2.8	-
PHLCORE	8	* 7.6 ± 0.3	* 1.6 ± 0.1	* 8.8 ± 1.4	* 117 ± 7
TIRCORE-A	31	8.2 ± 0.3	2.3 ± 0.3	2.0 ± 1.3	129 ± 7
TIRCORE-B	10	7.5 ± 0.3	2.7 ± 0.2	10.0 ± 2.2	136 ± 8
VOUCORE-L	40	-	-	13.0 ± 4.4	-
VOU-R	12	-	-	3.5 ± 1.8	-
ZYGCORE	20	* 7.7 ± 0.6	* 1.9 ± 0.3	11.5 ± 1.6	* 128 ± 17

TABLE 7-I - continued

<u>GROUP</u>	<u>Ti (%)</u>	<u>Mn (ppm)</u>	<u>Na (%)</u>	<u>K (%)</u>	<u>La (ppm)</u>
ASICORE	* 0.48 ± 0.06	837 ± 151	0.87 ± 0.22	2.3 ± 0.5	31.9 ± 4.5
KERCORE	0.46 ± 0.04	1120 ± 162	0.73 ± 0.36	2.0 ± 0.7	33.0 ± 3.6
KRKCORE	0.45 ± 0.03	961 ± 124	0.79 ± 0.41	2.2 ± 0.8	35.8 ± 2.2
LERCORE	-	967 ± 164	0.62 ± 0.24	2.5 ± 0.2	31.7 ± 1.9
PHLCORE	* 0.46 ± 0.04	1074 ± 431	0.56 ± 0.11	2.0 ± 0.2	32.9 ± 1.2
TIRCORE-A	0.49 ± 0.04	726 ± 80	1.06 ± 0.12	2.8 ± 0.3	38.6 ± 3.8
TIRCORE-B	0.43 ± 0.02	1104 ± 205	0.39 ± 0.07	2.7 ± 0.2	30.6 ± 1.7
VOUCORE-L	-	-	-	-	22.2 ± 2.7
VOU-R	-	-	-	-	22.9 ± 3.4
ZYGCORE	* 0.46 ± 0.03	866 ± 198	0.56 ± 0.15	2.6 ± 0.3	32.7 ± 2.3

TABLE 7-I - continued

<u>GROUP</u>	<u>Yb (ppm)</u>	<u>Rb (ppm)</u>	<u>Cs (ppm)</u>	<u>Sc (ppm)</u>	<u>Ce (ppm)</u>
ASICORE	2.7 ± 0.5	* 121 ± 26 (120 ± 30)	5.4 ± 2.1	18.9 ± 2.2	71 ± 14
KERCORE	2.5 ± 0.3	107 ± 46	10.6 ± 3.2	21.4 ± 2.1	78 ± 11
KRKCORE	2.5 ± 0.3	107 ± 41	11.3 ± 4.2	21.7 ± 1.7	74 ± 7
LERCORE	2.7 ± 0.4	(146 ± 42)	9.2 ± 2.7	20.5 ± 1.3	73 ± 5
PHLCORE	2.9 ± 0.6	(122 ± 31)	9.4 ± 2.2	20.7 ± 1.5	71 ± 2
TIRCORE-A	2.5 ± 0.4	121 ± 26	6.3 ± 0.9	20.3 ± 0.6	77 ± 7
TIRCORE-B	1.8 ± 0.3	118 ± 18	6.7 ± 1.0	22.0 ± 0.8	64 ± 4
VOUCORE-L	2.3 ± 0.3	74 ± 25	6.4 ± 1.9	17.3 ± 3.2	42 ± 6
VOU-R	3.2 ± 0.5	82 ± 23	4.1 ± 1.1	20.7 ± 2.4	51 ± 7
ZYGCORE	2.7 ± 0.5	(188 ± 94) * 141 ± 18	10.9 ± 1.7	20.8 ± 1.9	* 73 ± 6

TABLE 7-I - continued

<u>GROUP</u>	<u>Eu (ppm)</u>	<u>Th. (ppm)</u>	<u>Hf (ppm)</u>	<u>Cr (ppm)</u>	<u>Fe (%)</u>	<u>Co (ppm)</u>
ASICORE	1.14 ± 0.15	8.6 ± 1.1	4.9 ± 0.9	371 ± 141	4.8 ± 0.4	27 ± 4
KERCORE	1.23 ± 0.10	8.1 ± 1.1	3.8 ± 0.5	267 ± 61	5.3 ± 0.5	32 ± 6
KRKCORE	1.14 ± 0.18	8.6 ± 0.8	3.6 ± 0.6	267 ± 31	5.3 ± 0.4	30 ± 2
LERCORE	1.37 ± 0.18	(10.9 ± 0.9)	4.4 ± 0.8	295 ± 77	4.8 ± 0.4	30 ± 5
PHLCORE	1.24 ± 0.12	* 8.2 ± 0.4 (9.9 ± 2.0)	4.4 ± 0.3	237 ± 14	5.2 ± 0.3	29 ± 4
TIRCORE-A	1.10 ± 0.11	9.6 ± 0.9	5.6 ± 0.8	349 ± 110	5.1 ± 0.2	23 ± 3
TIRCORE-B	1.20 ± 0.14	7.5 ± 0.5	2.7 ± 0.4	382 ± 67	5.6 ± 0.3	37 ± 4
VOUCORE-L	1.01 ± 0.13	7.2 ± 1.1	3.2 ± 0.6	282 ± 116	4.3 ± 0.7	(29 ± 7)
VOU-R	1.21 ± 0.15	7.9 ± 1.5	4.9 ± 0.6	140 ± 54	4.5 ± 0.4	(22 ± 5)
ZYGCORE	1.22 ± 0.10	8.7 ± 1.3	3.6 ± 0.6	230 ± 20	5.0 ± 0.5	27 ± 3

* Based on fewer than the total number of samples: 16 for ASI; 4 for PHL; 15 for ZYG; 16 for LER.
() results may be unreliable.

TABLE 7-II: Elements Useful in Distinguishing the Reference Groups

	ASI	KER	KRK	LER	PHL	TIR-A	TIR-B	VOU-L	VOU-R	ZYG
ASI							Na, Yb, Sc Hf, Fe, Co	La, Ce, Hf	La, Ce, Cr	Mg, Ca, Cs
KER						Ca, Mn, Cs Hf, Co	Mg, Yb, Hf	La, Ce	Ca, La, Cs Ce, Cr	
KRK				La		Ca, Mn, Hf Co	Mg, La, Yb Cr, Co	La, Ce	Ca, La, Cs Ce, Hf, Cr	
LER					K	Na, La	Yb, Ce, Hf Fe	La, Ce, Eu	Ca, La, Cs Ce, Cr	
PHL						Na, K, La Cs, Hf	K, Yb, Ce Hf, Cr, Co	La, Ce, Hf	La, Cs, Ce Cr, Fe	K
TIR-A							Al, Ca, Ti Mn, Na, La Yb, Sc, Ce Th, Hf, Co	Ca, La, Ce Th, Hf	La, Cs, Ce Cr, Fe	Ca, Na, Cs Hf
TIR-B								La, Rb, Sc Ce, Fe	Ca, La, Cs Ce, Hf, Cr Fe	Mg, Yb, Cs Cr, Co
VOU-L									La, Ce, Th Cr, Fe	Th
VOU-R										Ca, La, Rb Cs, Ce, Cr
ZYG										

At the intersection of each row and column are listed the elements whose one-standard-deviation ranges of concentration do not overlap for that pair of groups.

with all the others. These groups are TIRCORE-B, VOUCORE-L, and VOU-R. Aspects of their composition patterns are sufficiently extreme that samples can be attributed to (or excluded from) each of them relatively unambiguously. In contrast, several of the other groups are so similar that no elements occupy the corresponding positions in the chart. ASICORE, KERCORE, KRKCORE, LERCORE, PHLCORE, and ZYGCORE fall into this category. TIRCORE-A is an intermediate case, very similar only to ASICORE.

This table shows several differences from the corresponding one (Attas 1980, p. 93) constructed on the basis of ten or fewer GANOS analyses from each site except Lerna (more data) and Tiryns (no data). In the earlier table, no box was empty. There are several explanations for this, some of which indicate that the more recent version is the more accurate. First of all, some sites were represented by as few as 5 (ZYG) or 3 (KRK) samples. Furthermore, the samples constituting the McGill groups include sherds of many forms and pastes, and so would be expected to show broader elemental distributions than the GANOS analyses, which were restricted to semifine sauceboat and bowl sherds. Most important, the samples from each site had been analyzed by GANOS as a set, each set with its own standard, thereby minimizing variations within that set but not controlling ones which may have existed from set to set. This is particularly serious for elements such as Th, whose determi-

nation at GANOS appears to have involved occasional difficulties (see section 5.4). Finally, the elements As and Co, occasionally appearing in the earlier chart, may have been unreliable discriminators on chemical and technical grounds respectively (see section 5.3).

Clearly, multivariate methods are required to distinguish these reference groups, or at least to determine to what extent they can be distinguished. The eight elements La, Yb, Cs, Sc, Eu, Hf, Cr, and Fe are common to the analyses of the samples in all 10 core groups. A stepwise discriminant analysis used all eight elements but was only 65% successful in distinguishing the 10 groups; that is, 65% of the samples were correctly assigned to their proper groups. The scatter plot (not shown here) is not a very useful means of displaying the separation of such a large number of groups. The three groups TIRCORE-B, VOUCORE-L, and VOU-R however, are quite distinct, as expected, so they may be set aside for the moment. Analytical data for the 7 remaining groups have the elements Na, K, Mn, and Co in common, in addition to the eight mentioned above. Using these extra elements and the "force" option, the program BMDP7M was more successful at distinguishing the groups; the proportion of correct assignments rose to 78%. TIRCORE-A and ZYGCORE were the best-isolated of the seven groups, with 90% and 95% of their samples attributed correctly, though 11 of the 30 samples assigned to Zygouriés came from other core groups. In

contrast, an F-test performed by the program indicated that the KER and PHL core groups were the most similar, their multivariate means being significantly different at the 0.05 level but not at the 0.01 level.

The Mahalanobis-distance calculations included in these discriminant analyses indicated that a few samples did not actually belong in their core groups. The samples ASI 32, KER 53, LER 29, and PHL 9 were all relatively distant from their respective groups. (The distinctiveness of the first two had already been recognized from the cluster analyses presented in chapter 6.) The sample LER 44, although not particularly distant from LERCORE, fell well within the Keramidhaki core group. While the definitive attribution of LER 44 awaited the systematic testing of all samples, the four others were excluded from subsequent discriminant analyses of core groups.

7.2.2 Group subdivisions

One factor which limits the performance of the discriminant analysis is the spread of concentration values within the reference groups. With several groups having similar average compositions, it is important that the variation about these averages be low. For the 7 core groups listed above, however, the within-group standard deviations often exceed those calculated for all the samples taken together. For four groups this problem was particularly

severe. Out of the 12 elements used in the preceding discriminant analysis, the following vary to a greater extent within the group listed than overall: La, Yb, Sc, Eu, Hf, Cr, and Fe in ASICORE; Na, K, La, Cs, Sc, Fe, and Co in KERCORE; Na, K, Cs, and Eu in KRKCORE; Cs, Eu, Hf, and Co in LERCORE. This indicates either that the reference groups have not been established strictly enough, thereby allowing samples of varied origins to be included in a single group, or that some of the groups are indeed indistinguishable. Since for Asine and Keramidhaki, at least, the reference groups are themselves composed of several clusters (see chapter 6), the second hypothesis did not need to be invoked until the first had been fully tested.

In an effort to pin down the sources of variation within and between the core groups, several discriminant analyses were performed using the constituent clusters of some of the groups. In particular, the 3 Asine, 3 Keramidhaki, and 2 Zygouries clusters described in chapter 6 were entered as separate groups. For the first attempt, the fourth Keramidhaki cluster (E of Table 6-I) was included as well, together with the Lerna, Korakou, Phlious, and Tiryns-A cores. Forced discriminant analysis of these 13 groups gave an 80% success rate in the attribution of the samples to their respective core groups. Every one of the samples from cluster E of Keramidhaki and cluster A of Asine was correctly assigned by the program, and none of the other samples was assigned to

either of those groups. Other groups were not as well-isolated, but the only two which were not significantly different are PHLCORE and KER-D (F-statistic of 1.80 against critical values for 12 and 137 degrees of freedom of 1.83 and 2.32 at the 0.05 and 0.01 levels respectively). The groups which lost the largest proportions of samples are LERCORE, KRKCORE, and PHLCORE; those to which most samples were assigned are PHLCORE, the two Zygouries groups, and KER-A. TIRCORE-A received several samples from ASI-B and ASI-C.

7.2.3 Group modifications

This information makes apparent the limitations on the eventual success of sample attributions. These limitations led to a reformulation of the reference groups designed to increase the reliability of the attributions. Several stages were involved in this reformulation. First of all, the quantity and nature of the analytical data for Phlious make conclusions regarding that site difficult. Its 7-sample core group closely resembles the KER-D Group. Removing PHL 10 from the Phlious core, on the grounds that it is over twice as far from the group centroid as the rest of the PHLCORE samples, did little to improve the situation. The Phlious core, reduced to 6 members, differs from KER-D and from ZYG-A at the 0.05 level but not at the 0.01 level of significance. The groups KER-D and ZYG-A are quite distinct, so the problem lay with PHLCORE. Since the

number of samples remaining in that core group was in any case hardly sufficient for useful archaeological inference, to withdraw the Phlious samples on technical grounds from the aspect of the study was not a great loss. The low archaeological value of the Phlious samples (no record of their stratification or the relative abundance of the various wares), the relatively isolated location of the site, and the lack of information concerning its nature and importance are all further support for this decision.

Almost half of the samples in LERCORE and in KRKCORE (and in PHLCORE as well) are closer to the centroids of other groups. These two groups are not quite as broad as the original Asine and Keramidhaki cores, nor do they contain as many samples. It therefore seemed less appropriate to try to subdivide them in the same way as the other two. The breadth of these groups, however, results in overlap with other cores: with ZYG-A and ASI-C in the case of Lerna, and with ZYG-B and KER-A in the case of Korákou.

For Korákou and Keramidhaki some simplification was possible. Because the two sites lie within 4 kilometres of each other on the same geological feature (the plain of Kórinthos), it is reasonable to expect the same (or similar) clay sources to have been used for pottery found at both locations. In that case one or more of the KERCORE subgroups would coincide with parts of the KRKCORE group. To test this hypothesis, a cluster analysis of the samples in both

these groups was performed, using the concentrations of all 19 reliable elements. The resulting dendrogram (Fig. 7-i) has three constituent clusters, corresponding quite closely to the Keramidhaki subgroups KER-A, KER-C, and KER-D. Within each is a contingent of Korakou samples. Samples from both sites are fairly well intermingled in all three clusters, indicating that compositional differences between the sites are minor compared to variations within the reference group of each one. Since the centroid of KRK is closest to that of KER-A, more KRK samples had been attributed to that group than to the other KER groups in the discriminant analysis discussed above; however, KRK samples actually belong in all three divisions of the Keramidhaki core. Differences between the core groups' centroids (as indicated by the discriminant-analysis F-tests) arise from the uneven distribution of samples among the various subgroups.

A discriminant analysis modified to take this information into account showed slightly improved distinctions between groups, the proportion of samples correctly assigned on the basis of 12-element discriminant functions rising to 82%.

With calcium concentrations included as well, this proportion becomes 87%. (The number of samples included is lower in that trial.) The modifications included rearranging the Keramidhaki and Korakou cores to form three groups in all, and omitting the Phlious core from the list of groups to be considered. The groups losing the largest proportion of

FIGURE 7-i: Cluster-analysis dendrogram for the 59 samples
in the Keramidhaki and Korakou core groups.

**ANALG.
DISTANCE**

1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	2101	2102	2103	2104	2105	2106	2107	2108	2109	2110	2111	2112	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122	2123	2124	2125	2126	2127	2128	2129	2130	2131	2132	2133	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143	2144	2145	2146	2147	2148	2149	2150	2151	2152	2153	2154	2155	2156	2157	2158	2159	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175	2176	2177	2178	2179	2180	2181	2182	2183	2184	2185	2186	2187	2188	2189	2190	2191	2192	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211	2212	2213	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	2234	2235	2236	2237	2238	2239	2240	2241	2242	2243	2244	2245	2246	2247	2248	2249	2250	2251	2252	2253	2254	2255	2256	2257	2258	2259	2260	2261	2262	2263	2264	2265	2266	2267	2268	2269	2270	2271	2272	2273	2274	2275	2276	2277	2278	2279	2280	2281	2282	2283	2284	2285	2286	2287	2288	2289	2290	2291	2292	2293	2294	2295	2296	2297	2298	2299	2300	2301	2302	2303	2304	2305	2306	2307	2308	2309	2310	2311	2312	2313	2314	2315	2316	2317	2318	2319	2320	2321	2322	2323	2324	2325	2326	2327	2328	2329	2330	2331	2332	2333	2334	2335	2336	2337	2338	2339	2340	2341	2342	2343	2344	2345	2346	2347	2348	2349	2350	2351	2352	2353	2354	2355	2356	2357	2358	2359	2360	2361	2362	2363	2364	2365	2366	2367	2368	2369	2370	2371	2372	2373	2374	2375	2376	2377	2378	2379	2380	2381	2382	2383	2384	2385	2386	2387	2388	2389	2390	2391	2392	2393	2394	2395	2396	2397	2398	2399	2400	2401	2402	2403	2404	2405</
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samples in both trials (with and without Ca) are LERCORE and ASI-C; those receiving the most are the two Zygouries groups, ASI-C, and ASI-B (the last from TIRCORE-A only).

7.2.4 "Natural" groups

The persistence of these reassignments necessitated a new approach to the definition of the groups themselves. Since Keramidhaki and Korakou pottery consists of several compositional groups, each including samples from both sites, it was thought that a similar situation might hold elsewhere as well. The way to determine which are the "natural" compositional groups among the samples analyzed is to subject them to cluster analysis. Although this procedure involves the omission of potentially useful information (namely the findspot of each object), no a priori classifications interfere with the formation of compositionally-similar clusters. (Actually, knowledge of the site from which each sample came can be used to judge the significance of the clusters at various levels of similarity.) Samples of similar composition from several sites should find themselves forming a single cluster. These clusters represent the characteristic composition types of the region better than the reference groups established each on the basis of one site's samples. This multi-site approach to group formation was used by Trigger et al. (1980) in their study of Iroquoian pottery production and exchange.

With this aim in mind, a series of cluster analyses was performed using analytical data from several sites and in each case the concentrations of as many elements as were common to the entire data set. Squared Euclidean distance and centroid clustering were the options chosen for each execution of the program BMDP2M. Only samples which were already members of core groups were included, in order to minimize distortion caused by the standardization procedure (see section 6.2.2). Samples not included were left for attribution to clusters at a later stage using discriminant analysis. The sample and element combinations parallel those of the previous discriminant analyses. In order to include all 225 samples belonging to the twelve core groups of chapter 6, only 8 elements were used in the first cluster analysis. As expected, the analysis showed the samples of TIRCORE-B, VOUCORE-L, and VOU-R forming clusters separately from the rest of the samples. The next stage used twelve elements for the clustering of the 163 samples remaining after these three clusters are removed. If Ca is included as well, the number of samples with complete data drops to 146. Finally, using all 19 reliable elements, 125 samples from 6 core groups were clustered. In all the dendrograms, samples from several sites were intermingled to form a small number of clusters, described below. Strong correspondences exist between certain clusters from one analysis to another, even though the sets of elements and samples being considered

differed.

Six clusters appeared in all four analyses, often with slight differences in the number of members depending on which samples had been included in the clustering. These clusters are designated M, N, O, P, Q, and R in Table 7-III, where their constituent samples are listed. Certain criteria were followed in listing samples which appeared in one analysis but not another. To start with, all the samples in clusters common to the four analyses are included. Samples with 12 or 13 reliable elements which form part of the clusters in the corresponding analyses are added in parentheses. From the 8-element analysis, the TIRCORE-B and the two Vouliagmeni clusters are included as well, labelled U, V, and W respectively. (The TIRCORE-B cluster maintains its identity even with more elements included, as was demonstrated in section 6.3.5.) Finally, when a cluster includes only a single sample from any given site, that sample is omitted for the time being, though it may be re-assigned to that cluster at a later stage. These criteria led to the inclusion of a total of 11 clusters in Table 7-III. In addition to bearing the letter designations M to W, the clusters are labelled according to the site groups which account for the greatest proportion of samples in each case.

Although these clusters are in some respects quite different from the core groups of chapter 6, they are just as suitable for attributions of provenance as the core groups,

TABLE 7-III: The Eleven "Natural" Clusters

<u>Designation</u>	<u>Constituent Samples</u>
M ("KER-A")	KER 1, 2, 6, 7, 14, 15, KOR 1; KRK 6, 14, 15, 22, 28
N ("KER-C")	KER 4, 10, 12, 16, 17, 21, 34, 35, 41, 55, 59, 60, 61, 66; KRK 5, 7, 10, 13, 20, 21, 38, 39, 40, 42; ZYG (8, 9, 10, 11), 12, 23, 24
O ("KER-D")	KER 5, 19, 32, 39, 40; ZYG (7), 19
P ("ZYG-A")	ZYG 3, 6, 25, 28, 29, 30; PHL 2, 3, 5
Q ("TIR-A")	TIR 2, 3, 4, 5, 6, 8, 9, 12, 13, 14, 15, 16, 17, 18, 19, 31, 32, 34, 35, 36, 37, 39, 40, 41, 43, 44, 45, 73, 74, 75, 85; ASI 10, (15), 20, (24), 25, 26, 33
R ("ASI-C")	ASI (5, 19), 21, 34, 35; (LER 7, 27, 47)
S ("ASI-A")	(ASI 1, 2, 3, 4, 6, 16, 17, 22)
T ("LER")	(LER 18, 19, 20, 37, 41, 56)
U ("TIR-B")	TIR 38, 56, 57, 59, 61, 62, 77, 86, 88
V ("VOU-L")	VOU 010, 011, 012, 013, 014, 101, 102, 105, 107, 108, 112, 113, 114, 115, 151, 201, 202, 203, 204, 205, 206, 302, 402, 403, 404, 406, 409, 410, 413, 414, 415, 419, 420, 422, 612, 623
W ("VOU-R")	VOU 155, 156, 157, 158, 159, 411, 602, 604, 608, 611

since they can be shown to have a significant archaeological interpretation. The most obvious distinction among them is geographical: the first four (M-P) contain samples from the Korinthia, the next five (Q-U) from the Argolid, and the last two (V-W) from Lake Vouliagmeni. Among the four compositional types characteristic of the Korinthia, the first is found exclusively at Keramidhaki and Korakou, the second is characteristic of these sites and Zygouries (ZYG-B), the third is found predominantly at Keramidhaki, and the fourth predominantly at Zygouries. We can therefore assign cluster M to the Korinthian plain. The objects of cluster O may have a similar origin, if the two Zygouries samples in that cluster represent imports. The number of Zygouries samples in cluster N is greater, but they account for roughly the same proportion of the total cluster size (23% against 29% in cluster O). This low proportion supports a Korinthian plain origin once again, but does not rule out an origin closer to Zygouries. Cluster P has no association with the coastal plain, but as it contains both Zygouries and Phlious samples it may be denoted the "highland" group.

Among the Argolid clusters, Q and U are plainly characteristic of Tiryns. Cluster Q also contains samples which belong to subgroup B of the Asine core, indicating the strong possibility of ceramic exports to Asine from Tiryns. Although cluster S is made up exclusively of Asinean objects (mostly mud bricks), and is identical to subgroup A of ASICORE,

cluster R is a mixture of objects from Asine and from Lerna. The inclusion of the mud brick ASI 5 in this cluster makes an origin at Asine more likely than one at Lerna. Cluster T, on the other hand, comes most probably from Lerna. Finally, although cluster V can definitely be attributed to Lake Vouliagmeni, the provenance of the objects in cluster W is not as securely determined. At any rate, that compositional type is not characteristic of any other site in this study. The origins of the clusters are discussed at greater length in section 7.4 after their membership has been augmented by some samples not belonging to the original core groups.

These clusters might have been derived from the core groups by continuing the series of group modifications begun in section 7.2.3. Their final forms may be interpreted in the spirit of those modifications. One of the 3 Keramidhaki/Korakou clusters has merged with ZYG-B, and the Zygouries cluster now incorporates a few Phlious samples. The main Tiryns core group has absorbed ASI-B. Clusters U, V, and W differ only slightly from TIRCORE-B, VOUCORE, and VOU-R, but since they were formed on the basis of the concentrations of only 8 elements, the core-group equivalents of these clusters represent the compositional types better. They were therefore used in subsequent calculations.

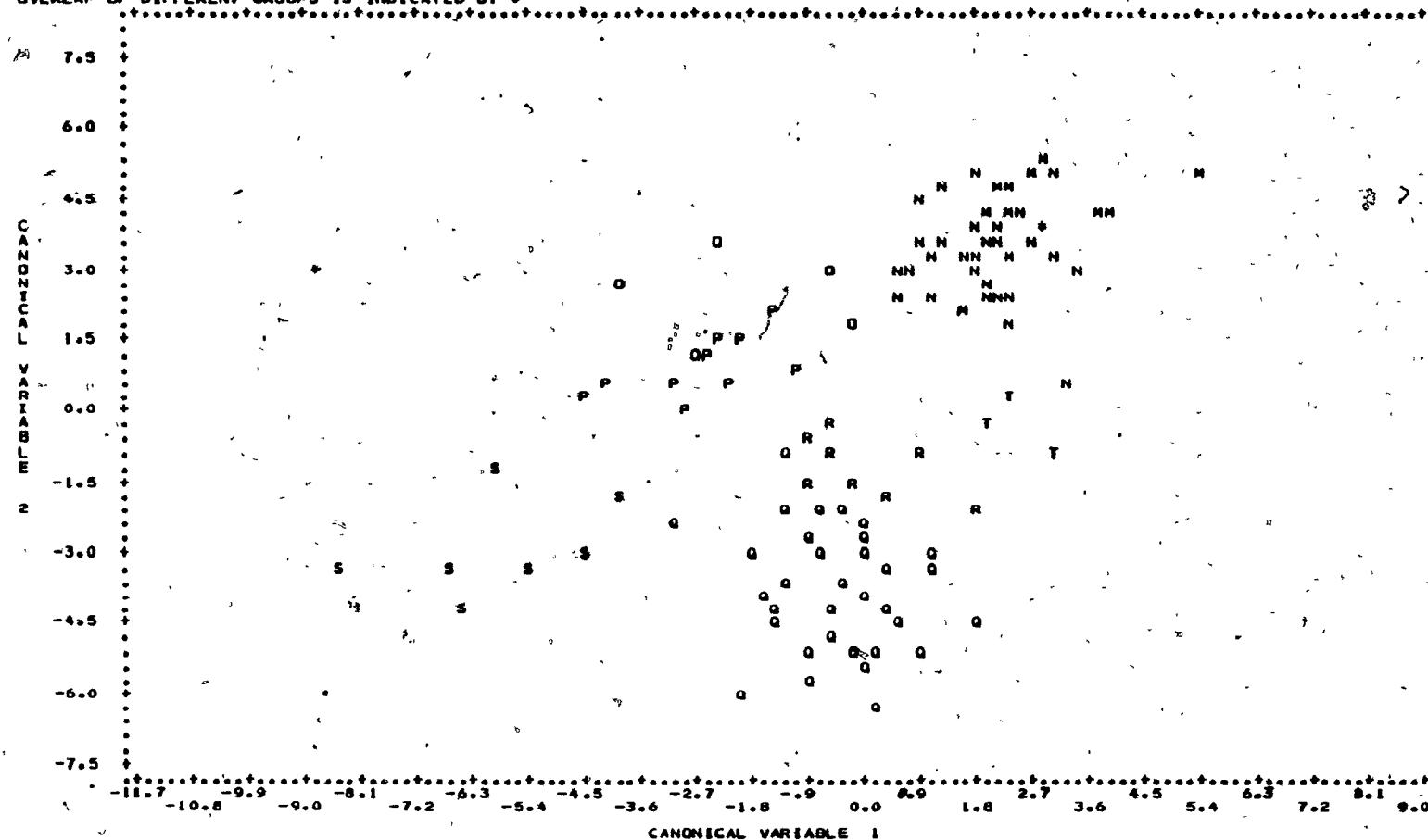
The most serious difference between the new arrangement of clusters and the one based on single-site core groups is the drastic reduction in the size of the group from Lerna.

Where LERCORE contains 19 samples, cluster T contains only 6, with 3 more Lerna samples to be found in cluster R. Overlaps caused by the large spread in concentration values within LERCORE had been a problem; reducing the group to minimum size is one way to avoid it. The remainder of the Lerna samples were left for assignment to clusters using discriminant analysis.

Not surprisingly, discriminant analysis of these clusters is almost 100% successful at placing (or rather replacing) each sample within its parent cluster. (Only ASI 26 is significantly closer to R than to its parent cluster Q.) This is true whether the analysis uses 19, 13, or 12 elemental concentrations as variables. Furthermore, the clusters seem to be reasonably well-isolated in discriminant space, although the bivariate plots are quite crowded with samples. The plot shown in Figure 7-ii is a faithful representation in two dimensions of the distribution of concentration values in multi-dimensional space, since the first two canonical variables account for 98% of the total dispersion. (The first one alone accounts for 94.7%.) In fact, some relationship to geographical position is also evident in this plot, the samples in Korinthian clusters appearing in the upper half and those in Argolid ones in the lower. This means that the geographical watershed between the two provinces may be a geochemical one as well. At any rate, it appears quite feasible to use discriminant analysis to attribute other

FIGURE 7-ii: Bivariate plot of the samples in 8 inter-site clusters, using the first two canonical coordinates as calculated by stepwise discriminant analysis on the basis of the concentrations of 12 elements.

OVERLAP OF DIFFERENT GROUPS IS INDICATED BY *



samples to these clusters, as is in fact done in section 7.3.

The preceding discussion of the clusters' significance has indicated that they represent the productions of a number of sites in the Argolid and Korinthia. We are therefore justified in calling them reference groups, if we keep in mind certain limitations. Pottery has been analyzed from eight sites in the region under study; surely these are only a few of the ones where pottery was produced. Attributions of the groups to production sites must be made in this light. By assigning a group to a certain site we do not exclude the possibility that some or all of the objects in that group were made at a nearby centre from which no excavated material was available for sampling. This is an example of Widemann's "zone of non-resolution", albeit arising from limitations of the site selection rather than from geochemical considerations (see section 2.2).

Attributions of samples to the reference groups are also subject to limitations. These are statistical in nature, arising from natural and experimental variations in composition within a single group (section 2.2). The assignments are therefore statements of probability. In order to maintain confidence in the results, only the high-probability attributions are considered (see section 7.3.1). There may nevertheless be a few samples which are misattributed, falling by chance either close to a group to which they do not belong, or far from one to which they do. We feel, however, that because

of their small number, they would not have a significant effect on the overall picture of pottery exchange in Argolis and Korinthia.

Before the attributions were made, an investigation was conducted of the chemical differences between the clusters. The order of the elements chosen by the program to separate the clusters is the following: Sc, Na, Eu, K, Mn, Ca, Al, Hf, Cs, Cr, Th, (Yb, Fe, V, Co, La, Ti, Ce, Rb). The elements after Th would not have been used had the "force" option not been in effect, so they are enclosed in parentheses. The stepwise discriminant analyses performed with 13 and 12 elements selected the elements in similar sequence, with La, Yb, and Co in the first case, and Co and Fe in the second, being included only to satisfy the "force" option.

The average concentration of a few elements is distinctively high or low in each cluster (Table 7-IV). A chart of the same form as Table 7-II shows that for every pair of clusters, one or more elements have one-standard-deviation ranges which do not overlap (Table 7-V). From this chart, the elements most useful in separating every pair of clusters can be picked out.

Several interesting features of the clusters' chemical compositions emerge from an examination of this table. First of all, clusters M and N differ only in the concentrations of the alkali elements Na, K, and Rb. The last two of these are positively correlated, so that the ratio of their

TABLE 7-IV: Average Compositions of the Samples
Constituting the Inter-site Clusters,
with Comparative Data (see text)

<u>Group</u>	<u>Al (%)</u>	<u>n</u>	<u>Ca (%)</u>	<u>n</u>	<u>V (ppm)</u>	<u>n</u>
M	8.2 ± 0.5	(12)	11.6 ± 0.8	(12)	151 ± 21	(12)
N	8.3 ± 0.3	(27)	9.9 ± 2.8	(31)	142 ± 15	(27)
O	7.1 ± 0.4	(6)	14.6 ± 2.4	(7)	115 ± 12	(6)
P	7.6 ± 0.3	(9)	10.0 ± 1.6	(9)	119 ± 10	(9)
Q	8.1 ± 0.4	(37)	2.1 ± 1.4	(37)	128 ± 7	(37)
R	7.4 ± 0.3	(4)	7.3 ± 2.9	(7)	121 ± 9	(4)
S	6.1 ± 0.6	(2)	4.8 ± 3.0	(2)	88 ± 12	(2)
T	-		8.1 ± 2.4	(4)	-	
U	7.5 ± 0.3	(10)	10.0 ± 2.2	(10)	136 ± 8	(10)
V	-		13.0 ± 4.4	(40)	-	
W	-		3.5 ± 1.8	(12)	-	
CRTH	8.2 ± 0.5	(5)	10.0 ± 2.1	(40)	-	
MYCN	8.1 ± 0.3	(16)	9.8 ± 0.8	(16)	-	
LGC	7.0 ± 0.6	(4)	5.3 ± 0.6	(4)	-	
PC	6.2 ± 0.6	(5)	3.9 ± 0.4	(5)	-	

TABLE 7-IV - continued

<u>Group</u>	<u>Ti (%)</u>	<u>n</u>	<u>Mn (ppm)</u>	<u>n</u>	<u>Na (%)</u>	<u>n</u>
M	0.48 ± 0.02	(12)	1031 ± 216	(12)	1.40 ± 0.19	(12)
N	0.47 ± 0.04	(27)	1065 ± 167	(31)	0.52 ± 0.11	(31)
O	0.42 ± 0.03	(6)	1139 ± 125	(7)	0.56 ± 0.12	(7)
P	0.46 ± 0.03	(9)	714 ± 72	(9)	0.59 ± 0.15	(9)
Q	0.50 ± 0.04	(37)	714 ± 86	(37)	1.06 ± 0.12	(37)
R	0.44 ± 0.02	(4)	967 ± 92	(9)	0.90 ± 0.09	(9)
S	0.40 ± 0.04	(2)	849 ± 113	(8)	0.82 ± 0.22	(8)
T	-		993 ± 74	(6)	0.64 ± 0.20	(6)
U	0.43 ± 0.02	(10)	1104 ± 205	(10)	0.39 ± 0.07	(10)
V	-		-		-	
W	-		-		-	
CRTH	0.46 ± 0.04	(40)	881 ± 97	(40)	0.70 ± 0.28	(40)
MYCN	0.42 ± 0.02	(16)	901 ± 66	(16)	0.62 ± 0.14	(16)
LGC	0.41 ± 0.04	(4)	-		0.70 ± 0.15	(7)
PC	0.38 ± 0.06	(5)	-		0.62 ± 0.21	(10)

TABLE 7-IV - continued

Group	K (%)	n	La (ppm)	n	Yb (ppm)	n
M	1.0 ± 0.3	(12)	35.8 ± 1.8	(12)	2.5 ± 0.4	(12)
N	2.7 ± 0.3	(31)	35.5 ± 2.0	(31)	2.6 ± 0.3	(31)
O	2.3 ± 0.2	(7)	27.8 ± 1.6	(7)	2.5 ± 0.2	(7)
P	2.3 ± 0.3	(9)	32.0 ± 1.2	(9)	2.6 ± 0.3	(9)
Q	2.8 ± 0.3	(37)	38.1 ± 3.8	(37)	2.5 ± 0.4	(37)
R	2.5 ± 0.1	(9)	32.1 ± 2.3	(9)	2.6 ± 0.3	(9)
S	1.8 ± 0.3	(8)	26.8 ± 2.3	(8)	2.8 ± 0.6	(8)
T	2.6 ± 0.3	(6)	33.4 ± 1.1	(6)	3.0 ± 0.3	(6)
U	2.7 ± 0.2	(10)	30.6 ± 1.7	(10)	1.8 ± 0.3	(10)
V	-		22.2 ± 2.7	(40)	2.3 ± 0.3	(40)
W	-		22.8 ± 3.4	(12)	3.2 ± 0.5	(12)
CRTN	-		31.0 ± 2.3	(40)	-	
MYCN	-		34.1 ± 1.2	(16)	-	
LGC	2.5 ± 0.4	(4)	44.4 ± 3.6	(7)	3.0 ± 0.4	(7)
PC	2.7 ± 0.3	(5)	47.2 ± 2.4	(10)	2.8 ± 0.2	(10)

TABLE 7-IV - continued

Group	Rb (ppm)	n	Cs (ppm)	n	Sc (ppm)	n
M	57 ± 20	(12)	11.7 ± 3.0	(12)	22.8 ± 1.4	(12)
N	146 ± 18	(27)	12.4 ± 3.4	(31)	22.5 ± 1.1	(31)
O	101 ± 28	(6)	8.7 ± 1.8	(7)	19.7 ± 1.1	(7)
P	121 ± 26	(9)	9.1 ± 1.4	(9)	19.4 ± 0.7	(9)
Q	123 ± 25	(37)	6.4 ± 1.0	(37)	20.2 ± 0.8	(37)
R	116 ± 27	(9)	5.4 ± 1.1	(9)	20.5 ± 0.9	(9)
S	110 ± 44	(8)	3.3 ± 0.8	(8)	16.3 ± 1.2	(8)
T	133 ± 62	(6)	7.7 ± 2.2	(6)	20.7 ± 1.4	(6)
U	118 ± 18	(10)	6.9 ± 1.0	(10)	22.0 ± 0.8	(10)
V	74 ± 25	(40)	6.4 ± 1.9	(40)	17.3 ± 3.2	(40)
W	82 ± 23	(12)	4.1 ± 1.1	(12)	20.7 ± 2.4	(12)
CRTN	143 ± 23	(40)	9.6 ± 2.1	(40)	20.7 ± 1.1	(40)
MYCN	145 ± 14	(16)	9.2 ± 0.8	(16)	21.1 ± 0.6	(16)
LGC	169 ± 13	(7)	8.6 ± 1.1	(7)	23.8 ± 1.8	(7)
PC	139 ± 28	(10)	8.9 ± 1.1	(10)	26.5 ± 2.3	(10)

TABLE 7-IV - continued

Group	Ce (ppm)	n	Eu (ppm)	n	Th (ppm)	n
M	78 ± 7	(12)	1.20 ± 0.11	(12)	8.7 ± 0.3	(12)
N	83 ± 8	(27)	1.25 ± 0.08	(31)	8.9 ± 0.6	(27)
O	63 ± 5	(6)	1.18 ± 0.07	(7)	6.3 ± 0.6	(6)
P	70 ± 3	(9)	1.18 ± 0.09	(9)	8.1 ± 0.5	(9)
Q	79 ± 8	(37)	1.11 ± 0.12	(37)	9.6 ± 0.9	(37)
R	73 ± 9	(9)	1.22 ± 0.08	(9)	8.1 ± 0.7	(4)
S	58 ± 8	(8)	0.98 ± 0.08	(8)	7.6 ± 0.6	(8)
T	73 ± 8	(6)	1.56 ± 0.06	(6)	11.8 ± 0.4	(6)
U	64 ± 4	(10)	1.20 ± 0.14	(10)	7.5 ± 0.5	(10)
V	42 ± 6	(40)	1.01 ± 0.13	(40)	7.2 ± 1.1	(40)
W	51 ± 7	(12)	1.21 ± 0.15	(12)	7.9 ± 1.5	(12)
CRTN	-	-	-	-	10.8 ± 0.6	(40)
MYCN	-	-	-	-	10.7 ± 0.3	(16)
LGC	81 ± 4	(7)	1.42 ± 0.13	(7)	11.1 ± 0.8	(7)
PC	86 ± 6	(10)	1.47 ± 0.21	(10)	11.4 ± 1.1	(10)

TABLE 7-IV - continued

Group	Hf (ppm)	n	Cr (ppm)	n	Fe (%)	n
M	3.7 ± 0.6	(12)	273 ± 23	(12)	5.6 ± 0.3	(12)
N	3.7 ± 0.5	(31)	286 ± 52	(31)	5.5 ± 0.3	(31)
O	3.2 ± 0.5	(7)	202 ± 41	(7)	4.9 ± 0.3	(7)
P	4.3 ± 0.3	(9)	226 ± 25	(9)	4.7 ± 0.3	(9)
Q	5.7 ± 0.8	(37)	333 ± 108	(37)	5.1 ± 0.2	(37)
R	4.4 ± 0.6	(9)	345 ± 25	(9)	5.1 ± 0.1	(9)
S	4.7 ± 0.5	(8)	474 ± 68	(8)	4.3 ± 0.2	(8)
T	4.8 ± 0.8	(6)	332 ± 50	(6)	5.0 ± 0.3	(6)
U	2.7 ± 0.4	(10)	382 ± 67	(10)	5.6 ± 0.3	(10)
V	3.2 ± 0.6	(40)	282 ± 116	(40)	4.3 ± 0.7	(40)
W	4.9 ± 0.6	(12)	140 ± 54	(12)	4.5 ± 0.4	(12)
CRTN	3.5 ± 0.3	(40)	234 ± 17	(40)	5.3 ± 0.3	(40)
MYCN	3.2 ± 0.3	(16)	221 ± 14	(16)	5.2 ± 0.2	(16)
LGC	2.7 ± 0.5	(7)	195 ± 19	(7)	5.8 ± 0.5	(7)
PC	2.7 ± 0.5	(10)	189 ± 30	(10)	5.3 ± 0.6	(10)

TABLE 7-IV - continued

Group	Co (ppm)	n
M	32 ± 2	(12)
N	32 ± 4	(31)
O	29 ± 2	(7)
P	24 ± 2	(9)
Q	23 ± 3	(37)
R	30 ± 3	(9)
S	28 ± 3	(8)
T	30 ± 2	(6)
U	37 ± 4	(10)
V	-	
W	-	
CRTH	28.6 ± 2.7	(40)
MYCN	28.2 ± 1.4	(16)
LGC	27.8 ± 2.0	(7)
PC	28.3 ± 3.2	(10)

Note: The $\pm$ figures represent 1 σ ; n is the number of samples included in each average.

TABLE 7-V: Elements Useful in Distinguishing the

Inter-site Clusters

	M	N	O	P	Q	R	S	T	U	V	W
M		Na, K, Rb	Al, V, Ti Na, K, La Sc, Cr, Th Cr, Fe	V, Mn, Na K, La, Rb Sc, Cr, Fe Co	Ca, Mn, Na K, Rb, Cs Sc, Hf, Fe Co	Al, Ca, V Ti, Na, K Rb, Cs, Sc Cr, Fe	Al, Ca, V Ti, Na, K La, Cs, Sc Ce, Eu, Th Cr, Fe	Ca, Na, K Eu, Fe	Ti, Na, K La, Yb, Rb Cs, Ce, Th Hf, Cr	La, Cs, Sc Ce, Th, Fe	Ca, La, Cs Ce, Th, Hf Cr, Fe
N			Al, La, Sc Ce, Th, Fe	Al, Mn, Sc Ce, Fe, Co	Ca, Mn, Na Cs, Sc, Hf Co	Al, Na, Cs Sc, Fe	Al, V, K La, Cs, Sc Ce, Eu, Th Hf, Cr, Fe	Eu	Al, La, Yb Cs, Ce, Th Hf	La, Rb, Cs Sc, Ce, Eu Th, Fe	Ca, La, Rb Cs, Ce, Hf Cr, Fe
O				Ca, Mn, La Th, Hf, Co	Al, Ca, Ti Mn, Na, K La, Ce, Th Hf, Co	Al, Ca, Ti Cs, Th, Hf Cr	Al, Ca, V Mn, K, Cs Sc, Eu, Th Hf, Cr, Fe	Ca, La, Yb Eu, Hf, Cr	Ca, K, Yb Sc, Th, Cr Fe, Co	La, Ce	Ca, La, Yb Cs, Ce, Hf
P					Ca, Na, La Cs, Th, Hf	Mn, Na, Cs Cr, Fe, Co	Ca, V, La Cs, Sc, Ce Eu, Cr	Mn, Eu, Cr Co	Mn, Yb, Sc Hf, Cr, Fe Co	La, Cs, Ce Hf	Ca, La, Cs Ce, Cr
Q						Al, Ca, Ti Mn, Co	Al, V, Ti K, La, Cs Sc, Ce, Th Fe	Ca, Mn, Na Eu, Co	Ca, Ti, Mn Na, La, Yb Sc, Ce, Th Hf, Fe, Co	Ca, La, Ce Th, Hf	La, Cs, Ce Cr, Fe
R							Al, V, K La, Cs, Sc Eu, Cr, Fe	Eu	Na, Yb, Hf Fe, Co	La, Ce, Hf Fe	La, Cs, Ce Cr, Fe
S								K, La, Cs Sc, Eu, Cr Fe	Al, Ca, V Na, K, Yb Cs, Sc, Eu Hf, Fe, Co	Ca, Cs, Ce Hf, Cr	Sc, Eu, Cr
T									La, Yb, Eu Hf, Fe, Co	La, Yb, Ce Eu, Hf	Ca, La, Cs Ce, Eu, Cr
U										La, Sc, Ce Fe	Ca, La, Yb Cs, Ce, Hf Cr, Fe
V											Ca, Yb, Hf
W											

At the intersection of each row and column are listed the elements whose one-standard-deviation ranges of concentration do not overlap for that pair of clusters.

concentrations $[K]/[Rb]$ is relatively constant, having similar values for clusters M and N (175 and 185 respectively). Na and K are negatively correlated, and their molar sum is relatively constant (see section 6.2.1), taking the value .086 for M and .092 for N. The strong chemical resemblance between these clusters, apart from these elements, implies that the corresponding clay sources are geochemically very similar and so probably relatively close to one another. Since the concentration ranges for cluster M are in many cases smaller than those for cluster N, a greater number of distinguishing elements is present in Table 7-V along row M than along row N.

Among the other clusters only T and V have entries with two or fewer elements listed. Cluster V has low concentrations of many elements, a characteristic linked to high concentrations of Ca. This feature is also evident for cluster O, which is nevertheless distinguished from cluster V by the very low La and Ce concentrations of the latter. Cluster T is distinguished from N and R only by its high Eu concentration (plus Th if the Lerna data are reliable). The pair N and R are separable on the basis of 5 elements, but because T has intermediate values of most elemental concentrations, it overlaps many of the other clusters. This characteristic of the Lerna composition was already evident from the analyses carried out by GANOS (Attas 1980, p. 94).

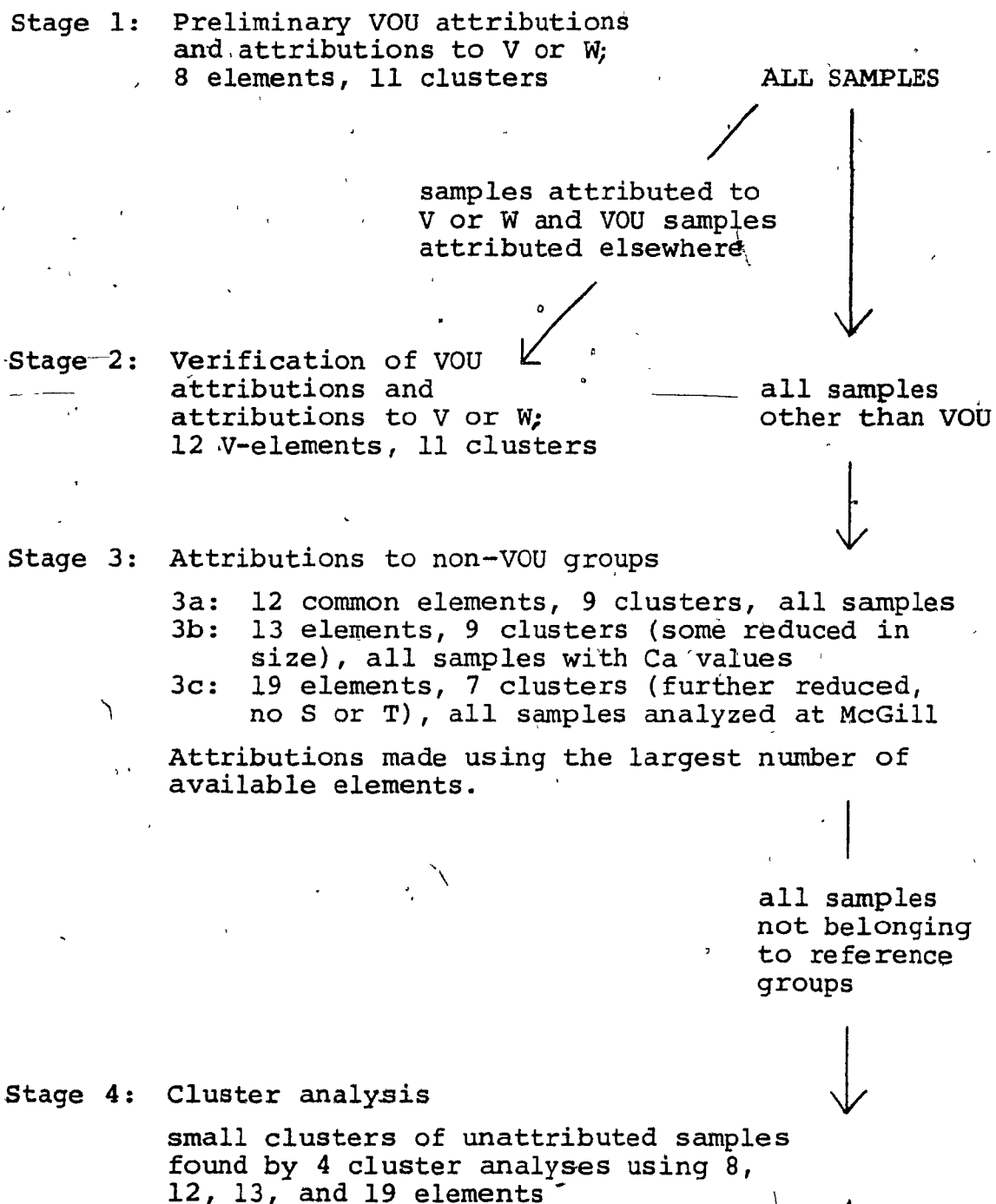
7.3 Single-sample attributions

7.3.1 Procedure

Because of the uneven quality of the analytical data and the large number of groups under consideration, the attribution of individual samples proceeded in steps. Figure 7-iii is a flowchart showing the sequence of tests which were carried out. The first stage, a discriminant analysis of the 11 clusters of section 7.2.4, provided a tentative attribution for each sample in a collection submitted to the program as a twelfth group, "X". That trial used the concentrations of the 8 elements common to the analysis of every sample: La, Yb, Cs, Sc, Eu, Hf, Cr, and Fe. Any sample attributed to one of the Vouliagmeni groups was tested, where possible, by a discriminant analysis using Ca, Rb, Ce, and Th concentrations in addition to the eight mentioned above. This test ensured that the final attribution to a Lake Vouliagmeni group was made on the basis of as full a data set as possible. The similarity of samples excavated at Lake Vouliagmeni to other groups was also tested in this way.

The rest of the samples passed to the next stage of comparison. This is the tentative attribution of samples to one of the main Argolid/Korinthia groups using the concentrations of the 12 elements common to all samples other than those excavated at Lake Vouliagmeni (the eight mentioned above plus Na, K, Mn, and Co). Just as in the previous stage, preliminary classifications were tested using as many

FIGURE 7-iii: Flow Chart Illustrating the Process of
Attributing Samples to Reference Clusters



of the 19 elemental concentrations determined at McGill as were available for both the sample and the cluster to which it is most similar. Actually, two extra discriminant analyses, with 13 elements (including Ca) and 19 elements in turn, were sufficient for reliable attributions of the unassigned samples. The results are most compactly presented in tabular form (Table 7-VI).

Criteria for definitive attributions were deliberately chosen cautiously. In other words, a sample was attributed to a reference cluster only if it was well within (i.e., close to the centroid of) that cluster, and relatively far from others. A sample which already belonged to a reference cluster had to be much closer to a second cluster before it was reassigned. One result of this approach was a collection of some samples whose attribution was vague. When the distance from a cluster centroid to a sample not belonging to one of the reference clusters was as great as that to the farthest samples belonging to that cluster, the sample was said to be "associated" with that cluster rather than attributed to it. If a sample was found to be associated with two or more clusters characteristic of separate parts of the region under study, the most that could be said about its origin is that it lies somewhere in the Argolid or the Korinthia. Its composition type was therefore termed "regional".

The assignment of samples to clusters is described in detail for the Lake Vouliagmeni samples and clusters, but

in summary form only for the rest, since the same procedure was followed. All the attributions and associations are presented as lists of samples in two formats. In the list arranged by site and by numerical order of sample number within each site (Table 7-VI), one or more letters accompanies each sample. An asterisked letter indicates that the sample was an original member of the cluster; a letter in parentheses represents an association. The abbreviation "reg." stands for the vaguer "regional" attribution. Unattributed samples are marked with a dash. A second list of samples is arranged by cluster (Table 7-VII). There the original members are accompanied by asterisks, the associated samples are listed in parentheses, and the definite attributions bear no special marks. Samples of "regional" composition and unattributed samples are listed separately. In both tables, an asterisked sample enclosed in parentheses marks an original cluster member which is relatively distant from the corresponding centroid.

7.3.2 Lake Vouliagmeni groups and samples

Although over a dozen samples from other clusters were attributed to cluster V in the 8-element discriminant analysis, most of these proved to be quite far from the V centroid as calculated by the 12-element analysis. Among these, three Lerna samples had a value of the squared Mahalanobis distance from the V centroid, D_V^2 , of less than 30: LER 21, 28, and 45.

TABLE 7-VI: Assignments of Samples to Inter-site Clusters

		<u>VOU</u>	
010	V*	301	-
011	V*	302	V*
012	V*	303	(V)
013	V*	304	R
014	V*		
015	-	401	-
016	-	402	V*
		403	V*
101	V*	404	V*
102	V*	405	-
103	-	406	V*
104	V	407	V*
105	V*	408	(V*)
106	reg.	409	V*
107	V*	410	V*
108	V*		
		411	W*
111	-	412	-
112	V*	413	V*
113	V*	414	V*
114	V*	415	V*
115	V*	416	V*
116	V	417	V*
		418	reg.
151	V*	419	V*
152	V	420	V*
153	V*	421	(Q)
154	(V, W)	422	V*
155	W*		
156	W*	501	-
157	W*	502	reg.
158	W*	503	N
159	W*	504	reg.
160	-	505	reg.
		506	-
201	V*	507	(M)
202	V*	508	reg.
203	V*	509	reg.
204	V*	510	-
205	V*	511	reg.
206	V*	512	-
		513	reg.
		514	(V)
		516	-
		517	reg.
		518	reg.
		519	-
		520	(P, R)
		521	-
		522	(P, R)
		523	-
		524	-
		525	-
		526	(V)
		601	W
		602	W*
		603	reg.
		604	W*
		605	-
		606	reg.
		607	reg.
		608	W*
		609	-
		610	(P, R)
		611	W*
		612	W*
		613	(V*) reg.
		614	reg.
		615	(P, R)
		616	(V)
		617	-
		618	-
		619	reg.
		620	(R)
		621	-
		622	V
		623	(W*)

TABLE 7-VI - continued

<u>Z Y G</u>		<u>P H L</u>		<u>T I R</u>	
1	-	1	-	1	Q
2	-	2	P*	2	Q*
3	P*	3	P*	3	Q*
4	Q	4	(M)	4	Q*
6	P*	5	P*	5	Q*
7	O*	7	reg.	6	Q*
8	N*	8	reg.	7	P
9	N*	9	reg.	8	Q*
10	N*	10	reg.	9	Q*
				10	reg.
11	N*	11	-	11	(Q)
12	N*	12	-	12	Q*
13	-	13	N	13	Q*
14	-	14	-	14	Q*
15	reg.	18	P	15	Q*
16	N			16	Q*
17	reg.	23	reg.	17	Q*
18	(N)	24	N	18	Q*
19	O*			19	Q*
20	M			20	reg.
				26	N
21	reg.				
22	P			31	Q*
23	N*			32	Q*
24	N*			33	Q
25	P*			34	Q*
26	P			35	Q*
27	(Q)			36	Q*
28	P*			37	Q*
29	P*			38	U*
30	P*			39	Q*
				40	Q*
				41	Q*
				42	Q
				43	Q*
				44	Q*
				45	Q*
				56	U*
				57	U*
				58	(U)
				59	U*
				60	(U*)
				61	U*
				62	U*
				70	-
				73	Q*
				74	Q*
				75	Q*
				76	-
				77	U*
				79	reg.
				80	(R)
				81	reg.
				82	R
				83	-
				84	reg.
				85	Q*
				86	U*
				87	U
				88	U*

TABLE 7-VI - continued

<u>AS I</u>		<u>LER</u>	
1	S*	1	-
2	S*	2	-
3	S*	3	-
4	S*	4	reg.
5	R*	5	-
6	S*	6	-
7	-	7	R*
8	(M)	8	reg.
9	reg.	9	-
10	Q*	10	-
11	reg.	11	(S)
12	-	12	P
13	-	13	reg.
14	-	14	P
15	Q*	15	reg.
16	S*	16	-
17	S*	17	-
18	P	18	T*
19	R*	19	T*
20	Q*	20	T*
21	R*	21	reg.
22	S*	22	-
24	Q*	23	(T)
25	Q*	24	-
26	R*	25	-
27	-	26	-
31	reg.	27	R*
32	-	28	V
33	Q*	29	R
34	R*	30	P
35	R*		
		31	-
		32	-
		33	-
		34	-
		35	-
		36	-
		37	(T*)
		38	-
		39	-
		40	-
		41	T*
		42	N
		43	O
		44	reg.
		45	(S)
		46	-
		47	R*
		48	(S)
		49	P
		51	-
		52	-
		53	-
		54	-
		55	reg.
		56	T*

Notes: Samples belonging to one of the original clusters of Table 7-III are marked with an asterisk. Cluster letters enclosed in parentheses denote associations. Samples marked "reg." are attributed only to the general region covered by this study; those followed by a dash are unattributed.

TABLE 7-VII: Samples Attributed to and Associated
with Each Group

<u>M</u>	<u>N</u>	<u>O</u>
KER 1*	KER 4*	KER 5*
2*	(9)	(13)
(3)	10*	19*
6*	12*	32*
7*	16*	(38)
14*	17*	39*
15*	21*	40*
(31)	34*	(42)
KOR 1*	(35*)	(48)
KRK 6*	41*	51
14*	55*	56
15*	59*	KRK (19)
22*	60*	ZYG 7*
28*	61*	19*
ZYG 20	(65)	LER 43
PHL (4)	66*	
ASI (8)	KRK 5*	
VOU (507)	7*	
	10*	
	13*	
	20*	
	21*	
	38*	
	39*	
	40*	
	42*	
	44	
	ZYG 8*	
	9*	
	10*	
	11*	
	12*	
	16	
	(18)	
	23*	
	24*	
	PHL 13	
	24	
	TIR 26	
	LER 42	
	VOU 503	

TABLE 7-VII - continued

	<u>P</u>	<u>Q</u>	<u>R</u>
KER	36	KRK 8	TIR (80)
	52	47	82
	67	ZYG 4	ASI 5*
KRK	43	(27)	19*
	46	TIR 1	21*
ZYG	3*	2*	26*
	6*	3*	34*
	22	4*	35*
	25*	5*	LER 7*
	26	6*	27*
	28*	8*	29
	29*	9*	47*
	30*	(11)	VOU 304
PHL	2*	12*	(520, P)
	3*	13*	(522, P)
	5*	14*	(610, P)
	18	15*	(615, P)
TIR	7	16*	(620)
ASI	18	17*	
LER	12	18*	
	14	19*	
	30	31*	
	49	32*	
VOU (520, R)		33	
(522, R)		34*	
(610, R)		35*	
(615, R)		36*	
		37*	
		39*	
		40*	
		41*	
		42	
		43*	
		44*	
		45*	
		73*	
		74*	
		75*	
		85*	
		ASI 10*	
		15*	
		20*	
		24*	
		25*	
		33*	
		VOU (421)	
			<u>S</u>
			ASI 1*
			2*
			3*
			4*
			6*
			16*
			17*
			22*
			LER (11)
			(45)
			(48)

TABLE 7-VII - continued

<u>T</u>		<u>V</u>		<u>W</u>	
KRK	16	LER	28	VOU	(154, V)
	17	VOU	010*		155*
LER	18*		011*		156*
	19*		012*		157*
	20*		013*		158*
	(23)		014*		159*
	(37*)		101*		411*
	41*		102*		601
	56*		104*		602*
			105*		604*
			107*		608*
			108*		611*
			112*		612*
			113*		(623*)
			114*		
			115*		
			116		
			151*		
			152		
			153*		
			(154, W)		
			201*		
			202*		
			203*		
			204*		
			205*		
			206*		
			302*		
			(303)		
			402*		
			403*		
			404*		
			406*		
			407*		
			(408*)		
			409*		
			410*		
			413*		
			414*		
			415*		
			416*		
			417*		
			419*		
			420*		
			422*		
			(514)		
			(526)		
			(616)		
			622		

TABLE 7-VII - continued

<u>Regional</u>				<u>Unassociated</u>					
KER	8	ASI	9	KER	11	ZYG	1	VOU	015
	22		11		18		2		106
	23		31		20		13		103
	25	LER	4		24		14		111
	27		8		26	PHL	1		160
	33		13		28		11		301
	44		15		29		12		401
	58		21		37		14		405
KOR	4		44		45	TIR	70		412
KRK	11		55		46		76		501
	12	VOU	106		47		83		506
	18		418		49	ASI	7		510
	23		502		50		12		512
	25		504		53		13		516
	26		505		54		14		519
	31		508		62		27		521
	32		509		63		32		523
	34		511		64	LER	1		524
	36		513		68		2		525
	41		517		69		3		605
ZYG	15		518	KOR	2		5		609
	17		603		3		6		617
	21		606	KRK	3		9		618
PHL	7		607		4		10		621
	8		613		9		16		
	9		614		29		17		
	10		619		30		22		
	23				33		24		
TIR	10				35		25		
	20				37		26		
	79				48		31		
	81						32		
	84						33		
							34		
							35		
							36		
							38		
							39		
							40		
							46		
							51		
							52		
							53		
							54		

Note: Samples marked with an asterisk belong to one of the original clusters of Table 7-III; parentheses denote associated samples.

Samples collected under the heading "regional" are attributed

Note: Samples marked with an asterisk belong to one of the original clusters of Table 7-III; parentheses denote associated samples.

Samples collected under the heading "regional" are attributed generally to the Argolid and Korinthia.

The first and last of these were almost the same distance from the centroid of cluster R, an Argolid cluster, and the Argolid origin is inherently more likely. The bowl rim LER 28, however, had a D_V^2 of 16.0, similar to values for samples in cluster V. It was next closest to cluster O, with $D_O^2 = 35.5$. An origin at Lake Vouliagmeni was therefore suggested.

Among the samples from Lake Vouliagmeni which were not originally part of clusters V or W, the following had D_V^2 values under 30: VOU 104, 116, 152, 154, 603, and 622. All but two of these could clearly be attributed to cluster V. The exceptions were VOU 154, almost equidistant from the V and W centroids, and VOU 603, equidistant from the V, P, and R centroids. The first of these two samples is listed as "associated" with those clusters, and the second as "regional"; that is, assigned to Argolis/Korinthia without further differentiation. Also associated with V are KRK 34 and VOU 303, 418, 514, 526, and 616, since the program attributed them to cluster V but their D_V^2 values were between 30 and 40. Of these samples, KRK 34 and VOU 418 were associated also with clusters Q and T respectively, so they are listed instead as "regional".

The number of new samples which could be linked to cluster W is smaller. Only the "frying pan" VOU 601, with $D_W^2 = 19.9$, could be attributed to that cluster unequivocally. In form and paste it resembles VOU 611 and 612, also members

of VOU-R. It had not been attributed to that group in the original study (Attás 1975) because contamination from the tungsten-carbide drill bit had affected the concentrations of Lu, Co, and Ta, elements which had been used in the original statistical analyses. Two other samples, LER 3 and VOU 607, were as close to the W centroid as they were to the centroids of clusters R and S respectively (D_W^2 values of 33.2 and 35.0 but $D_R^2 = 38.0$ and $D_S^2 = 34.4$ respectively). A further two, TIR 83 and LER 8, were assigned to W by the discriminant analysis, but their D_W^2 values were above 40. An origin at Lake Vouliagméni is unlikely for any of these Lerna or Tiryns samples. LER 3, a tile fragment from the House of the Tiles, and LER 8, the rim of a decorated hearth, were probably made close to where they were found, and the deep bowl TIR 83 is dated by both style and context to EH III, during which the Vouliagméni site was not occupied. VOU 607, an incised rim sherd, may be a frying-pan fragment, but neither its form nor its decoration resemble those of the other Vouliagméni pans, which belong to cluster W. The origin of that cluster is in any case not clear (see section 7.4.12). The provenance of these and other coarse-paste wares is further discussed in section 8.3.4.

A number of samples found at Lake Vouliagméni and analyzed as part of the earlier provenance study have been attributed here to clusters other than V or W. One of these, VOU 613, is a member of cluster V, but it is closer to the

centroids of O and U (D^2 of 31.7 and 33.5) than to those of V or W (42.7 and 41.6). It may therefore have a Peloponnesian origin, although not necessarily the same one as the samples which had formed the group VOU-F. A large proportion of the samples in the group VOU-F (Table 6-VII) can be shown to have origins in the north-east Peloponnese, but limitations of the Vouliagmeni data set make more precise attributions complicated. Fully 16 of the 45 samples were attributed to cluster T by the 12-element discriminant analysis, 6 of these with D_T^2 values below 30. A further 2 were close to N, 1 to M, 4 to P, 2 to R, and 1 to S. These are several reasons why a cluster T (Lerna) origin is inappropriate for these samples. First of all, many of the VOU-F samples (including several here attributed to T) are Corinthian-style painted sherds of the Archaic period, for which an origin on the plain of Korinthos seems well-established. As well, Lerna is one of the most southerly sites in the study, whereas Lake Vouliagmeni is the most northerly. Furthermore, the reference cluster T itself contained only 4 samples in the discriminant analysis, since Ca was not determined in LER 37 and 56. Finally, the Rb and Th measurements for these 4 samples are not very useful, as the Rb values are very imprecise and those of Th may have a systematic overestimation. Attributions to cluster T on the basis of this particular discriminant analysis are therefore not reliable.

Cluster T was not included in a similar discriminant analysis designed to avoid these problems. Cluster S was removed as well, since only 2 of its samples had Ca data. That cluster as a whole is made up primarily of mud bricks from Asine, and contains no samples from any other site. With these changes the attributions became more realistic, though less definite (Table 7-VI). VOU 304 was attributed to R; VOU 503, to N. VOU 421 was associated with Q, 507 with M, and 620 with R. The clusters P and R have sufficiently similar concentration ranges for the 12 elements in this discriminant analysis that several samples were associated with both clusters: VOU 520, 522, 610, and 615. Finally, 13 samples each resembled at least three clusters, and so were best called "regional": VOU 106, 502, 504, 505, 508, 509, 511, 513, 517, 518, 606, 614, and 619. Most of the Corinthian pottery samples could be found near or in cluster N, lending further support to an origin on the plain of Korinthos for the objects of this cluster. The "highlands" cluster P shared with R many of the Mycenaean and Early Helladic I objects. The four Early Helladic II samples from VOU-F, VOU 106, 304, 421, and 510, were respectively "regional", attributed to R, associated with Q, and unassociated. In all, 24 VOU samples remained unassociated.

7.3.3 Samples from other sites

Three discriminant analyses formed the basis for the attributions of the rest of the samples. Besides the 12-element analysis mentioned in section 7.3.1, both a 13-element analysis (including Ca) and a 19-element analysis were performed. For the last of these, the clusters S and T were omitted, since the numbers of samples in these clusters with Ca concentration data were only 2 and 4 respectively. Both the 12- and the 13-element analyses included these clusters with complete and reduced numbers of samples respectively, thus permitting samples to be compared to them.

The attributions of only a few of the samples within the main clusters were changed by these analyses. KER 35 was found to be quite far from its own cluster N, LER 37 of cluster T was equally close to cluster R, and TIR 60 of cluster U was equally close to clusters N and P. These samples are listed in the tables as associated with their parent clusters.

Many of the samples which had formed part of the core groups for each site but which had not been included in the clusters were assigned to (or associated with) one of the clusters popular with samples from that site. Of the samples which had not belonged to core groups, only a small fraction could be attributed to clusters; many of them, however, had compositions typical of the region as a whole. In order to search for compositional similarities among

samples not in the inter-site reference groups, these samples were subjected to cluster analysis. The program BMDP2M was run five times, with 19, 13, 12 (common to all VOU samples), 12 (common to all other samples), and 8 elements used in turn. Clusters which formed at high similarity levels in several of these analyses are listed in Table 7-IX.

7.4 Distributions and origins of the groups

7.4.1 Introduction

In this section the composition of each group, as summarized in Table 7-VIII, is examined for information concerning the objects' place of origin. When samples from a single site constitute a large proportion of a group, that site becomes the most likely candidate. Other evidence, such as the nature of certain samples or comparative analyses by other laboratories, is also brought to bear on this problem. Aspects of the overall distributions are discussed as well.

7.4.2 Group M

Keramidhaki and Korakou account for all but one of the 13 samples attributed to this group. This is strong evidence for an origin on the Korinthian plain. Its distribution away from the plain is limited to a single attribution at Zygouries and one association each at Phlious and Asine (plus the Mycenaean sherd VOU 507).

TABLE 7-VIII: Attributions and Associations of Early Helladic II and III Material

<u>Site: Group</u>	<u>KER</u>	<u>KRK</u>	<u>ZYG</u>	<u>PHL</u>	<u>TIR</u>	<u>ASI</u>	<u>LER</u>	<u>VOU</u>	<u>Total</u>
M	7 (2)	5	1	(1)		(1)			13 (4)
N	13 (3)	11	8 (1)	2	1		1		36 (4)
O	7 (4)	(1)	2				1		10 (5)
P	3	2	8	4	1	1	4		23 (0)
Q		2	1 (1)		34 (1)	6		(1)	43 (3)
R					1 (1)	6	4	1	12 (1)
S						8	(3)		8 (3)
T		2					4 (1)		6 (1)
U	1 (1)	1			10 (2)				12 (3)
V							1	41 (3)	42 (3)
W								6 (1)	6 (1)
reg.	(9)	(11)	(3)	(5)	(5)	(3)	(6)	(2)	(44)
unass.	(22)	(9)	(4)	(4)	(3)	(6)	(20)	(10)	(78)
TOTALS	72	44	29	16	59	31	45	65	361

Not included: LER 36-39 and 51-56; all VOU 500's and 600's except VOU 510 (EH II).

TABLE 7-IX: Clusters of Samples not Belonging to the
Reference Groups

KER 68, 69, ZYG 17	KER 23, 26
ZYG 13, 14, 15	KER 47, 49
KER 31, 50	KER 45, 62
ZYG 20, ASI 8	KRK 37, 48
KER 37, 42	LER 6, 31, 32, 34
LER 4, 21	LER 22, 25, 26
TIR 79, 80, 82	KRK 47, ZYG 4, 27, TIR 1, 11, 33, 42
KRK 16, 17, ASI 31	LER 36, 38, 39, ZYG 2
TIR 7, 10, 20	VOU 015, 016
KRK 11, 12, 23	VOU 154, 401
KER 22, 25, 27, 44, 58, 65, KOR 4, KRK 31, LER 48	VOU 152, 303
	VOU 405, 412

7.4.3 Group N

Once again, Keramidhaki and Korakou are the findspots of the largest share of this group's samples, two-thirds of them in this case. Another quarter were found at Zygouries, with two samples at Phlious and one each at Tiryns, Lerna, and Vouliagmeni. Although possible, an origin at Zygouries is less likely than one on the Korinthian plain because of the close resemblance between groups M and N for all elements except the alkalis, and because of the inclusion of VOU 503, a Corinthian-style miniature bowl.

7.4.4 Group O

Most of the samples in group O were found at Keramidhaki, making that site the most likely place of origin. Could Korakou have been uninhabited while Keramidhaki potters were exploiting this clay source? It is difficult to find support for such fine chronological distinctions, since within group O are samples from the latest EH II phase at Zygouries and an early EH III phase at Lerna, besides the majority from Keramidhaki, which was probably inhabited for a relatively short period during the middle of the EH II phase (Cherry 1973, p. 121). This matter is further discussed in section 8.2.

7.4.5 Group P

Samples belonging to this group have a broad distribution, with several being found at Keramidhaki, Korakou, Zygouries,

Phlious, and Lerna. (Four Vouliagmeni samples, two from Mycenaean vessels and two EH I sherds, are associated with this group and group R.) The Zygouries samples are the most numerous, making that site (or one in its vicinity) a more likely place of origin than any of the others for the group as a whole.

7.4.6 Group Q

Tiryns samples make up 80% of the 43 samples in this group, with six more found at Asine. Since almost all Early Helladic II and Transitional sherds sampled from Tiryns belong to this group, it may be called the Tiryns group par excellence. The Asine samples would then be imports. It is curious that no Lerna samples belong to this group, even though two group Q samples have been found as far away as Korakou. Possible explanations for this are discussed in section 8.2.

7.4.7 Group R

Although both Asine and Lerna are represented among the samples of group R, the former site is the more likely source for two reasons. First of all, the six Asine samples in this group represent a larger proportion of the Asine analyzed total than the four Lerna ones do of the Lerna total. Secondly, among the Asine samples is the mud-brick fragment ASI 5. The five associated samples found at Lake

Vouliagmeni contribute no information, since their origin is not constrained to agree with that of the rest of the group. The possibility still exists, however, that some clay beds near Asine and Lerna are so similar that samples from the two sites have been merged into this one group.

7.4.8 Group S

Five mud bricks, a modern clay, and two sherds, all from Asine, constitute the 8 samples attributed to this group. A further 3 Lerna samples are associated with it, but they need not share its definite Asinean origin.

7.4.9 Group T

Lerna samples predominate in this small group. They are sherds of several different periods, from early EH II to early Middle Helladic, so that an origin at least close to Lerna is likely. It is disappointing, however, that so few Lerna samples are actually attributed to this group. The only group T objects not from the Lerna excavations are a pair of slipped-and-polished sherds found at Korakou.

7.4.10 Group U

Early Helladic III pottery from Tiryns accounts for almost all the samples in group U, leaving little doubt as to its origin. A couple of sherds from the Korinthian plain sites are also included.

7.4.11 Group V

Group V contains nearly all the samples considered in the earlier study to be local products of Lake Vouliagmeni. These include the clay samples, the mud bricks, and the rest of what had then been called group L. A single sherd from Lerna is the only object in this group not found at Lake Vouliagmeni.

7.4.12 Group W

This collection is also equivalent to one from the earlier study, namely VOU-R. Its membership is limited exclusively to Vouliagmeni samples from Early Helladic I and II deposits, but the group includes no objects pinning its origin to that site. Furthermore, there is no evidence for associating it with any of the sites included in this study.

7.4.13 Comparative data

Two laboratories have analyzed reference collections of pottery from the north-east Peloponnese, producing data which are directly comparable to the ones in this study; i.e., using the Perlman-Asaro pottery as a standard. The creators of that standard have published analyses of both painted Corinthian sherds ("CRTH") from the seventh to the third centuries BC (Farnsworth et al. 1977) and Late Helladic IIIB sherds ("MYCN") from Mycenae (Karageorghis et al. 1972).

A group from the Greek Nuclear Research Centre "Democritos" (Grimanis et al. 1980) has analyzed sets of Late Geometric Corinthian ("LGC") and Protocorinthian ("PC") sherds as reference material for a study of "Thapsos Class" vases. The average composition of each of these four groups is reproduced in Table 7-IV. Unfortunately, although these all demonstrate a general similarity to groups M to U, no strong link between any of these comparison groups and a particular Early Helladic group is evident. The group CRTH resembles the Korinthia clusters M, N, O, and P more than it does the Argolid ones (Q, R, S, T, U); the opposite holds for the group MYCN. The two groups LGC and PC, however, seem to be closer in composition to Argolid groups than to Korinthia ones. Indeed, although one would expect them to resemble CRTH strongly, there are significant differences in composition for the elements Al, Ca, Sc, Hf, and particularly La. These differences limit the information obtainable from the Berkeley and the Democritos data for fixing the origins of the Early Helladic groups.

A research team at Brookhaven National Laboratory (BNL) has been compiling a data bank of pottery analyses for several years (Harbottle 1976). Considerable effort was recently expended in determining conversion factors for reliable intercomparison of those data and ones obtained using the Perlman-Asaro analytical standard (Yeh and Harbottle 1981). These factors (Yeh and Harbottle 1981,

Table 9, here reproduced as Table 7-X) can be used to convert analytical data in the BNL bank to a form which is directly comparable to that generated in the present study. For each element the conversion factor incorporates both the oxide gravimetric factor and the ratio (usually within a few percent of unity) of the concentration in Perlman-Asaro standard pottery as determined at BNL to the value quoted by Perlman and Asaro (1971).

Several data sets from the BNL bank have been converted to McGill-compatible form. Some of these have been published; they are reproduced in Appendix B. Bieber et al. (1976b; see also 1976a) have analyzed many Aegean and East Mediterranean samples, among which are Mycenaean sherds from Berbáti in the Argolid and Áyios Stéphanos in Lakonia, and "black-glazed" sherds from Tell el-Hesi in Israel and from Idalion in Cyprus. The presence in the Idalion and Hesi groups of one black-figured and two red-figured sherds points to an Attic origin for both groups, which are compositionally very similar. This link is strengthened by close compositional matches with unpublished analyses of Attic pottery found in the Marseilles area and of a reference group from Athens itself (Fillières 1978). The set of 82 sherds and other ceramic objects from the Sparta area, analyzed at BNL by Attas et al. (1982), forms another strong Greek reference group.

TABLE 7-X: Factors for Conversion Between Analytical
Values Obtained by Using the Six USGS
Rock and Asaro-Perlman Standards*

<u>Element oxide</u>	<u>Conversion factor</u> <u>(element to oxide)</u>
Na ₂ O	1.340
K ₂ O	1.164
Rb ₂ O	0.988
Cs ₂ O	1.050
BaO	1.215
MnO	1.339
CoO	1.217
ZnO	1.586
Sc ₂ O ₃	1.611
Cr ₂ O ₃	1.299
Fe ₂ O ₃	1.437
Sb ₂ O ₃	0.842
La ₂ O ₃	1.240
Sm ₂ O ₃	1.271
Eu ₂ O ₃	1.347
Yb ₂ O ₃	1.261
Lu ₂ O ₃	1.495
CeO ₂	1.215
HfO ₂	0.998
ThO ₂	1.161
Ta ₂ O ₅	1.625

*Data from Yeh and Harbottle (1981, Table 9).

These data were compared to the analyses of Early Helladic material on a sample-by-sample basis using cluster analysis. In order to reduce the burden of computation, the McGill core samples and the other McGill samples were considered separately. Each set was clustered with the entire BNL comparative data set, consisting of 275 analyses, using BMDP2M with the standardization, Euclidean-distance, and centroid-clustering options. The elements used were Na, K, Cs, Ca, Sc, La, Ce, Eu, Hf, Th, Cr, Mn, and Fe. (The Lake Vouliagmeni data, lacking Na and K values, had already been compared extensively with BNL analyses in 1977; the only resemblances found were between members of Vouliagmeni group F and Berbati samples.) To a large extent the BNL and the McGill samples formed distinct clusters, similar to those published by Bieber et al. (1976b, Table IV, pp. 131-133) and those listed in Table 7-III respectively. In most cases links between samples from the two categories took place only at high distance coefficients. There were, however, moderately close correspondences between a few samples from the largest Berbati cluster and samples assigned to clusters N and P. The most telling similarities were between Lerna samples and Lakonian reference material. The samples LER 20 and 27 from the Lerna core were found within the main Lakonian cluster, while LER 18, 19 and 41 resemble samples in that cluster less closely. Among the McGill outliers, LER 22, 25, and 26 on the one hand, and

LER 23 and 30 on the other, were found in two subclusters of the main Lakonian cluster, LER 8 also resembles some Sparta sherds, and LER 21 is associated with the Attic cluster (perhaps only because of its high Cr concentration).

Two interpretations, not necessarily mutually exclusive, can be put forth to account for the numerous analytical links between Lerna and Lakonia. Sherds may have been brought to Lerna from the region of Sparta, or else the clay compositions at the two locations may be very similar. The proximity of the two locations makes both interpretations reasonable. The hearth of which LER 8 is a sample is unlikely to have travelled far (it was too big), as is the sherd it most closely resembles, SPM 6, a fragment of a votive mask typical of the Sanctuary of Artemis Orthia at Sparta. Perhaps the two centres of production of these objects, at least, used clays of very similar composition. Exchange between the two regions, however, is a possible explanation for the other similarities.

8. DISCUSSION OF POTTERY PRODUCTION AND EXCHANGE

8.1 Introduction

Given the constitutions, origins, and distributions of the compositional groups as set forth in chapter 7, what can be said about Early Helladic trade? As was noted in section 1.6, quantitative results are not possible with archaeological material of this nature, but useful qualitative deductions may still be made from the analytical data. The results for the Early Helladic II reference objects - sauceboats and small bowls - are presented first, since those objects form the core of the study. These results also serve as a point of departure for examining the production and exchange of other ceramic material. The provenances of certain special wares are of particular interest because their modes of distribution may have differed from those of the common table ware. The final section examines the bearing of the analytical results on the study of the transition to Early Helladic III at three sites in Argolis and Korinthia.

8.2 Common Early Helladic II table ware

8.2.1 Sauceboats and bowls

The first step in studying the provenance of these objects was the modification of Table 7-VIII to include only Early Helladic II reference material, i.e., the samples of sauceboats and small bowls in the finer paste categories

TABLE 8-I: Attributions and Associations of Early Helladic II Reference

Material: Sauceboats and Small Bowls

<u>Site:</u> <u>Group</u>	<u>KER</u>	<u>KRK</u>	<u>ZYG</u>	<u>PHL</u>	<u>TIR</u>	<u>ASI</u>	<u>LER</u>	<u>VOU</u>	<u>Totals</u>
M	4	4	1						9
N	4 (2)	8	8 (1)	2					22 (3)
O	1 (1)	(1)	2						3 (2)
P	2		3		1		3		9
Q		1	1		16 (1)	4			22 (1)
R						4	2		6
S						1			1
T							3 (1)		3 (1)
U									
V							1	5 (1)	6 (1)
W									
reg.	(1)	(3)	(3)	(4)	(2)	(1)	(3)		(17)
unass.	(2)	(1)	(2)	(2)		(3)	(6)	(1)	(17)
TOTALS	17	18	21	8	20	13	19	7	123

Note: Associated, "regional", and unassigned samples are listed in parentheses.

(Table 8-I). The incidence of high numbers of samples along and near the main diagonal of this table is striking. It implies first of all that the reference samples from a given site belong to a small number of groups, and conversely that each group is made up of samples found at a small number of sites. Except for the position of VOU, the order of the sites is roughly geographical, from north to south. The groups have been labelled to follow this order. The fact that almost every entry is close to the diagonal therefore means that almost every object has been found close to its supposed place of manufacture. Exchanges have taken place over short distances only. The two exceptions among the reference sherds are LER 28, which falls into V, the composition group characteristic of Lake Vouliagméni, and KRK 8, a member of Q, the characteristic Tiryns group.

That certain composition groups are characteristic of certain sites implies that these sites at least were centres of production (or that the centres lay in their immediate geographic vicinity). In fact, all sites in this study with the exception of Phlious and possibly Zygouriés appear to have produced sauceboats and bowls, although differentiation between Keramidhaki and Korá kou productions is not possible. No composition type has been found to be characteristic of Phlious, and Zygouriés reference material includes sherds belonging to five groups, more than any other site (but see below).

Lake Vouliagmeni and Tiryns were the most self-sufficient centres, each producing almost the entirety of its own archaeological reference group. At Tiryns, in fact, no pottery from any of the other Argolid groups (R, S, or T) was among the EH II sherds sampled. In contrast, several group Q (i.e., Tiryns) reference sherds were found at Asine, where material from groups R and S is considered to be local. A couple of the Lerna reference sherds also belong to group R. It seems that Lerna received pottery from a variety of sources (P, R, V) in addition to probably producing its own (group T). Pottery of group Q, however, is conspicuously absent from Lerna.

The proportion of samples in the "regional" and "unassigned" categories varies from site to site and serves as a reminder that ceramic material from only a small fraction of the known Early Helladic II settlements has been sampled. Many other settlements must have produced pottery, some of which would have ended up at our sites. For instance, since six out of the eight Phlious reference objects could not be attributed to a group, it is likely that they were made at production centres elsewhere than at one of these sites. They do not form a coherent group, indicating that several sources may be involved, perhaps including one or more at Phlious itself. A high proportion of unassigned samples is found among the Lerna reference material as well. Three of these samples (LER 22, 25, 26) form a small cluster

(section 7.3.3), similar to the one called LEROUT-B2 in section 6.3.7. The origin of this cluster is not evident. Since Lerna is on the edge of the region being considered, it is quite possible that objects such as these were brought from production centres outside the region. Border sites would of course be more susceptible to this occurrence than centrally-located ones. Group W at Lake Vouliagmeni may also fall into this category.

Because two ceramic forms were used to constitute the archaeological reference groups, it is important to check that similar results are obtained from both of them. It is possible that one production centre might specialize in the manufacture of bowls and another in the manufacture of sauceboats. Examination of the constitution of these reference groups, however, reveals that both the sauceboats and the bowls at every site are divided among the one or more analytical groups represented at that site. The treatment of these two forms in combination is therefore justified.

8.2.2 Ladles

This situation is in marked contrast to that of the ladle samples. Because the semifine paste and Urfirnis slip of many ladle fragments resemble those of the sauceboats and bowls, several samples of ladles had been taken to serve as supplementary reference material. This was the case particularly for Phlious, from which the number of sherds available

for sampling was limited. A glance at Table 8-II shows that 8 of the 12 ladles sampled belong to a single group, namely P. Three of the unattributed ladles are the ones from Keramidhaki and Korakou; the fourth is the only coarse-paste specimen sampled from Phlious. The origins of these four samples are unknown. In contrast, group-P ladles are found at Zygouriés, Phlious, and Asine. At the last two sites, group P is represented only by the ladles, whereas reference sherds and other objects belonging to that composition group are also present at Zygouriés. Even though only a small number of samples is involved, the analyses point to Zygouriés as the origin of the group-P ladles, and by extension, of the rest of group P as well. This agrees with, and therefore supports, the indications of sections 7.2.4 and 7.4.5, which had been reached without considering the archaeological nature of the samples.

This distribution pattern, namely a single production centre supplying three widely-separated sites, is unexpected for an object apparently so simple to manufacture. Since there is evidence that ladles were not used throughout the whole of the Early Helladic II phase, but only in its earlier stages (Blegen 1928, pp. 96-97; Frödin and Persson 1938, p. 224), perhaps the distribution reflects a trade pattern not maintained till the end of EH II. The long duration of that phase means that changes in the pattern of pottery production within EH II would not be surprising.

TABLE 8-II: Attributions and Associations
of Ladle Samples

<u>Sample</u>	<u>Group</u>	<u>Paste</u>
KER 22	reg.	coarse
KRK 29	-	coarse
30	-	fine
ZYG 28	P*	fine
29	P*	semifine
30	P*	semifine
PHL 2	P*	fine
3	P*	semifine
4	(M)	coarse
5	P*	semifine
18	P	medium
ASI 18	P	fine

8.2.3 Changes within EH II

At several sites the stratigraphy and the storage of finds were sufficiently clear that samples could be taken of objects from early and from late deposits within Early Helladic II. Although no exact contemporaneity is claimed between deposits at the various sites, analyses of reference material from the two deposits at each site can be examined for possible changes in composition and attribution. The Zygouriés samples ZYG 21-30 come from one of the earliest deposits there, whereas ZYG 7-20 are objects from a house of the latest EH II occupation. Similarly, at Lerna, LER 12-20 are common sauceboats and bowls from the earliest EH II deposit ("pre-fill") at that site, whereas LER 21-30 come from the House of the Tiles, the final building of the Early Helladic II phase there. In addition, of the three phases sampled at Tiryns, one is definitely EH II, one clearly EH III, and one a Transitional phase falling between the two.

The attributions and associations of these samples can be found in Table 7-VI. Differences between early and late deposits are greatest at Zygouriés. The most frequent attribution of the early objects is P, even if the 3 ladle samples are excluded. Among the late sherds, however, group P is not even represented. Instead N is the predominant group. A significant change in the utilization of clay resources or ceramic products has clearly taken place. The nature,

causes, and implications of this change are unfortunately not so clear. If groups P and N are correctly assigned origins at Zygouriés and on the Korinthian plain respectively, then it appears that Zygouriés was no longer manufacturing sauceboats and bowls at the end of the EH II phase there. Instead they were being imported from some distance to the north. The extent and apparent importance of the EH II settlement at Zygouriés, however, stressed by (among others) Hope Simpson and Dickinson (1979, p. 66), encourage one to think that pottery-making might be a likely activity throughout that phase. Could the clay source used for pottery of group N have been located at some point partway between the Gulf of Kórinthos and Zygouriés, and exploited by both groups of potters? Or was the change rather one of commercial patterns and activity? It is difficult to tell.

At Lerna the data are confusing. Only 9 of the 19 reference samples are assigned to groups, and several groups are represented among the objects of both the early and late deposits. No useful deductions can be made from these results. At Tiryns, on the other hand, the results are straightforward: there was no change in clay exploitation between EH II and the Transitional phase. Both sets of samples, TIR 1-20 and TIR 31-45, belong almost exclusively to the compositional group Q, local to Tiryns.

These comparisons between early and late deposits serve to emphasize that Early Helladic II was a long phase, during

which some changes in pottery manufacturing and distribution patterns doubtlessly occurred. The investigator has only limited control over the chronological factor, however, since it is not yet possible to correlate sub-phases within EH II from site to site. At a given site interesting diachronic variations may be discovered, as they have been at Zygouries, but it is difficult to relate them to trends occurring at other sites. The overall study of EH II trade must remain to a certain extent chronologically imprecise, with the result that diachronic fluctuations in patterns of producing/acquiring pottery at individual sites are averaged out over the period as a whole. The qualitative information obtained on production centres and the distributions of their products is nevertheless both reliable and useful.

8.3 Special wares

8.3.1 Fine slipped-and-polished ware

Fourteen examples of this ware, described in section 4.4, were analyzed. Their attributions and associations are shown in Table 8-III. The only striking feature of that table is the frequent occurrence of unattributed samples: there are seven of them, whereas no more than two samples among the rest are attributed to a single group. Table 7-IX can be consulted to determine which of the unattributed samples are similar. The pair KER 68 and 69, which very probably came from a single sauceboat, of course resemble each other.

TABLE 8-III: Attributions and Associations of the
Fine Slipped-and-Polished Sherds

<u>Sample</u>	<u>Group</u>	<u>Form</u>
KER 68	-	sauceboat
69	-	sauceboat
KRK 16	T	sauceboat
17	T	wall sherd
18	reg.	bowl
TIR 26	N	sauceboat
76	-	? sauceboat (base)
ASI 21	R*	wall sherd
27	-	wall sherd
31	reg.	sauceboat
LER 40	-	sauceboat
VOU 160	-	sauceboat
421	(Q)	bowl
510	-	wall sherd

strongly. Together with them is found the bowl sample ZYG 17, also unattributed. The only other small cluster with samples of this ware is made up of KRK 16 and 17 and ASI 31. The objects in this cluster may have an origin in the Argolid, since the first two samples are attributed to T. The other samples all have different compositions, only a few of which match the inter-site reference groups. This implies that many centres produced vases of this ware, and that most of these centres (or at least their clay sources) are not ones included in this study. Perhaps the major production centres were located outside the region covered, with a small proportion of imitations having been fashioned within the region. In any case it appears that the technical expertise required to make fine slipped-and-polished ware was not so esoteric as to be restricted to one or two specialized centres of production, as was postulated in section 4.4.

8.3.2 Animal representations

The ten samples of figurines, animal-shaped vases, and vases with animal-shaped handles or spouts present a varied set of provenances (Table 8-IV). The ram-vase and fish-vase from Lake Vouliagméni were both made with local clay. Groups M and N are represented by quadruped figurines from Keramidhaki and Corinth. The animal-head handle from Phlious and the two Zygouriés sauceboats with ram's-head spouts are all unattributed. It was unfortunately not possible to

TABLE 8-IV: Attributions and Associations of the
Animal Representations

<u>Sample</u>	<u>Group</u>	<u>Type</u>
VOU 108	V* *	ram-vase
114	V*	fish-vase
KER 65	(N)	quadruped
66	N*	quadruped
KOR 1	M*	quadruped
2	-	ram
PHL 1	-	animal head
ZYG 1	-	sauceboat with ram's-headed spout
2	-	sauceboat with ram's-headed spout
LER 49	P	ram

sample the similar examples from Tiryns (Müller 1938, pl. V). Finally, the ram figurine LER 49, which resembles so strongly KOR. 2 (unattributed) from ancient Corinth, belongs to group P. As with the slipped-and-polished sherds, it seems that many production centres were involved.

8.3.3 Unusual sauceboats

The sauceboat is the EH II vase form which shows the widest variety in surface treatment and decoration. The analyses of fine slipped-and-polished sauceboats have been discussed in section 8.3.1, and of ones with ram's heads in section 8.3.2. Three other sampled sauceboats are painted with diagonal strokes or hatched triangles around the inside of the rim: KER 67, KOR 3, and PHL 10. These are respectively attributed to P, unattributed, and of regional (i.e., general Argolic/Korinthian) composition (Table 7-VI). Two more bear applied strips of clay periodically indented to give a "piecrust" effect: LER 11, associated with S, and KOR 4, of regional composition (and a member of Keramidhaki cluster E of section 6.2.2). The sauceboat fragment ZYG 3, decorated with rows of short impressed dashes, belongs to group P and so is likely to be a local Zygouriés product. On the other hand, ZYG 4, the tall neck fragment of a closed vase with a spout in the form of a sauceboat, is chemically most similar to the Tiryns group Q. Finally, a high foot is rarely found on a sauceboat (or other EH II form, for that matter) from

the Peloponnese, but several have been sampled, not all definitely from sauceboats. KRK 3 and 4 and KER 68 all have unusual compositions and so are left unattributed, but ZYG 24 belongs to group N. It might have been possible to say if any of these objects had been imported from central Greece, where high bases are more common (Weinberg 1937, p. 518 note 3), had analytical reference groups been available from that region.

8.3.4 Coarse wares

8.3.4.1 Introduction

Samples of coarse-paste vases were taken because it was hoped that they would provide additional data to establish reference compositions for each site. It was expected that the larger domestic pots had been made not far from their place of use and, ultimately, their findspot. It now appears, however, that the distorting effect of temper is sufficient to obscure the connection between the coarse and the fine wares produced at a single site. This, at least, is a more acceptable hypothesis than the one that all the coarse wares were made at a completely different set of production centres in Argolis and Korinthia or elsewhere. In any case, for sites from which both fine and coarse wares were sampled in quantity (Keramidhaki, Korakou, Lerna), the majority of the coarse-ware samples did not have compositions which fit the analytical reference composition(s) for that

site (see chapter 6). Lake Vouliagmeni is the exception. The proportion of unattributed and regionally-attributed VOU samples is low compared to those at other sites (Table 7-VIII), even though many of the objects sampled had coarse or medium pastes. Perhaps this occurs because at that site the paste appears, on the average, to be coarser than at other sites, even for archaeological reference material. Another possible explanation is that in Lake Vouliagmeni pottery the inclusions or temper have a composition more similar to the clay matrix than is the case at other sites.

This second hypothesis corresponds to the second possible effect of addition of temper, discussed in section 2.3. It has not been observed at any other site. Neither has the first possible effect; namely, a proportional decrease in elemental concentrations caused by dilution of the ceramic paste with inert (i.e., relatively pure) tempering material. This was discussed explicitly in section 6.3.5 with regard to the Tiryns group U, and checked in samples from other sites as well. Had the temper consisted of pure quartz or calcite, the dilution effect would have been evident. The presence of a more complex material would distort the concentration values too greatly to permit a mathematical reconstruction of the untempered clay's composition (unless the inclusions could be separately analyzed; see section 9.2).

The analyses of coarse-paste material nevertheless serve to organize these objects into groups of similar composition

(and thus provenance). The nature of some of the objects is such that a knowledge of their provenance or at least their compositional cousins would be interesting. The remainder of section 8.3.4 deals with these objects under the categories of decorated vases, domestic objects, and construction material.

8.3.4.2 Decorated vases

Two sampled sherds from pithoi (large storage jars) bear impressions from a roll stamp. In fact, ZYG 6 and LER 7 have been decorated using the same stamp, since even the flaws in the impressions are identical. Caskey (1959, p. 206) has hypothesized that an itinerant potter made both pithoi (as well as one found at Tiryns, for which permission to sample could not be obtained) using the locally-available clay in each case. This hypothesis is supported by the analyses, which attribute ZYG 6 to group P and LER 7 to group R. Group P is closely associated with Zygouries, while group R has connections with both Asine and Lerna (see section 7.4.7).

The origins of the discoid ceramic objects known as "frying pans" had been investigated in the earlier study of Lake Vouliagmeni material (Attas 1975, p. 101). Three of them, VOU 608, 611, and 612, belonged to VOU-R, so it follows that they are now found in the corresponding group, namely W. The sample VOU 601, which had been contaminated by drilling,

is now also attributed to group W. VOU 607, previously part of VOU-F, is here designated "regional", as are many of the other VOU-F members. (All the sampled Vouliagméni pans come from Early Helladic I levels there.) From sites other than Lake Vouliagméni, only one pan was sampled: KRK 35. It is not associated with any group. Since the origin of group W is not known (section 7.4.12), it is possible to say only that most of the sampled frying pans have a common origin.

Several other coarse vases bear unusual decoration. KER 60 and 61 are two sherds, probably from the same vase, with applied clay strips zigzagging across the exterior. Since they resemble a vase found at Eutresis (Goldman 1931, p. 105 fig. 139), a Boiotian (i.e., different) composition would not be unexpected, but instead they belong to group N. KRK 36 closely resembles a vase illustrated by Blegen (1921, p. 5 fig. 3 no. 7) in its pattern of lustrous black slip and bands of incised rope decoration. It has a regional composition. Two sauceboat sherds, LER 11 and KOR 4, have coarse pastes; as stated in section 8.3.3, they are respectively associated with S and of regional composition.

8.3.4.3 Domestic objects

The compositions of four types of objects are discussed under this heading: "baking pans", "fire-dogs", weights, and hearths. Their forms have been described in section 4.5.1. Apart from VOU 105, local to Lake Vouliagméni, none of the

six pans sampled was attributed to a group. Instead, KRK 31 and 32 are of regional composition, while KRK 33 and KER 45 and 62 remain unattributed. KRK 33 is a member of the multi-site cluster (Table 7-IX) which corresponds to the original Keramidhaki cluster E (section 6.2.2). The last two formed a separate cluster in those analyses. Their similarity had been noted in section 6.2.7, where their unusual temper was characterized as "sand?" by eye but "abundant glass" by petrographic observation. These are the only two pan sherds of this study with paste of that appearance.

The situation of the 3 sampled fire-dogs is analogous, with KER 23 and 26 forming a cluster but KER 27 staying a member of the original cluster E. None of them is attributed to any of the inter-site groups.

The two sampled weights, KRK 37 and PHL 14, resemble neither each other nor any of the groups. The sample most similar to KRK 37 is KRK 48, some soil taken from the plugged holes of KRK 37. It is therefore likely that the unfired KRK 37 is a local Korakou product made with earth not resembling (or not treated the same way as) the potter's clay(s) used in that region.

The situation of the three sampled hearths from Lerna (LER 8, 9, 10) is analogous to that of the weights. They resemble neither any of the groups nor each other.

8.3.4.4 Construction material

Construction material was sampled as an aid to forming reference groups which could be attributed without question to specific sites. This approach was successful for Lake Vouliagméni and Asine. In both cases clay samples (VOU 010-016; ASI 22) and mud-brick samples (VOU 201-206; ASI 1-6) could be used to link groups V and S respectively to these sites. The single mud brick ASI 5, which is a member of group R, supports an origin at Asine for that group. Analyses of similar samples at Lerna, however, were of no help. Neither the clay LER 1 nor the mud bricks LER 5 and 6 matched any of the reference groups. LER 6 did fall into the same cluster as LER 31, 32, and 34, three of the five clay sealings from the House of the Tiles. These 4 objects are judged, therefore, to have been fashioned from locally-available earth. This earth may have been used for the other two sealings as well, since large variations in its composition are to be expected. LER 33 at least resembles the others if the dilution caused by its extra lime content (Ca concentration of 25% against about 4% for the others) is taken into consideration (Attas 1980, p. 69). Three tiles from the House of the Tiles, LER 2, 3, and 4, were again different in composition. At Lake Vouliagméni, in contrast, both the single tile sampled (VOU 115) and the single sealing found (VOU 113) could be attributed to the local group.

8.4 The transition to Early Helladic III

Early Helladic III sherds were sampled from three sites: Korá kou, Lerna, and Tiryns. Two patterns are apparent from a rapid inspection of the attributions. At Korá kou and Lerna the EH III sherds fell into a number of different groups, many of them made up primarily of EH II material (Table 8-V). At Tiryns a separate cluster, U, of primarily EH III objects has been formed. Closer examination reveals that the situation is more complex, as the sampling criteria were not comparable in the two cases.

Two styles of pattern-painted ware were produced in the Early Helladic III period: dark-on-light and light-on-dark. The first is said to be more common in the Peloponnese, the second in central Greece (see Donovan 1961 and section 4.3.2). LER 46, the only Lerna sherd painted in the light-on-dark style, is also the only pattern-painted sherd left unassigned. Among the other pattern-painted sherds sampled from Lerna and Korá kou, groups N, O, P, Q, U, and (S) are represented. Surprisingly, it is the two Korá kou sherds KRK 45 (dark-on-light) and KRK 47 (light-on-dark) which belong to Tiryns groups (U and Q respectively), while LER 42 and 43 belong to the Korinthia groups N and O respectively. In fact KRK 47 is found in the same cluster (of Table 7-IX) as ZYG 4 and 27 and TIR 1, 11, 33, and 42, a subcluster of the main Tiryns compositional group. Both KRK 46 (the other light-on-dark sherd sampled from Korá kou) and KRK 43 belong to group P.

TABLE 8-V: Attributions and Associations of Early
Helladic III and EH II/III Transitional
Samples from Tiryns, Lerna, and Korá kou

<u>Pattern-painted ware</u>			<u>Polished bowls</u>	
LER 42	N	dark-on-light	LER 41	T*
43	O	"	47	R*
44	reg.	"	48	(S)
45	(S)	"	TIR 79	reg.
46	—	light-on-dark	80	(R)
KRK 42	N*	dark-on-light	81	reg.
43	P	"	82	R
44	N	"	83	—
45	U	"	84	reg.
46	P	light-on-dark		
47	Q	"		
<u>Other Tiryns EH III samples</u>			<u>Tiryns Transitional EH II/III samples</u>	
TIR 56	U*	jar	TIR 31	Q* bowl
57	U*	"	32	Q* "
58	(U)	"	33	Q "
59	U*	"	34	Q* "
60	(U*)	"	35	Q* "
61	U*	"	36	Q* "
62	U*	"	37	Q* "
86	U*	"	38	U* "
75	Q*	? sauceboat	39	Q* "
76	—	"	40	Q* "
77	U*	sauceboat	41	Q* sauceboat
85	Q*	plain bowl	42	Q "
87	U	painted bowl	43	Q* "
88	U*	" "	44	Q* "
			45	Q* "
			70	— pyxis
			73	Q* ouzo cup
			74	Q* " "

In short, there is evidence for a number of production centres in both the Argolid and Korinthia, decorating EH III vases in both pattern-painted styles. The unusual composition of LER 46 indicates that importing of light-on-dark-painted pots may also have taken place.

Polished grey bowls are another ceramic type characteristic of EH III at Lerna and other sites (Caskey 1960, p. 286). Three of these were sampled from Lerna: LER 41, 47, and 48. They were assigned on the basis of their compositions to groups T, R, and (S) respectively. The Tiryns samples TIR 79-84 are also sherds of this ware. Except for TIR 83, which remains unassigned, they were all of regional composition, including one attribution to and one association with group R. TIR 79, 80, and 82 are particularly similar (Table 7-IX). Almost all the examples found at these sites, then, need not have come from outside the Argolid.

Examples of several other EH III wares were sampled at Tiryns. The jars covered with a thin brown or black slip are the most numerous of these. TIR 56-62 and 86 are all attributed to or associated with group U. In fact they constitute just over half of the group's members. The link between U and Tiryns is thus well-established (see section 7.4.10). Several more Tiryns samples, all from EH III or Transitional deposits, belong to this group. TIR 87 and 88, two bowl rims with painted decoration on their broad lips, are among these. Also included are the Transitional (EH II-

style) bowl rim TIR 38 and the sauceboat rim TIR 77, from an EH III level. Two other EH III sherds (TIR 75 and 76), probably sauceboat bases, are respectively attributed to Q (the main EH II Tiryns group) and unattributed. TIR 85 is the rim of an EH III plain bowl also attributed to group Q. In fact, almost all of the Transitional sherds belong to that group. Most of these are EH II-style sauceboats and bowls (TIR 31-45), but the two EH III-style "ouzo cups" (TIR 73 and 74) are also members. The only Transitional sherds not members of Q are TIR 38, mentioned above, and TIR 70, a pyxis fragment suspected of being a Cycladic import (H.-J. Weisshaar, personal communication 1980). The composition of the pyxis is unlike any others encountered in this study.

We may summarize the results concerning the EH III samples. Pattern-painted sherds sampled at Korakou and Lerna have mixed, but almost entirely regional origins. At Tiryns, sampled sherds from the EH II/III Transitional phase (sauceboats, bowls, and "ouzo cups") belong to the same group as the majority of the EH II sherds, namely Q. No pattern-painted sherds from Tiryns were sampled, but the brown-slipped jars of the EH III phase belong to group U, apparently characteristic of that phase at Tiryns. Polished grey bowls of that phase, however, do not belong to group U, having a variety of regional compositions instead. This evidence, admittedly based on a small number of samples,

suggests that at Tiryns the changes in pottery production/ acquisition patterns which accompanied the beginning of the third Early Helladic phase were more extensive than those at Lerna or Korá kou.

9. CONCLUSIONS

9.1 Summary and contribution to knowledge

A study has been made of ceramic trade in Early Bronze Age Greece. Powdered samples were taken from 255 objects of the Early Helladic (or EH) II and III periods found at Keramidhaki, Korakou, Phlious, Zygouriés, Tiryns, and Asine in the provinces of Korinthia and Argolis. Instrumental neutron activation analysis was used to determine, with respect to the Perlman-Asaro standard pottery, the concentrations in these samples of the elements Na, K, Rb, Cs, Ca, Al, Sc, La, Ce, Eu, Yb, Th, Ti, Hf, V, Cr, Mn, Fe, and Co. Analytical data from previous studies of pottery found at two other sites in the same region, Lerna and Lake Vouliagmeni (Perakhóra), were included in the data-interpretation phase. Multivariate methods, including cluster analysis and stepwise discriminant analysis, were used to form and compare analytical reference groups and to assign other samples to these groups. The distributions of selected pottery types were used to propose centres of production for many of these groups.

The following inferences could be made from these distributions.

1. Ordinary EH II table ware (sauceboats and small bowls) was produced at all the sites in this study except perhaps Phlious.

2. Distributions of these vases among the sites studied extended in most cases from each production centre only to the neighbouring sites.
3. Some variations in the distribution patterns within the EH II phase are evident at Zygouriés.
4. Ceramic ladles, characteristic of the earlier part of that phase, seem to have had fewer centres of production, among which one at or near Zygouriés figured prominently.
5. Samples of various special wares from EH II levels, including slipped-and-polished sherds, animal representations, and pattern-painted and other unusual sauceboats, often had compositions different from those of the table wares. They were therefore made of different clays, probably at different production centres within or outside the region studied.
6. Coarse wares in general (except those at Lake Vouliagmeni) could not be attributed to production centres, but in their case it is likely that the added temper has distorted the compositions too greatly to allow reliable attributions to be made.

Analytical data were produced for EH III material from Korákou, Lerna, and Tiryns, with the following implications.

7. Pattern-painted sherds sampled at Korákou and Lerna have mixed, but almost entirely regional origins.
8. At Tiryns, sampled sherds from the EH II/III Transitional phase belong to the same group as the majority of the

EH II sherds.

9. Brown-slipped jars at Tiryns belong to a separate group, apparently characteristic of the EH III phase there.
10. Polished grey bowls of that phase at Tiryns and Lerna, on the other hand, do not belong to that group but have a variety of regional compositions.
11. This evidence, admittedly incomplete, suggests that at Tiryns the changes in pottery production/acquisition patterns which accompanied the beginning of the EH III phase were more extensive than those at Lerna or at Korakou.

9.2 Suggestions for future research

This project could be extended in several directions. The geographical coverage could be broadened to include EH II sites to the north, in Boiotia and Phokis; to the east, in Aigina and Attica; to the south-west, in Arkadia, Lakonia, and the rest of the Peloponnese; and to the south-east, in the Cycladic islands. This would reduce the proportion of "border" sites (see section 8.2.1), which would be more likely than "central" sites to receive imports from sources outside the region under consideration. Even within Argolis and Korinthia it should eventually be possible to obtain permission to sample material from more sites, thereby potentially improving the short-range aspect of this trade study. A study on that scale would require certain improve-

ments in methodology. Specifically, larger numbers of reference samples would be needed (resembling the selection from Tiryns, sampled in 1980, when the methodology was more developed than it had been in 1977, the year when most of the samples were taken). In fact, more samples of every kind would lead to more secure statistical arguments and more reliable conclusions. One aspect deserving of particular consideration is the linking of chemical reference groups to specific locations. The analysis of modern clay samples has occasionally been useful in this respect (e.g., at Asine and Lake Vouliagméni) and should be continued where possible. One approach that has not yet been tried is the analysis of kiln débris. Although no Early Helladic kilns are known, material from later periods may be available, and would provide firm links between composition types and specific production centres, perhaps applicable backwards to the EH II phase as well.

The extension of the study of regional exchange to earlier and later periods is also feasible. The commercial history of a few sites where habitation continued over a long time-span could be examined through analysis of pottery from successive strata. The degree of similarity between the patterns of trade during the three phases of the Early Helladic period is of particular interest. A problem which has recently stimulated much discussion (see section 4.2) is the nature of the transition between EH II and EH III.

Tracing the origins of the new pottery types which appear abruptly in the archaeological record at sites along the east coast of Greece and in the Cycladic islands is a task to which provenance determination by chemical analysis is well-suited. The forms, surface treatments, and pastes are at present undergoing careful study (Rutter 1979; Barber and MacGillivray 1980), so that typological evidence can be used to full advantage in selecting the samples and interpreting the results. Key sites include Lerna, Ayía Marina in Phokis, Lefkandí in Euboia, Ayía Iríni on Kéa, and other Cycladic settlements. At each one the local reference composition(s) would need to be determined and compared to the compositions of the various Early Helladic and Early Cycladic II wares.

The final set of extensions to this work may ultimately be the most important. These are the technical studies; i.e., verifications of, and improvements to, different aspects of the method of provenance determination itself. While various tests have been made of certain assumptions of the method (detailed in chapter 2), there is a need for more comprehensive research into the validity of these assumptions under a variety of conditions. Careful work is now being carried out to verify some of these by the Collegium Archaeometricum, a team at the University of Toronto. Tests of the effect on pottery of heat (Franklin and Hancock 1979) and of simulated burial (Franklin and Hancock 1981; Ajdacic

and Franklin, personal communication 1981), as well as the influence of different sample sizes on analytical results (Hancock 1982) have already been carried out. Close contact with groups such as this one, in order to choose priorities and to avoid duplication of effort, would seem to be the most efficient route to making these verifications.

One technical consideration of particular interest to this researcher is the distribution of the elements within the ceramic paste. Heterogeneity on different scales such as between surface and core or between inclusions and matrix produces distortions and uncertainties in the analytical results to ranging degrees. Methods of chemical imaging and magnification, such as X-ray fluorescence analysis using a scanning electron microprobe, X-radiography, neutron activation autoradiography, and low-energy gamma radiography with microchannel plates, should provide information with high spatial resolution on elemental distributions within selected sherds. The effect of temper in particular could be investigated more directly as well, by mechanical or magnetic separation of the grains from carefully crushed sherds, using methods similar to those employed in preparing ceramic samples for thermoluminescence measurements. An understanding of these effects might permit the application of mathematical transformations to the concentration data in order to reduce or eliminate the influence of added temper or natural inclusions on the grouping procedures. Study of

the correlations between elemental concentrations should play a large part in developing these mathematical techniques.

Archaeometry is a youthful discipline; it is fortunate that with youth come the boundless energy and confidence necessary to meet the many challenges that face us.

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APPENDIX A: Analyses of Early Helladic pottery

The samples are listed alphabetically by site name. The concentration (in ppm or per cent, as noted) of each element in each sample is followed by the value of the imprecision arising from counting statistics only, expressed as $\pm 1\sigma$.

Elements enclosed in parentheses represent less-precise determinations or ones which may be unreliable (see text).

The cobalt and tantalum concentrations have been corrected for drill-bit contamination.

Zero entries indicate either elements not determined (by GANOS or in the earlier McGill work) or concentrations below detection limits.

SAMPLE	AL (X)	MG (X)	CA (X)	V (PPM)	TI (X)	(NA) (X)	NA (X)	K (X)	MN (PPM)
ASI 1	0.00	0.00	0.0	0.0	0.0	0.00	0.820	1.50	789.
ASI 2	0.00	0.00	0.0	0.0	0.0	0.00	0.731	1.52	750.
ASI 3	0.00	0.00	0.0	0.0	0.0	0.00	0.742	1.60	794.
ASI 4	0.00	0.30	0.0	0.0	0.0	0.00	0.820	1.70	853.
ASI 5	0.00	0.00	0.0	0.0	0.0	0.00	0.762	2.41	927.
ASI 6	5.71	0.03	2.1	0.3	2.7	0.03	0.700	1.81	760.
ASI 7	10.83	0.05	1.9	0.3	2.9	0.02	1.130	2.82	990.
ASI 8	9.00	0.05	2.7	0.3	10.7	0.03	1.420	1.00	1100.
ASI 9	8.24	0.05	2.8	0.3	10.5	0.03	0.460	2.73	990.
ASI 10	8.32	0.04	2.7	0.3	1.2	0.1	1.140	2.88	530.
ASI 11	7.97	0.04	2.4	0.3	6.2	0.2	0.780	0.10	1170.
ASI 12	7.71	0.04	2.1	0.3	3.1	0.2	0.280	2.39	1331.
ASI 13	0.00	0.00	0.0	0.0	0.0	0.0	0.947	2.07	762.
ASI 14	0.00	0.00	0.0	0.0	0.0	0.0	0.667	1.96	782.
ASI 15	7.18	0.04	2.6	0.4	5.4	0.2	0.870	2.75	754.
ASI 16	6.54	0.04	2.6	0.4	6.9	0.2	0.730	2.29	1035.
ASI 17	0.00	0.00	0.0	0.0	0.0	0.0	0.686	2.17	1015.
ASI 18	7.19	0.04	2.0	0.4	11.3	0.3	0.460	2.28	825.
ASI 19	0.00	0.00	0.0	0.0	0.0	0.0	1.023	2.57	906.
ASI 20	8.14	0.04	2.2	0.4	0.5	0.1	1.090	3.13	544.
ASI 21	7.19	0.04	3.0	0.4	8.9	0.3	0.870	2.67	951.
ASI 22	0.00	0.00	0.0	0.0	0.0	0.0	1.346	1.68	797.
ASI 24	8.42	0.06	2.6	0.3	3.5	0.2	1.166	2.93	669.
ASI 25	8.37	0.07	2.2	0.3	2.0	0.1	1.086	2.94	707.
ASI 26	7.86	0.06	2.2	0.3	7.1	0.3	0.868	2.47	968.
ASI 27	9.16	0.06	1.2	0.3	0.5	0.1	0.340	1.82	1517.
ASI 31	9.29	0.08	2.3	0.4	4.6	0.3	0.703	3.97	870.
ASI 32	7.28	0.06	2.4	0.3	2.8	0.2	0.991	2.30	768.
ASI 33	8.23	0.06	2.8	0.3	0.9	0.1	1.234	2.73	736.
ASI 34	7.38	0.06	2.3	0.3	9.5	0.3	0.857	2.36	1013.
ASI 35	7.20	0.06	2.5	0.3	11.0	0.3	0.666	2.21	974.

SAMPLE	(U)	(PFM)	(SC)	(PFM)	W (PPM)	LA (PPM)	(EM)	(PPM)	YB (PPM)	(LU)	(PPM)	AS (PPM)	(SB)	(PPM)				
ASI 1	0.0	0.0	0.0	0.0	34.	5.	25.9	C.5	5.7	0.2	2.7	0.5	0.23	0.05	10.8	1.1	0.00	0.00
ASI 2	0.0	0.0	0.0	0.0	22.	3.	24.2	C.5	1.1	0.2	2.1	0.5	0.27	0.05	5.0	1.0	0.00	0.00
ASI 3	0.0	0.0	0.0	0.0	25.	4.	25.3	C.5	4.0	0.2	2.6	0.5	0.31	0.05	8.1	1.0	0.00	0.00
ASI 4	0.0	0.0	0.0	0.0	17.	3.	27.0	C.5	5.1	0.2	4.0	0.6	0.32	0.05	4.8	1.1	0.00	0.00
ASI 5	0.0	0.0	0.0	0.0	28.	4.	29.1	C.5	5.6	0.2	3.0	0.5	0.29	0.05	6.5	1.1	0.00	0.00
ASI 6	1.6	0.6	0.0	0.0	4.	1.	27.3	C.4	4.8	0.1	2.8	0.4	0.42	0.17	4.7	0.9	0.70	0.20
ASI 7	1.1	0.4	0.0	0.0	126.	3.	15.2	C.5	4.2	0.1	2.7	0.4	0.41	0.11	5.9	1.0	0.34	0.16
ASI 8	2.6	0.8	0.0	0.0	12.	1.	33.7	C.6	5.2	0.1	3.1	1.1	0.36	0.11	2.4	0.6	0.50	0.19
ASI 9	2.8	0.6	0.0	0.0	26.	1.	34.1	C.4	4.7	0.1	2.6	0.3	0.46	0.08	7.7	0.8	0.64	0.12
ASI 10	2.1	0.4	0.0	0.0	40.	1.	35.7	C.6	5.1	0.1	2.1	0.4	0.44	0.12	4.1	0.8	0.91	0.22
ASI 11	2.5	1.1	0.0	0.0	45.	1.	35.4	C.5	5.5	0.1	3.2	1.1	0.43	0.13	9.4	1.1	0.48	0.21
ASI 12	1.7	0.6	0.0	0.0	29.	1.	44.2	C.4	7.0	0.1	3.3	0.4	0.51	0.11	15.3	1.0	0.78	0.14
ASI 13	0.0	0.0	0.0	0.0	22.	3.	35.9	C.6	3.5	0.2	3.3	0.6	0.38	0.06	3.6	1.2	0.00	0.00
ASI 14	0.0	0.0	0.0	0.0	33.	5.	29.9	C.5	7.6	0.2	3.0	0.5	0.31	0.05	2.5	1.0	0.00	0.00
ASI 15	1.9	0.8	0.0	0.0	31.	1.	31.7	C.5	5.2	0.1	1.8	0.3	0.37	0.11	2.7	0.7	0.42	0.16
ASI 16	1.5	0.3	0.0	0.0	23.	1.	28.2	C.4	4.9	0.1	2.4	0.4	0.44	0.12	5.2	0.9	0.50	0.17
ASI 17	0.0	0.0	0.0	0.0	37.	5.	25.4	C.5	9.9	0.2	2.7	0.5	0.36	0.05	4.0	1.0	0.00	0.00
ASI 18	2.5	0.4	0.0	0.0	9.	1.	32.8	C.4	5.6	0.1	2.4	0.2	0.50	0.09	4.3	0.8	0.55	0.12
ASI 19	0.0	0.0	0.0	0.0	20.	3.	32.5	C.6	7.0	0.2	2.8	0.5	0.38	0.05	7.0	1.2	0.00	0.00
ASI 20	2.7	0.6	0.0	0.0	68.	2.	37.4	C.1	6.0	0.1	2.6	0.3	0.51	0.09	5.8	0.7	0.80	0.14
ASI 21	1.9	0.7	0.0	0.0	9.	1.	30.8	C.1	4.6	0.1	2.4	0.3	0.43	0.08	7.9	0.9	0.40	0.11
ASI 22	0.0	0.0	0.0	0.0	12.	2.	22.9	C.6	5.7	0.2	2.7	0.5	0.22	0.05	7.7	1.4	0.00	0.00
ASI 24	2.0	0.5	22.0	0.4	160.	4.	35.5	C.6	5.2	0.2	2.9	0.8	0.42	0.14	5.1	0.8	0.64	0.18
ASI 25	2.9	1.1	20.8	0.4	225.	4.	32.4	C.4	4.6	0.4	3.0	0.4	0.20	0.17	5.0	0.6	0.65	0.21
ASI 26	2.6	0.5	20.6	0.4	173.	4.	36.7	C.3	4.8	0.3	2.5	0.4	0.33	0.14	13.6	1.1	1.12	0.19
ASI 27	3.2	0.5	21.9	0.2	157.	2.	35.0	C.3	5.1	0.2	3.8	0.3	0.61	0.12	15.6	0.7	1.35	0.14
ASI 31	2.5	0.6	23.4	0.7	52.	2.	46.9	C.8	6.2	0.2	2.6	0.6	0.57	0.22	8.1	0.6	0.94	0.43
ASI 32	2.2	0.5	20.1	1.1	78.	2.	35.0	C.5	5.6	0.2	2.6	0.4	0.27	0.14	11.8	1.0	1.14	0.21
ASI 33	3.9	1.2	20.3	0.5	174.	3.	35.9	C.6	4.2	0.4	3.3	0.5	0.01	0.18	8.9	0.8	0.90	0.25
ASI 34	1.9	0.7	21.2	0.4	100.	3.	33.4	C.5	5.9	0.3	2.0	0.3	0.40	0.16	7.4	0.9	0.88	0.21
ASI 35	2.2	0.7	20.0	0.4	30.	1.	32.8	C.5	4.8	0.2	2.4	0.4	0.32	0.12	12.3	1.4	0.87	0.19

SAMPLE	RB (PPM)		CS (PPM)		(EA) (PPM)		SC (PPM)		CE (PPM)		EU (PPM)		TH (PPM)	
ASI 1	133.	54.	3.9	0.9	0.	0.	16.1	0.1	56.3	2.0	1.07	0.11	7.5	0.8
ASI 2	38.	33.	3.0	0.8	0.	0.	15.6	0.1	49.1	2.0	0.85	0.09	7.1	0.8
ASI 3	157.	61.	2.0	0.8	0.	0.	16.4	0.1	61.5	2.1	0.92	0.10	8.3	0.8
ASI 4	124.	52.	2.7	0.8	0.	0.	15.4	0.1	56.0	2.1	1.00	0.10	8.4	0.8
ASI 5	99.	48.	3.0	1.0	0.	0.	19.2	0.1	56.5	2.2	1.29	0.12	8.7	0.8
ASI 6	66.	7.	3.4	0.8	0.	0.	16.4	0.2	70.1	4.2	1.06	0.09	7.1	0.2
ASI 7	71.	9.	5.4	0.8	0.	0.	28.2	0.1	32.3	1.4	1.35	0.12	2.9	0.2
ASI 8	104.	49.	5.8	0.5	0.	0.	22.5	0.1	74.9	3.5	1.12	0.09	8.2	0.3
ASI 9	162.	9.	8.3	0.5	0.	0.	23.9	0.1	78.2	2.0	1.06	0.09	8.3	0.3
ASI 10	152.	8.	6.4	0.5	0.	0.	19.8	0.1	97.7	3.6	1.36	0.11	10.4	0.3
ASI 11	137.	9.	6.9	1.1	0.	0.	20.7	0.2	88.4	4.2	1.36	0.11	8.8	0.3
ASI 12	140.	11.	7.7	0.5	0.	0.	22.6	0.1	100.0	2.2	1.71	0.12	10.1	0.3
ASI 13	152.	62.	6.9	1.1	0.	0.	19.3	0.1	75.5	2.4	1.18	0.11	10.1	0.9
ASI 14	116.	51.	6.5	1.0	0.	0.	17.5	0.1	60.3	2.1	1.32	0.12	9.4	0.8
ASI 15	148.	9.	9.5	0.8	0.	0.	20.5	0.1	77.0	1.8	1.21	0.10	8.5	0.3
ASI 16	103.	8.	4.8	0.8	0.	0.	16.5	0.2	64.3	3.5	1.07	0.08	6.8	0.2
ASI 17	165.	65.	3.5	0.9	0.	0.	18.9	0.1	55.7	2.2	0.98	0.10	8.2	0.8
ASI 18	131.	10.	10.4	1.4	0.	0.	19.3	0.1	61.9	3.3	1.17	0.11	8.0	0.4
ASI 19	99.	48.	5.2	1.0	0.	0.	15.9	0.1	59.9	2.2	1.08	0.11	10.5	0.9
ASI 20	145.	14.	6.5	0.4	0.	0.	17.5	0.1	67.4	2.4	1.13	0.07	10.0	0.2
ASI 21	106.	22.	5.4	0.6	0.	0.	20.2	0.1	71.9	4.2	1.19	0.12	7.2	0.3
ASI 22	96.	44.	2.8	0.8	0.	0.	15.0	0.1	47.4	1.9	0.90	0.10	7.8	0.8
ASI 24	116.	15.	6.1	0.6	0.	0.	21.9	0.1	80.5	3.1	1.31	0.11	9.1	0.5
ASI 25	127.	8.	6.7	0.6	0.	0.	20.3	0.1	79.2	2.6	1.11	0.12	8.3	0.2
ASI 26	105.	11.	4.3	0.4	0.	0.	20.4	0.1	66.5	6.3	1.14	0.08	8.6	0.4
ASI 27	122.	14.	7.1	1.1	0.	0.	22.2	0.1	95.7	5.6	1.85	0.10	11.6	0.5
ASI 31	206.	24.	9.3	1.7	0.	0.	23.7	0.2	87.2	3.7	1.41	0.13	9.9	0.6
ASI 32	128.	12.	6.4	0.5	0.	0.	19.5	0.1	80.9	2.6	1.34	0.29	8.8	0.3
ASI 33	133.	15.	6.6	1.1	0.	0.	20.7	0.1	94.7	5.7	1.03	0.08	10.8	0.5
ASI 34	96.	14.	4.6	0.4	0.	0.	20.4	0.1	76.3	2.8	1.28	0.09	8.5	0.4
ASI 35	86.	29.	3.9	0.4	0.	0.	19.5	0.1	78.4	2.4	1.30	0.10	7.9	0.4

SAMPLE	HF (PPM)	(TA) (PPM)	CR (PPM)	FE (X)	CO (PPM)	(NI) (PPM)	SB (PPM)
ASI 1	4.0	0.5	1.02	0.37	438.	26.	4.21 0.12 27.2 0.9 0. 0. 0.00 0.00
ASI 2	4.2	0.5	0.38	0.32	555.	32.	3.96 0.11 28.1 0.9 0. 0. 0.00 0.00
ASI 3	5.1	0.6	1.14	0.39	474.	28.	4.28 0.12 29.4 0.9 0. 0. 0.00 0.00
ASI 4	5.3	0.6	0.44	0.33	489.	28.	4.08 0.12 30.9 0.9 0. 0. 0.00 0.00
ASI 5	4.0	0.6	0.97	0.35	332.	20.	5.13 0.14 32.1 1.0 0. 0. 0.00 0.00
ASI 6	5.0	0.5	0.72	0.11	577.	10.	4.39 0.04 26.5 0.4 183. 59. 0.53 0.12
ASI 7	3.9	0.8	0.23	0.10	31.	4.	6.22 0.06 17.6 0.5 0. 0. 0.61 0.17
ASI 8	4.2	0.5	0.98	0.14	261.	9.	5.23 0.05 31.0 0.5 121. 39. 0.47 0.15
ASI 9	3.8	0.6	0.63	0.05	328.	10.	5.46 0.04 32.3 0.5 0. 0. 0.59 0.14
ASI 10	6.3	0.5	1.22	0.11	253.	7.	4.83 0.04 23.9 0.5 176. 64. 0.67 0.17
ASI 11	5.5	0.5	0.82	0.13	344.	10.	5.20 0.14 30.0 0.5 325. 103. 0.75 0.14
ASI 12	6.3	0.5	1.09	0.12	651.	12.	6.56 0.05 49.4 0.5 592. 127. 0.67 0.14
ASI 13	5.4	0.6	0.71	0.38	410.	24.	5.27 0.15 36.0 1.0 0. 0. 0.00 0.00
ASI 14	4.2	0.5	0.60	0.35	203.	14.	4.44 0.13 21.7 0.7 0. 0. 0.00 0.00
ASI 15	5.7	0.6	0.76	0.05	279.	8.	4.95 0.04 27.6 0.4 0. 0. 0.80 0.16
ASI 16	5.0	0.6	0.58	0.07	447.	9.	4.47 0.04 26.5 0.4 171. 45. 0.48 0.13
ASI 17	4.4	0.6	0.72	0.36	436.	26.	4.66 0.13 26.9 0.9 0. 0. 0.00 0.00
ASI 18	4.5	0.7	0.65	0.12	211.	10.	4.49 0.16 28.5 0.6 0. 0. 0.73 0.17
ASI 19	3.8	0.6	0.55	0.36	323.	20.	5.01 0.14 25.0 0.9 0. 0. 0.00 0.00
ASI 20	7.3	0.5	1.00	0.05	203.	5.	4.53 0.03 20.2 0.3 0. 0. 0.70 0.11
ASI 21	4.1	0.6	0.58	0.10	366.	10.	5.21 0.05 31.1 0.5 210. 81. 0.47 0.18
ASI 22	4.4	0.5	0.25	0.31	371.	22.	4.01 0.12 22.5 0.7 0. 0. 0.00 0.00
ASI 24	5.9	0.4	0.46	0.11	293.	13.	4.91 0.06 23.8 0.8 0. 0. 0.25 0.11
ASI 25	5.3	0.5	0.38	0.06	194.	5.	4.83 0.03 16.8 0.3 120. 28. 0.58 0.10
ASI 26	5.1	0.4	0.46	0.06	327.	12.	5.03 0.19 25.2 0.5 153. 46. 1.05 0.19
ASI 27	7.9	0.5	0.57	0.14	275.	11.	5.40 0.16 22.5 0.5 0. 0. 0.76 0.15
ASI 31	4.3	0.6	0.94	0.12	372.	18.	5.81 0.28 35.7 0.7 250. 99. 0.54 0.18
ASI 32	5.4	0.4	0.73	0.11	834.	16.	5.00 0.03 26.2 0.5 129. 38. 0.68 0.21
ASI 33	5.7	0.9	0.46	0.10	266.	11.	5.12 0.05 24.6 1.8 178. 51. 0.89 0.15
ASI 34	4.3	0.4	0.57	0.10	327.	13.	5.17 0.05 26.6 0.5 130. 36. 0.49 0.17
ASI 35	3.6	0.9	0.89	0.13	374.	13.	5.06 0.05 29.2 0.4 350. 76. 0.55 0.15

SAMPLE	AL (%)	MG (%)	CA (%)	V (PPM)	TI (%)	(NA) (%)	NA (%)	K (%)	MN (PPM)									
KER 1	8.59	0.05	2.2	0.4	11.4	0.4	169.	4.	0.46	0.03	1.48	0.03	1.514	0.014	1.11	0.43	1105.	20.
KER 2	7.85	0.05	2.0	0.3	10.4	0.3	116.	4.	0.48	0.03	1.17	0.03	1.180	0.002	1.20	0.07	1538.	20.
KFR 3	7.57	0.05	2.3	0.3	12.7	0.3	104.	4.	0.43	0.03	1.22	0.03	1.198	0.004	0.92	0.09	985.	17.
KER 4	8.57	0.05	2.1	0.4	8.1	0.3	166.	4.	0.54	0.03	0.48	0.02	0.491	0.001	2.90	0.07	1091.	19.
KER 5	7.78	0.05	2.0	0.3	13.8	0.3	99.	4.	0.47	0.03	0.61	0.02	0.632	0.001	2.32	0.07	1250.	18.
KER 6	8.05	0.05	2.2	0.4	11.2	0.3	162.	4.	0.44	0.03	1.34	0.03	1.376	0.012	0.90	0.11	1022.	19.
KER 7	9.20	0.05	2.6	0.4	12.6	0.4	184.	4.	0.51	0.03	1.46	0.03	1.460	0.012	0.63	0.10	911.	18.
KER 8	7.95	0.05	1.8	0.3	11.4	0.3	126.	4.	0.49	0.03	0.96	0.03	0.939	0.002	1.37	0.07	931.	16.
KER 9	9.52	0.05	2.2	0.4	12.2	0.4	170.	5.	0.48	0.04	0.43	0.02	0.447	0.004	2.62	0.24	839.	20.
KER 10	8.33	0.05	2.2	0.3	10.0	0.3	132.	4.	0.48	0.03	0.60	0.02	0.629	0.004	2.72	0.27	1155.	20.
KFR 11	8.89	0.05	2.4	0.3	8.5	0.3	150.	4.	0.47	0.03	0.63	0.02	0.645	0.005	2.98	0.28	823.	17.
KER 12	8.32	0.05	2.2	0.4	8.8	0.3	142.	4.	0.46	0.03	0.50	0.02	0.484	0.006	2.46	0.29	1227.	21.
KER 13	7.24	0.05	2.1	0.3	16.5	0.4	127.	4.	0.45	0.03	0.59	0.02	0.607	0.005	1.03	0.15	1086.	19.
KER 14	8.11	0.05	2.4	0.3	11.5	0.3	159.	4.	0.51	0.03	1.27	0.03	1.360	0.007	1.21	0.29	1054.	18.
KER 15	8.77	0.05	2.1	0.4	11.6	0.3	175.	4.	0.50	0.04	1.48	0.03	1.543	0.012	0.75	0.33	867.	17.
KFR 16	8.44	0.05	2.3	0.3	11.3	0.3	139.	4.	0.52	0.03	0.60	0.02	0.634	0.015	2.59	0.27	1213.	18.
KER 17	7.74	0.05	2.2	0.3	13.1	0.4	124.	4.	0.52	0.04	0.58	0.02	0.591	0.003	2.28	0.14	1282.	20.
KFR 18	9.26	0.06	2.1	0.4	11.1	0.4	162.	5.	0.49	0.04	0.48	0.02	0.502	0.007	2.77	0.12	823.	19.
KER 19	6.82	0.05	2.1	0.3	11.4	0.3	128.	4.	0.41	0.03	0.41	0.02	0.409	0.003	2.32	0.18	1337.	18.
KER 20	6.78	0.05	1.4	0.3	15.4	0.4	92.	4.	0.42	0.03	0.49	0.02	0.560	0.004	1.90	0.19	941.	17.
KER 21	8.14	0.05	2.0	0.3	7.5	0.3	150.	4.	0.51	0.04	0.39	0.02	0.427	0.009	2.78	0.18	1312.	20.
KER 22	6.46	0.05	0.7	0.3	3.9	0.2	108.	4.	0.40	0.03	0.21	0.01	0.200	0.001	1.64	0.07	1217.	18.
KER 23	6.00	0.04	1.9	0.3	8.7	0.3	108.	4.	0.34	0.03	0.39	0.02	0.421	0.002	2.42	0.11	1805.	22.
KFR 24	7.80	0.05	0.6	0.3	1.5	0.1	86.	4.	0.51	0.03	0.28	0.01	0.284	0.002	1.72	0.08	388.	11.
KER 25	5.92	0.05	1.2	0.3	3.9	0.2	103.	4.	0.46	0.04	0.29	0.02	0.299	0.002	1.83	0.08	1538.	22.
KER 26	6.37	0.05	2.2	0.3	4.0	0.2	109.	4.	0.39	0.04	0.32	0.01	0.351	0.002	1.89	0.09	1531.	22.
KFR 27	7.12	0.05	1.8	0.3	5.4	0.2	122.	3.	0.41	0.03	0.34	0.01	0.354	0.002	2.28	0.09	1376.	19.
KFR 28	5.86	0.05	0.8	0.2	0.6	0.1	75.	3.	0.44	0.03	0.56	0.02	0.590	0.002	1.91	0.29	1453.	17.
KFR 29	8.04	0.06	2.3	0.4	4.6	0.3	186.	5.	0.46	0.05	0.36	0.02	0.340	0.002	2.63	0.12	1242.	23.
KFR 31	6.70	0.05	3.2	0.3	16.2	0.4	116.	4.	0.37	0.04	1.05	0.03	1.102	0.003	0.77	0.25	1231.	19.
KFR 32	7.23	0.05	1.1	0.3	15.1	0.4	115.	4.	0.44	0.04	0.67	0.02	0.721	0.003	2.44	0.14	1101.	20.
KFR 33	6.92	0.05	2.0	0.3	17.1	0.4	91.	4.	0.34	0.04	0.52	0.02	0.580	0.003	1.82	0.32	1472.	21.
KER 34	6.82	0.06	2.0	0.4	9.9	0.3	132.	4.	0.52	0.04	0.63	0.02	0.641	0.003	2.21	0.13	947.	18.
KER 35	8.18	0.05	2.0	0.3	13.2	0.4	154.	4.	0.48	0.04	0.39	0.02	0.425	0.002	2.75	0.13	1050.	18.
KER 36	7.68	0.05	1.6	0.3	10.1	0.3	122.	4.	0.45	0.04	0.47	0.02	0.502	0.003	2.30	0.12	857.	17.
KER 37	7.44	0.05	2.3	0.3	16.8	0.4	152.	4.	0.41	0.04	0.60	0.02	0.625	0.003	2.57	0.15	1540.	22.
KFR 38	6.05	0.04	2.4	0.3	18.7	0.4	122.	3.	0.44	0.03	0.50	0.02	0.484	0.002	2.12	0.12	1040.	16.
KER 39	6.68	0.05	1.7	0.3	18.5	0.4	108.	4.	0.38	0.04	0.53	0.02	0.571	0.004	1.84	0.22	996.	18.
KER 40	7.11	0.05	1.6	0.3	12.4	0.4	111.	4.	0.43	0.04	0.60	0.02	0.624	0.005	2.54	0.68	1140.	19.
KER 41	8.14	0.06	2.0	0.2	12.0	0.3	150.	4.	0.43	0.04	0.37	0.01	0.385	0.004	2.44	0.25	1330.	15.
KER 42	7.88	0.06	2.5	0.2	16.7	0.7	140.	4.	0.44	0.04	0.67	0.02	0.695	0.003	2.21	0.15	1601.	16.
KER 43	7.28	0.06	2.6	0.2	12.3	0.3	131.	4.	0.46	0.03	0.65	0.01	0.675	0.003	2.44	0.13	1106.	12.
KFR 44	7.67	0.06	1.6	0.2	2.6	0.1	130.	4.	0.41	0.04	0.53	0.01	0.548	0.002	2.34	0.12	1780.	15.
KER 45	5.06	0.07	2.3	0.2	7.0	0.2	110.	4.	0.26	0.03	0.25	0.01	0.247	0.006	1.24	0.08	860.	12.
KFR 46	7.87	0.06	2.0	0.2	2.7	0.1	172.	3.	0.37	0.03	0.33	0.01	0.313	0.005	2.44	0.11	1008.	11.
KER 47	8.81	0.06	2.1	0.3	14.1	0.3	195.	4.	0.46	0.04	1.33	0.02	1.395	0.004	1.47	0.14	1844.	17.
KER 48	7.62	0.06	1.8	0.2	12.1	0.3	85.	3.	0.45	0.03	0.71	0.02	0.736	0.004	1.81	0.27	1148.	13.
KFR 49	8.68	0.06	2.6	0.3	14.1	0.3	163.	4.	0.47	0.04	1.49	0.02	1.514	0.008	1.26	0.23	1758.	17.
KER 50	6.56	0.07	2.7	0.2	17.4	0.4	100.	4.	0.38	0.04	1.00	0.02	1.042	0.003	0.63	0.12	1344.	15.
KFR 51	7.27	0.07	1.7	0.2	13.1	0.3	111.	4.	0.45	0.04	0.71	0.02	0.724	0.001	1.47	0.06	1238.	14.
KFR 52	8.32	0.06	1.5	0.2	10.4	0.3	132.	4.	0.52	0.03	0.88	0.02	0.886	0.003	1.47	0.11	1023.	12.
KFR 53	7.10	0.06	1.9	0.2	10.4	0.2	112.	3.	0.44	0.03	0.82	0.02	0.821	0.002	1.19	0.10	1196.	12.
KER 54	6.27	0.06	2.1	0.2	17.7	0.4	114.	4.	0.36	0.03	0.59	0.02	0.638	0.002	2.17	0.08	985.	13.
KER 55	8.49	0.06	2.2	0.2	6.2	0.2	156.	4.	0.50	0.04	0.52	0.01	0.534	0.005	2.82	0.07	1249.	14.
KER 56	6.59	0.06	1.6	0.2	18.3	0.4	96.	4.	0.42	0.03	0.61	0.02	0.614	0.002	1.56	0.08	1160.	14.
KER 57	7.84	0.06	3.1	0.2	7.2	0.2	124.	4.	0.44	0.03	0.53	0.01	0.564	0.002	2.47	0.09	934.	13.
KER 58	7.86	0.06	2.1	0.2	2.9	0.1	122.	3.	0.44	0.03	0.43	0.01	0.431	0.002	2.20	0.10	1885.	15.
KER 59	8.79	0.08	2.2	0.2	4.7	0.2	162.	5.	0.42	0.04	0.26	0.01	0.277	0.002	2.39	0.10	1228.	12.
KER 60	8.54	0.06	1.9	0.2	3.1	0.1	159.	4.	0.39	0.03	0.32	0.01	0.312	0.006	2.61	0.11	1272.	13.
KFR 61	8.22	0.06	1.7	0.2	2.9	0.1	157.	4.	0.46	0.04	0.30	0.01	0.307	0.007	2.25	0.11	1211.	14.
KER 62	4.36	0.05	2.3	0.2	7.1	0.2	97.	3.	0.28	0.03	0.26	0.01	0.269	0.002	0.86	0.07	845.	10.
KFR 63	7.16	0.06	7.3	0.3	5.5	0.2	215.	4.	0.31	0.03	0.28	0.01	0.278	0.002	1.71	0.09	763.	10.
KER 64	8.02	0.06	1.8	0.2	2.4	0.1	143.	4.	0.46	0.04	0.34	0.01	0.337	0.003	2.23	0.13	1613.	16.
KER 65	7.73	0.06	1.8	0.2	11.3	0.3	132.	4.	0.40	0.04	0.42	0.01	0.449	0.004	2.15	0.22	1355.	15.
KER 66	7.86	0.06	2.2	0.2	10.8	0.3	141.	4.	0.43	0.03	0.54	0.01	0.567	0.002	2.39	0.06	887.	12.
KER 67	6.97	0.06	1.5	0.2	8.6	0.2	110.	4.	0.42	0.03	0.51	0.01	0.497	0.001	2.36	0.07	934.	12.
KER 68	9.18	0.06	3.2	0.3	4.7	0.2	178.	4.	0.59	0.03	0.45	0.01	0.451	0.004	2.81	0.06	665.	10.
KFR 69	9.00	0.06	3.3	0.3	6.4	0.2	179.	4.	0.55	0.03	0.49	0.01	0.515	0.002	2.81	0.08	647.	10.
KOR 1	8.25	0.06	2.0	0.3	12.6	0.3	157.	4.	0.49	0.04	0.95	0.02	0.960	0.003	1.44	0.10	1268.	14.
KOR 2	5.16	0.05	1.1	0.2	17.9	0.3	92.	3.	0.36	0.03	0.31	0.01	0.319	0.001	1.90	0.06	1121.	13.
KOR 3	10.74	0.07	1.5	0.3	6.1	0.2	170.	4.	0.64	0.03	0.60	0.01	0.606	0.002	2.41	0.09	672.	11.
KOR 4	7.21	0.06	1.7	0.2	4.7	0.2	131.	4.	0.39	0.04	0.40	0.01	0.401	0.002	2.99	0.08	1484.	15.

SAMPLE	(U) (PPM)	(SC) (PPM)	W (PPM)	LA (PPM)	(SM) (PPM)	YB (PPM)	(LU) (PPM)	AS (PPM)	(SB) (PPM)									
KER 1	2.2	0.5	24.6	0.5	61.	3.	35.7	0.6	5.6	0.1	2.0	0.3	0.45	0.11	0.0	0.0	0.00	0.00
KER 2	2.0	0.5	21.1	0.5	102.	2.	32.2	0.5	5.7	0.1	2.1	0.4	0.40	0.11	6.1	0.7	0.59	0.18
KER 3	1.9	0.7	19.1	0.4	59.	2.	28.2	0.4	5.6	0.1	2.7	0.4	0.56	0.10	12.2	1.0	2.31	0.24
KER 4	2.3	0.8	24.3	0.4	241.	3.	34.2	0.4	5.4	0.1	2.4	0.4	0.77	0.14	6.5	0.5	0.61	0.16
KER 5	1.1	0.7	20.4	0.4	50.	1.	25.9	0.4	5.2	0.1	2.7	0.4	0.51	0.10	32.2	1.2	2.04	0.16
KER 6	2.4	0.8	23.6	0.4	14.	1.	34.8	0.6	4.9	0.1	2.9	0.9	0.40	0.12	3.2	0.9	0.51	0.19
KER 7	2.5	0.6	26.6	1.1	9.	1.	35.4	0.6	5.5	0.1	2.4	0.3	0.41	0.10	3.5	1.2	0.42	0.10
KER 8	2.2	0.7	20.8	0.5	24.	1.	32.9	1.2	5.4	0.1	2.6	0.4	0.46	0.11	3.5	0.8	0.50	0.19
KER 9	2.7	0.6	26.6	0.3	27.	2.	36.3	0.5	5.6	0.1	2.6	0.3	0.47	0.08	6.8	1.5	0.83	0.21
KER 10	2.4	0.6	24.7	0.3	9.	1.	33.9	0.5	5.1	0.1	2.6	0.3	0.44	0.09	5.8	1.1	0.74	0.17
KER 11	3.4	0.7	25.3	0.7	15.	2.	36.0	0.5	5.0	0.1	3.1	0.4	0.51	0.16	9.6	1.5	1.18	0.23
KER 12	2.1	0.6	22.0	0.2	80.	3.	35.6	0.4	5.0	0.1	2.9	0.3	0.43	0.11	11.1	1.6	0.47	0.13
KER 13	2.7	0.7	19.7	0.3	10.	1.	34.6	0.5	5.5	0.1	2.7	0.3	0.46	0.14	10.3	1.7	0.63	0.19
KER 14	3.0	0.8	23.4	0.3	21.	2.	34.4	1.5	5.5	0.1	2.6	0.4	0.40	0.09	4.0	1.3	0.67	0.23
KER 15	1.9	0.8	26.0	0.3	15.	3.	36.5	0.6	5.2	0.1	2.3	0.3	0.45	0.15	2.4	0.9	0.55	0.18
KER 16	1.9	0.6	24.4	0.3	20.	2.	34.4	0.4	5.6	0.1	2.7	0.3	0.45	0.16	6.7	1.4	0.68	0.18
KER 17	2.6	0.7	22.0	0.0	9.	1.	33.8	0.4	5.5	0.1	2.6	0.3	0.42	0.09	6.6	0.9	0.68	0.15
KER 18	3.6	0.7	25.9	0.0	22.	1.	36.1	0.4	5.1	0.1	2.2	0.2	0.38	0.08	6.6	0.6	0.70	0.13
KER 19	2.6	0.6	19.8	0.2	13.	1.	30.2	0.4	4.7	0.1	2.3	0.3	0.39	0.09	5.1	1.1	0.65	0.18
KER 20	1.7	0.6	18.4	0.3	24.	2.	26.4	0.4	5.0	0.1	2.9	0.2	0.42	0.08	15.8	1.4	1.95	0.21
KER 21	1.9	0.5	21.1	0.5	103.	3.	36.1	0.4	5.8	0.1	2.8	0.3	0.50	0.13	8.8	0.9	0.67	0.12
KER 22	1.5	0.5	17.1	0.6	253.	3.	36.0	0.3	5.8	0.1	2.5	0.3	0.38	0.09	9.0	0.5	0.67	0.10
KER 23	1.6	0.5	16.2	0.2	6.	1.	26.8	0.4	4.3	0.1	1.9	0.3	0.42	0.10	6.0	0.7	0.71	0.13
KER 24	2.8	0.8	16.8	0.2	267.	4.	31.7	0.4	4.7	0.1	2.7	0.3	0.57	0.10	12.8	0.7	0.66	0.12
KER 25	2.3	0.5	16.6	0.6	43.	1.	29.1	0.4	4.8	0.1	2.4	0.3	0.44	0.09	6.5	0.7	1.00	0.13
KER 26	2.5	0.6	17.0	0.6	4.	1.	26.8	0.3	3.9	0.1	2.1	0.2	0.37	0.09	4.4	0.6	0.57	0.12
KER 27	1.7	0.5	18.7	0.3	52.	1.	36.2	0.4	5.6	0.1	2.3	0.5	0.45	0.09	12.9	1.0	0.69	0.11
KER 28	2.5	0.7	13.2	0.3	286.	4.	34.6	0.4	5.1	0.1	2.2	0.3	0.50	0.11	5.4	0.6	0.75	0.16
KER 29	3.4	0.9	21.6	0.3	295.	4.	33.3	0.4	5.0	0.1	2.4	0.3	0.41	0.09	7.6	0.7	0.71	0.15
KER 31	1.6	0.5	21.1	0.4	7.	1.	28.2	0.5	4.8	0.1	2.6	0.4	0.37	0.10	6.9	1.3	0.56	0.17
KER 32	2.1	0.7	22.9	0.9	52.	2.	28.1	0.5	5.2	0.1	2.4	0.3	0.42	0.11	9.8	1.2	1.72	0.26
KER 33	2.4	0.6	21.6	0.4	0.	0.	36.2	0.5	5.9	0.1	2.5	0.3	0.44	0.17	6.8	1.1	0.55	0.17
KER 34	2.2	0.8	22.6	0.4	21.	1.	34.2	0.5	5.6	0.1	2.6	0.4	0.45	0.10	2.6	0.8	0.46	0.17
KER 35	3.2	0.7	23.9	0.4	3.	1.	38.7	0.4	5.9	0.1	2.6	0.3	0.41	0.09	7.0	1.0	0.67	0.16
KER 36	2.5	0.7	21.5	0.3	12.	1.	33.3	0.4	5.4	0.1	2.1	0.4	0.42	0.10	4.4	1.0	0.44	0.18
KER 37	1.5	0.4	22.4	0.4	30.	2.	21.8	0.4	4.2	0.1	2.0	0.3	0.35	0.10	82.7	2.2	3.73	0.21
KER 38	1.9	0.6	20.0	0.7	0.	0.	24.8	0.4	4.2	0.1	1.9	0.3	0.34	0.09	5.0	0.8	0.53	0.13
KER 39	2.3	0.7	18.6	0.3	6.	1.	26.7	0.4	4.6	0.1	2.3	0.3	0.40	0.10	19.5	1.6	1.36	0.18
KER 40	1.3	0.6	19.4	0.3	33.	2.	26.7	0.4	4.9	0.1	2.5	0.3	0.45	0.09	32.1	2.1	3.21	0.27
KER 41	1.2	0.4	21.4	0.3	61.	3.	35.6	0.5	5.7	0.1	3.1	0.4	0.51	0.09	4.7	1.2	0.65	0.20
KER 42	1.9	0.4	23.5	1.0	18.	1.	25.4	0.5	4.7	0.1	2.4	0.9	0.40	0.19	54.4	1.9	3.00	0.22
KER 43	2.0	0.6	21.7	0.4	13.	1.	29.7	0.4	4.9	0.1	2.2	0.3	0.36	0.10	9.2	1.1	0.71	0.16
KER 44	1.1	0.4	19.1	0.3	43.	2.	36.2	0.4	5.2	0.1	3.0	0.3	0.42	0.10	9.5	1.1	0.76	0.16
KER 45	2.1	0.7	17.4	0.3	14.	1.	21.4	1.0	3.7	0.1	1.4	0.2	0.34	0.10	9.1	1.3	0.65	0.19
KER 46	1.9	0.3	18.3	0.3	72.	2.	27.3	0.3	4.1	0.1	1.6	0.2	0.44	0.17	12.9	1.0	1.04	0.15
KER 47	2.3	1.0	26.3	0.5	6.	1.	24.0	0.5	4.4	0.1	3.0	0.5	0.38	0.12	41.3	1.9	1.83	0.22
KER 48	2.3	0.6	19.8	0.3	30.	2.	29.9	0.4	5.0	0.1	2.9	0.3	0.44	0.09	7.7	1.1	1.55	0.22
KER 49	2.0	1.0	25.8	0.4	16.	2.	25.0	0.5	4.9	0.1	2.3	0.3	0.40	0.10	55.8	2.6	2.92	0.24
KER 50	0.7	0.3	21.9	0.5	10.	1.	26.8	0.6	5.1	0.1	2.2	0.4	0.43	0.12	5.7	1.3	0.41	0.20
KER 51	1.5	0.4	19.1	0.5	23.	1.	31.6	1.2	5.9	0.1	3.2	0.4	0.38	0.13	3.1	0.4	0.59	0.19
KER 52	3.0	0.8	20.9	0.4	16.	1.	33.2	0.5	5.2	0.1	2.2	0.3	0.36	0.11	3.7	0.9	0.51	0.18
KER 53	2.1	0.7	18.6	0.3	32.	1.	30.5	0.5	5.2	0.1	2.5	0.3	0.39	0.10	5.7	1.0	0.54	0.17
KER 54	2.4	0.8	18.3	0.5	16.	1.	26.3	1.1	4.5	0.1	2.2	0.4	0.39	0.10	6.5	0.9	0.47	0.18
KER 55	2.4	0.7	23.5	0.5	122.	2.	37.8	0.4	5.7	0.1	2.7	0.4	0.47	0.11	7.5	0.7	0.72	0.18
KER 56	1.3	0.6	16.7	0.4	12.	1.	25.5	0.5	5.1	0.1	2.7	0.4	0.39	0.11	8.4	0.9	0.96	0.18
KER 57	2.8	0.9	23.6	0.4	23.	1.	28.6	0.4	4.7	0.1	2.6	0.7	0.47	0.11	9.3	1.0	0.63	0.16
KER 58	1.9	0.6	18.6	0.3	10.	1.	40.2	1.3	6.3	0.1	2.8	0.3	0.35	0.08	9.0	1.0	0.91	0.17
KER 59	2.0	0.5	22.6	0.3	14.	1.	35.6	0.4	5.7	0.1	2.5	0.3	0.47	0.08	9.3	1.0	1.12	0.18
KER 60	1.6	0.6	22.3	0.4	35.	2.	34.3	0.4	5.5	0.1	2.5	0.3	0.41	0.09	7.7	0.9	0.86	0.16
KER 61	1.5	0.4	22.3	0.3	79.	2.	33.9	0.4	5.6	0.1	2.2	0.3	0.46	0.10	11.4	1.2	0.51	0.16
KER 62	1.6	0.5	15.5	0.3	15.	1.	17.6	0.3	3.3	0.1	1.1	0.2	0.32	0.11	2.8	0.4	0.00	0.00
KER 63	1.2	0.3	20.9	0.7	56.	2.	23.8	0.3	3.9	0.1	1.3	0.2	0.36	0.18	5.7	0.4	0.00	0.00
KER 64	2.2	1.0	20.5	0.4	191.	4.	42.6	0.4	6.4	0.1	1.9	0.3	0.45	0.09	10.9	1.0	0.92	0.19
KER 65	2.5	0.8	20.4	0.7	64.	3.	38.1	1.6	5.6	0.1	2.3	0.3	0.44	0.10	8.3	1.5	0.38	0.17
KER 66	3.0	0.8	23.3	0.5	26.	1.	34.0	0.4	5.5	0.1	2.5	0.4	0.54	0.25	5.0	0.8	0.63	0.18
KER 67	1.9	0.5	19.0	0.5	35.	1.	27.3	0.4	5.0	0.1	2.3	0.4	0.31	0.12	18.8	1.3	0.74	0.18
KER 68	3.4	1.1																

SAMPLE	RR (PPM)	CS (PPM)	(BA) (PPM)	SC (PPM)	CE (PPM)	EU (PPM)	TH (PPM)							
KER 1	44.	9.	16.3	1.3	304.	61.	24.3	0.1	80.0	4.7	1.17	0.07	8.9	0.3
KER 2	74.	9.	11.1	1.1	351.	59.	21.6	0.1	83.7	4.9	1.33	0.10	8.9	0.3
KER 3	26.	4.	13.1	1.2	239.	108.	18.9	0.1	67.8	4.3	1.35	0.23	6.3	0.3
KER 4	175.	13.	17.1	0.7	424.	83.	24.6	0.1	82.8	5.4	1.17	0.10	8.7	0.4
KFR 5	85.	10.	9.9	0.5	485.	65.	20.5	0.1	57.5	4.0	1.26	0.08	6.0	0.3
KER 6	44.	7.	8.6	1.2	315.	47.	22.6	0.1	75.0	2.4	1.16	0.09	8.4	0.3
KER 7	58.	10.	10.3	0.6	483.	83.	24.1	0.1	75.8	2.5	1.09	0.09	8.8	0.4
KER 8	72.	10.	10.7	0.6	457.	69.	20.8	0.1	74.7	2.9	1.38	0.10	8.6	0.4
KER 9	212.	14.	11.6	1.6	453.	92.	25.5	0.1	79.8	6.0	1.34	0.12	8.9	0.4
KER 10	167.	12.	8.3	0.6	436.	75.	23.6	0.1	79.0	2.4	1.25	0.10	9.0	0.3
KER 11	165.	12.	28.4	1.4	344.	72.	23.4	0.1	77.9	2.6	1.11	0.09	8.8	0.3
KER 12	145.	13.	9.2	0.5	693.	191.	21.8	0.1	82.6	5.5	1.36	0.11	8.8	0.3
KER 13	107.	10.	6.1	0.4	423.	78.	19.3	0.1	76.2	2.4	1.13	0.10	8.0	0.3
KER 14	61.	8.	9.4	0.6	647.	94.	22.8	0.1	82.3	4.9	1.22	0.08	8.4	0.3
KER 15	42.	7.	11.3	1.2	368.	64.	25.2	0.1	81.5	2.7	1.28	0.10	8.7	0.3
KFR 16	149.	10.	9.5	1.1	345.	61.	22.9	0.1	79.7	2.2	1.23	0.09	8.4	0.3
KER 17	127.	10.	7.1	0.5	575.	67.	21.6	0.1	77.7	5.1	1.28	0.04	8.0	0.3
KER 18	171.	14.	12.2	0.7	467.	172.	25.6	0.1	82.7	3.0	1.21	0.06	8.9	0.4
KER 19	141.	11.	9.4	0.5	486.	140.	19.2	0.1	68.8	2.0	1.10	0.08	7.2	0.3
KER 20	68.	10.	6.8	0.6	593.	92.	18.0	0.1	56.3	2.2	1.25	0.10	6.5	0.4
KER 21	140.	13.	14.4	0.8	366.	68.	20.4	0.1	84.6	4.8	1.24	0.05	9.0	0.3
KFR 22	81.	9.	6.2	1.0	524.	69.	16.6	0.1	72.4	4.3	1.24	0.08	8.8	0.3
KFR 23	130.	11.	10.6	1.2	355.	64.	16.5	0.2	63.7	2.1	0.82	0.07	6.2	0.3
KER 24	102.	9.	8.1	0.5	466.	69.	16.7	0.1	88.3	4.4	0.97	0.07	11.7	0.4
KER 25	98.	9.	10.3	0.5	428.	80.	16.3	0.1	79.6	2.5	0.94	0.08	8.8	0.3
KER 26	110.	12.	15.4	1.2	353.	57.	16.7	0.1	75.9	2.0	0.89	0.07	7.4	0.3
KER 27	136.	11.	14.5	1.1	396.	64.	18.3	0.1	81.1	4.2	1.32	0.24	8.8	0.3
KER 28	96.	9.	5.9	0.5	199.	39.	13.0	0.1	82.0	3.8	1.17	0.08	8.3	0.3
KER 29	152.	30.	39.1	2.0	299.	91.	21.7	0.1	77.1	3.6	1.01	0.11	8.8	0.5
KER 30	49.	6.	11.3	1.3	406.	73.	20.5	0.1	62.8	2.4	1.16	0.09	6.4	0.3
KER 31	94.	11.	7.1	0.5	421.	148.	22.0	0.1	58.1	2.7	1.13	0.11	6.0	0.3
KER 32	99.	9.	4.4	0.4	546.	59.	21.2	0.1	70.6	1.8	1.36	0.07	7.7	0.2
KER 33	120.	14.	12.1	0.6	189.	57.	22.0	0.0	96.1	3.3	1.16	0.05	9.8	0.3
KER 34	137.	10.	14.0	0.6	435.	81.	23.3	0.1	87.4	2.0	1.24	0.21	8.6	0.3
KER 35	128.	12.	10.6	0.5	516.	111.	20.8	0.1	76.8	2.2	1.27	0.10	7.8	0.3
KER 36	67.	11.	10.8	0.5	380.	70.	22.2	0.1	41.6	2.3	1.01	0.08	4.2	0.4
KER 37	81.	11.	8.4	0.5	549.	95.	19.6	0.1	44.0	2.1	0.91	0.04	5.8	0.3
KER 38	85.	19.	6.8	1.0	665.	116.	18.7	0.3	60.0	2.4	1.18	0.08	6.2	0.4
KER 39	69.	13.	6.7	0.4	418.	108.	19.2	0.1	65.0	3.5	1.14	0.06	5.5	0.4
KER 40	167.	17.	12.5	0.6	585.	157.	21.3	0.1	94.5	3.2	1.25	0.05	8.2	0.3
KER 41	54.	12.	7.7	0.4	435.	84.	22.9	0.1	54.8	2.9	1.07	0.06	5.1	0.4
KER 42	121.	14.	7.1	0.5	599.	117.	21.6	0.1	65.4	5.6	1.27	0.09	7.3	0.3
KER 43	103.	10.	7.4	0.5	428.	95.	19.1	0.1	91.7	5.1	1.33	0.06	9.3	0.4
KER 44	48.	8.	32.8	0.8	324.	76.	17.2	0.1	53.5	3.0	0.82	0.08	5.8	0.3
KER 45	149.	13.	34.5	1.2	150.	100.	16.9	0.1	56.6	2.2	0.81	0.06	6.2	0.3
KER 46	59.	11.	11.3	1.1	394.	104.	25.5	0.1	43.6	2.7	1.15	0.08	5.3	0.3
KER 47	48.	8.	7.8	0.5	510.	147.	18.7	0.2	41.4	2.9	1.32	0.06	6.9	0.4
KER 48	44.	10.	11.3	0.9	430.	141.	25.0	0.1	63.6	2.3	1.33	0.07	5.5	0.3
KER 49	40.	12.	7.8	0.5	538.	187.	21.6	0.1	62.3	3.3	1.04	0.10	6.1	0.3
KER 50	72.	21.	7.0	0.5	1234.	565.	18.5	0.1	65.7	2.5	0.98	0.13	7.5	0.4
KER 51	64.	10.	7.5	0.6	471.	122.	21.3	0.1	75.7	6.1	1.10	0.09	8.8	0.4
KER 52	94.	18.	6.7	0.4	391.	129.	18.6	0.2	56.9	2.9	1.31	0.07	7.2	0.2
KER 53	131.	17.	8.9	1.1	542.	94.	18.3	0.1	63.2	2.7	1.33	0.25	6.0	0.3
KER 54	161.	40.	18.0	1.2	580.	207.	23.0	0.1	95.6	7.0	1.16	0.09	8.8	0.4
KER 55	56.	12.	7.2	0.5	618.	130.	17.1	0.1	63.0	2.6	1.21	0.08	5.6	0.3
KER 56	152.	23.	8.1	0.5	491.	146.	23.4	0.1	77.9	3.4	1.06	0.08	7.3	0.4
KER 57	109.	13.	10.5	1.0	338.	83.	18.6	0.1	97.4	2.5	1.44	0.08	9.3	0.3
KER 58	156.	17.	15.9	1.1	568.	150.	22.3	0.1	102.0	4.9	1.38	0.08	8.9	0.3
KER 59	129.	16.	11.5	0.5	687.	153.	21.8	0.1	89.9	3.0	1.22	0.09	8.8	0.4
KER 60	133.	19.	12.3	0.6	554.	187.	22.4	0.1	88.4	2.8	1.32	0.09	8.8	0.4
KER 61	66.	14.	23.3	1.3	521.	173.	15.2	0.1	53.6	2.8	0.77	0.06	4.3	0.2
KER 62	122.	18.	21.0	1.2	377.	153.	21.4	0.1	84.8	4.6	0.78	0.07	7.6	0.3
KER 63	143.	19.	15.9	0.6	277.	91.	20.7	0.1	98.8	7.3	1.60	0.28	9.4	0.4
KER 64	165.	22.	13.6	1.0	262.	124.	20.1	0.3	70.0	3.5	1.44	0.09	8.8	0.3
KER 65	164.	21.	9.2	0.6	441.	153.	22.7	0.3	82.5	3.1	1.32	0.26	8.7	0.4
KER 66	119.	15.	14.2	0.6	509.	144.	18.9	0.1	67.2	2.9	1.02	0.08	7.8	0.4
KER 67	191.	44.	21.1	0.7	407.	141.	25.6	0.1	86.7	3.2	1.30	0.10	8.8	0.4
KFR 68	159.	20.	22.7	1.4	760.	257.	24.4	0.3	85.6	3.9	1.26	0.08	8.4	0.4
KOR 1	111.	20.	12.7	1.1	409.	162.	21.3	0.3	87.8	3.2	1.40	0.09	9.2	0.5
KOR 2	36.	13.	9.4	1.2	607.	156.	12.6	0.1	80.5	4.5	1.07	0.07	6.7	0.4
KOR 3	114.	14.	13.7	1.4	532.	198.	26.1	0.1	101.0	5.7	1.51	0.09	9.2	0.6
KOR 4	136.	49.	7.6	1.2	496.	154.	16.4	0.1	92.0	4.8	1.33	0.23	8.2	0.4

SAMPLE	HF (PPM)	TA (PPM)	CR (PPM)	FE (X)	CC (PPM)	NI (PPM)	SB (PPM)							
KFR 1	3.9	0.9	0.62	0.10	282.	10.	5.32	0.05	36.2	0.5	180.	45.	0.40	0.
KFR 2	3.2	0.7	0.71	0.10	254.	8.	5.69	0.04	35.0	0.5	222.	48.	0.83	0.
KFR 3	4.4	0.8	0.44	0.09	174.	7.	4.55	0.04	22.9	0.4	168.	39.	2.44	0.
KFR 4	3.2	0.4	0.06	0.09	257.	10.	5.23	0.05	26.6	0.5	157.	39.	0.37	0.
KFR 5	3.8	0.4	0.44	0.06	160.	7.	4.90	0.05	26.6	0.2	122.	25.	1.87	0.
KFR 6	3.4	0.4	0.57	0.08	258.	10.	5.57	0.16	31.5	0.5	219.	52.	0.84	0.
KFR 7	3.2	0.3	0.60	0.11	266.	10.	5.92	0.05	33.7	0.4	304.	69.	0.36	0.
KFR 8	3.6	0.4	0.60	0.10	253.	10.	5.22	0.05	30.1	0.5	295.	65.	0.67	0.
KFR 9	3.5	0.4	0.62	0.11	270.	12.	6.42	0.06	35.9	2.0	199.	60.	0.83	0.
KFR 10	3.6	0.4	0.90	0.11	274.	9.	6.26	0.05	35.3	0.5	147.	44.	0.53	0.
KFR 11	3.2	0.3	0.91	0.30	257.	9.	5.54	0.05	30.5	0.4	138.	36.	0.50	0.
KFR 12	4.1	0.4	0.60	0.05	374.	11.	5.65	0.05	30.1	0.5	347.	64.	0.61	0.
KFR 13	3.8	0.7	0.78	0.10	253.	9.	5.33	0.16	29.4	0.4	224.	50.	0.71	0.
KFR 14	3.3	0.3	0.34	0.06	269.	9.	5.72	0.16	33.2	0.5	266.	60.	0.77	0.
KFR 15	3.5	0.4	0.72	0.11	279.	10.	6.21	0.05	35.3	0.5	147.	38.	0.57	0.
KFR 16	2.9	0.7	0.75	0.10	266.	9.	5.77	0.05	32.9	0.4	222.	48.	0.60	0.
KFR 17	3.1	0.4	0.59	0.07	256.	9.	5.61	0.04	32.2	0.3	156.	34.	0.60	0.
KFR 18	3.2	0.4	0.89	0.09	274.	10.	6.44	0.06	63.1	0.3	205.	50.	0.45	0.
KFR 19	3.0	0.3	0.50	0.25	270.	8.	5.10	0.04	31.7	0.4	85.	31.	0.44	0.
KFR 20	3.8	0.4	0.45	0.14	160.	10.	4.37	0.05	165.4	0.8	127.	58.	2.53	0.
KFR 21	4.0	0.4	0.62	0.07	389.	11.	5.47	0.05	36.1	0.9	267.	51.	0.54	0.
KFR 22	4.6	0.4	0.34	0.09	456.	13.	4.54	0.04	28.2	1.8	238.	53.	0.63	0.
KFR 23	2.3	0.3	0.30	0.07	374.	11.	4.55	0.04	34.0	0.4	240.	60.	0.27	0.
KFR 24	6.9	0.4	0.70	0.12	208.	7.	4.76	0.04	10.2	0.5	105.	35.	0.54	0.
KFR 25	4.3	0.4	0.89	0.12	352.	10.	4.51	0.04	27.3	0.4	273.	60.	0.86	0.
KFR 26	3.2	0.3	0.66	0.08	420.	10.	4.71	0.04	43.6	0.5	285.	58.	0.28	0.
KFR 27	4.2	0.3	0.79	0.11	400.	10.	5.21	0.14	31.5	1.4	219.	56.	0.96	0.
KFR 28	6.3	0.4	0.41	0.11	516.	11.	3.85	0.04	20.2	0.5	152.	35.	0.61	0.
KFR 29	3.5	1.1	0.20	0.16	302.	13.	5.17	0.06	56.0	0.8	267.	89.	0.99	0.
KFR 30	2.6	0.3	0.63	0.10	615.	14.	5.53	0.04	43.4	0.5	523.	71.	0.79	0.
KFR 31	3.5	0.4	0.58	0.12	212.	10.	5.28	0.18	28.0	0.5	216.	60.	1.20	0.
KFR 32	2.5	0.5	0.63	0.07	254.	7.	5.49	0.03	36.6	0.3	231.	42.	0.67	0.
KFR 33	4.5	0.3	0.84	0.06	262.	8.	5.07	0.10	35.5	0.8	185.	33.	0.76	0.
KFR 34	3.7	0.3	0.98	0.09	259.	5.	5.26	0.05	47.0	0.2	255.	35.	1.07	0.
KFR 35	4.3	0.3	0.73	0.07	225.	8.	5.12	0.05	28.3	0.2	136.	34.	0.60	0.
KFR 36	2.3	0.3	0.34	0.07	144.	11.	5.49	0.05	47.4	0.4	105.	26.	3.20	0.
KFR 37	2.3	0.3	0.48	0.12	350.	12.	4.78	0.05	35.0	0.2	275.	38.	0.50	0.
KFR 38	3.2	0.4	0.49	0.11	186.	11.	4.52	0.05	27.8	0.4	189.	50.	1.27	0.
KFR 39	3.7	0.4	0.35	0.08	151.	10.	4.67	0.05	27.5	0.5	101.	33.	2.91	0.
KFR 40	3.6	0.3	0.65	0.06	299.	8.	5.24	0.10	33.2	0.2	217.	33.	0.63	0.
KFR 41	2.9	0.3	0.40	0.07	195.	13.	5.20	0.06	35.0	0.3	174.	46.	2.48	0.
KFR 42	3.0	0.4	0.66	0.11	398.	13.	5.54	0.17	42.2	0.5	347.	70.	0.41	0.
KFR 43	5.2	0.5	0.90	0.10	411.	13.	5.33	0.05	33.8	0.3	253.	52.	0.97	0.
KFR 44	2.5	0.3	0.40	0.10	3106.	31.	5.49	0.05	94.2	0.8	885.	108.	0.26	0.
KFR 45	2.9	0.4	0.34	0.07	226.	10.	4.14	0.13	24.3	0.4	138.	45.	1.32	0.
KFR 46	3.4	0.4	0.51	0.09	183.	9.	5.99	0.05	41.7	0.5	207.	57.	1.18	0.
KFR 47	4.4	0.4	0.54	0.07	202.	11.	4.87	0.15	33.8	0.3	180.	40.	1.82	0.
KFR 48	3.1	0.4	0.53	0.21	175.	9.	5.71	0.04	34.5	0.4	223.	67.	2.77	0.
KFR 49	2.9	0.5	0.59	0.12	663.	19.	5.42	0.06	58.7	0.6	418.	78.	0.48	0.
KFR 50	3.9	0.3	0.68	0.06	260.	11.	4.45	0.06	30.6	0.2	254.	48.	0.50	0.
KFR 51	4.6	0.5	0.73	0.25	250.	12.	4.91	0.17	27.0	0.4	199.	61.	0.53	0.
KFR 52	4.6	0.3	0.75	0.10	273.	9.	4.78	0.04	52.6	0.4	197.	49.	0.52	0.
KFR 53	3.0	0.4	0.68	0.12	299.	12.	4.61	0.17	56.6	0.6	325.	64.	0.53	0.
KFR 54	4.4	0.4	0.68	0.12	349.	13.	5.39	0.17	30.7	0.5	279.	66.	0.82	0.
KFR 55	4.7	0.4	0.52	0.08	190.	10.	4.06	0.05	24.6	0.4	211.	57.	1.14	0.
KFR 56	1.1	0.5	0.61	0.11	552.	10.	6.11	0.06	42.3	0.5	621.	241.	0.61	0.
KFR 57	5.3	1.0	1.08	0.11	437.	12.	5.30	0.05	35.3	0.4	391.	67.	0.90	0.
KFR 58	4.1	0.4	0.88	0.10	390.	11.	5.83	0.16	37.7	0.4	315.	57.	1.17	0.
KFR 59	3.8	0.4	0.95	0.29	362.	13.	5.71	0.05	35.6	0.4	188.	56.	0.50	0.
KFR 60	4.3	1.1	0.62	0.11	387.	14.	5.77	0.06	35.5	0.5	120.	38.	0.82	0.
KFR 61	2.7	0.4	0.40	0.08	3541.	28.	4.90	0.05	63.0	0.5	1034.	78.	0.44	0.
KFR 62	2.2	0.9	0.34	0.10	3630.	55.	6.79	0.05	68.9	0.5	874.	77.	0.32	0.
KFR 63	5.1	0.4	0.84	0.14	1006.	19.	6.10	0.19	43.1	0.6	502.	73.	0.73	0.
KFR 64	4.9	1.1	0.83	0.12	367.	12.	4.92	0.16	30.4	0.5	273.	58.	0.73	0.
KFR 65	3.7	0.5	0.77	0.12	315.	13.	5.76	0.06	34.2	0.5	270.	50.	0.64	0.
KFR 66	2.8	0.4	0.70	0.11	219.	11.	4.55	0.16	23.4	0.4	210.	73.	0.50	0.
KFR 67	4.4	1.0	0.70	0.13	692.	19.	6.23	0.06	38.8	0.5	601.	90.	2.39	0.
KFR 68	5.9	1.4	0.60	0.12	660.	18.	5.90	0.06	32.8	1.8	402.	64.	2.86	0.
KFR 69	4.2	0.5	0.97	0.12	297.	13.	5.49	0.05	35.2	0.5	314.	71.	2.17	0.
KFR 70	4.5	0.4	0.71	0.09	231.	10.	3.41	0.04	20.9	0.4	140.	37.	0.48	0.
KFR 71	6.9	1.4	0.75	0.12	160.	10.	5.44	0.06	23.2	0.5	85.	39.	0.62	0.
KFR 72	4.9	0.4	0.64	0.09	314.	12.	4.76	0.05	24.5	0.4	243.	55.	1.00	0.

SAMPLE	AL (X)	MG (X)	CA (X)	V (PPM)	TI (X)	NA (X)	NA (X)	NA (X)	K (X)	MN (PPM)								
KRK 3	8.33	0.05	1.7	0.3	5.3	0.4	179.	2.	0.42	0.02	1.15	0.02	1.230	0.004	3.52	0.16	837.	14.
KRK 4	8.63	0.06	2.6	0.3	6.8	0.3	149.	4.	0.55	0.03	0.71	0.02	0.761	0.002	2.40	0.06	623.	13.
KRK 5	8.05	0.06	1.7	0.2	9.7	0.3	123.	4.	0.47	0.02	0.53	0.02	0.556	0.002	2.66	0.08	1019.	13.
KRK 6	7.70	0.06	2.1	0.2	12.5	0.3	126.	3.	0.46	0.02	1.26	0.02	1.343	0.004	1.50	0.15	1158.	13.
KRK 7	7.90	0.05	2.3	0.3	10.9	0.3	123.	3.	0.46	0.02	0.74	0.02	0.778	0.003	2.99	0.16	998.	12.
KRK 8	8.74	0.05	2.6	0.3	0.7	0.1	130.	3.	0.50	0.02	0.93	0.02	0.968	0.003	3.40	0.17	455.	8.
KRK 9	7.67	0.06	2.2	0.3	11.7	0.3	134.	4.	0.43	0.02	0.38	0.02	0.429	0.001	2.55	0.14	581.	11.
KRK 10	7.70	0.06	2.0	0.3	13.0	0.4	105.	4.	0.45	0.03	0.62	0.02	0.632	0.002	2.27	0.08	1108.	16.
KRK 11	6.25	0.06	2.3	0.3	16.2	0.4	59.	4.	0.37	0.03	0.75	0.02	0.801	0.002	1.46	0.07	1438.	10.
KRK 12	6.42	0.05	1.5	0.3	15.2	0.3	106.	3.	0.33	0.02	0.47	0.01	0.454	0.001	1.41	0.05	998.	12.
KRK 13	8.02	0.06	2.2	0.3	10.5	0.3	136.	4.	0.55	0.03	0.58	0.02	0.612	0.001	1.33	0.06	991.	15.
KRK 14	8.10	0.06	2.6	0.3	10.5	0.3	142.	4.	0.46	0.02	1.31	0.02	1.386	0.004	1.03	0.16	783.	12.
KRK 15	8.00	0.05	2.6	0.3	10.7	0.3	145.	4.	0.46	0.02	1.54	0.02	1.533	0.005	0.84	0.11	899.	11.
KRK 16	8.67	0.06	2.3	0.3	5.5	0.2	174.	4.	0.54	0.03	0.86	0.02	0.856	0.003	3.19	0.17	1054.	15.
KRK 17	7.78	0.06	2.4	0.3	5.3	0.2	142.	4.	0.46	0.02	0.59	0.02	0.634	0.003	2.91	0.16	778.	13.
KRK 18	7.10	0.06	1.6	0.3	12.9	0.3	108.	4.	0.43	0.03	0.63	0.02	0.668	0.002	2.24	0.11	900.	14.
KRK 19	6.79	0.06	2.0	0.3	14.2	0.4	117.	4.	0.42	0.03	0.54	0.02	0.555	0.002	2.18	0.11	924.	16.
KRK 20	7.92	0.06	2.3	0.3	12.3	0.3	127.	4.	0.43	0.02	0.62	0.02	0.615	0.004	2.54	0.19	852.	13.
KRK 21	8.25	0.06	2.5	0.3	10.3	0.3	125.	4.	0.43	0.03	0.68	0.02	0.651	0.003	2.55	0.16	929.	14.
KRK 22	7.67	0.06	2.6	0.3	12.5	0.3	130.	4.	0.51	0.02	1.48	0.02	1.486	0.016	0.62	0.14	970.	15.
KRK 23	6.64	0.06	1.1	0.3	15.4	0.4	79.	4.	0.40	0.03	0.70	0.02	0.707	0.004	1.80	0.17	1276.	17.
KRK 25	7.11	0.06	2.6	0.3	10.9	0.3	108.	4.	0.44	0.03	1.22	0.02	1.210	0.006	1.80	0.22	975.	15.
KRK 26	5.96	0.05	2.8	0.3	15.6	0.4	85.	3.	0.34	0.02	1.17	0.02	1.177	0.004	1.07	0.15	938.	14.
KRK 28	8.34	0.06	2.5	0.3	10.9	0.3	143.	4.	0.47	0.03	1.67	0.03	1.710	0.005	0.58	0.14	798.	14.
KRK 29	5.69	0.06	7.0	0.3	8.7	0.3	114.	3.	0.30	0.02	0.49	0.02	0.462	0.002	1.91	0.11	937.	14.
KRK 30	8.54	0.06	2.4	0.3	7.2	0.2	159.	4.	0.47	0.02	0.76	0.02	0.740	0.005	2.83	0.33	557.	11.
KRK 31	7.01	0.06	1.4	0.3	8.2	0.3	126.	4.	0.42	0.02	0.53	0.02	0.541	0.003	2.04	0.14	1339.	17.
KRK 32	6.41	0.05	2.3	0.3	5.4	0.2	110.	3.	0.37	0.02	0.63	0.02	0.678	0.003	2.98	0.17	322.	17.
KRK 33	3.82	0.05	1.0	0.2	7.2	0.3	86.	3.	0.20	0.02	0.42	0.02	0.442	0.004	1.13	0.12	447.	10.
KRK 34	5.55	0.05	2.3	0.3	15.8	0.4	109.	3.	0.31	0.02	0.58	0.02	0.618	0.004	3.09	0.26	901.	14.
KRK 35	5.27	0.05	1.0	0.3	20.0	0.4	96.	3.	0.28	0.02	0.34	0.02	0.352	0.004	1.36	0.15	853.	14.
KRK 36	7.43	0.06	1.8	0.3	7.4	0.3	140.	4.	0.45	0.02	0.53	0.02	0.614	0.005	2.28	0.25	1077.	16.
KRK 37	3.31	0.04	2.0	0.1	23.7	0.4	56.	2.	0.24	0.02	0.29	0.01	0.272	0.002	0.84	0.08	775.	12.
KRK 38	8.49	0.07	2.1	0.4	9.0	0.4	147.	5.	0.42	0.03	0.46	0.03	0.471	0.002	2.74	0.12	857.	18.
KRK 39	8.26	0.06	2.4	0.3	8.6	0.3	140.	4.	0.46	0.02	0.55	0.02	0.578	0.011	2.44	0.17	1275.	17.
KRK 40	8.26	0.06	2.2	0.3	9.6	0.3	154.	4.	0.46	0.02	0.51	0.02	0.554	0.002	3.03	0.14	980.	16.
KRK 41	6.84	0.06	2.0	0.3	15.0	0.4	106.	4.	0.35	0.02	0.65	0.02	0.689	0.010	2.49	0.15	851.	14.
KRK 42	8.36	0.06	2.3	0.3	7.2	0.3	139.	4.	0.44	0.02	0.50	0.02	0.533	0.003	3.77	0.15	1016.	16.
KRK 43	7.17	0.06	1.8	0.3	11.7	0.4	108.	4.	0.46	0.02	0.44	0.02	0.502	0.010	2.61	0.16	1070.	17.
KRK 44	8.69	0.07	2.7	0.4	8.9	0.3	167.	5.	0.46	0.03	0.44	0.03	0.453	0.003	3.35	0.17	637.	14.
KRK 45	8.02	0.06	2.2	0.3	10.8	0.3	155.	4.	0.42	0.03	0.46	0.02	0.494	0.004	3.16	0.25	852.	14.
KRK 46	7.51	0.06	2.5	0.3	12.4	0.4	128.	4.	0.45	0.03	0.31	0.02	0.342	0.004	1.92	0.22	844.	16.
KRK 47	8.53	0.06	2.8	0.3	0.4	0.1	136.	4.	0.52	0.02	1.05	0.02	0.670	0.017	2.46	0.23	552.	11.
KRK 48	2.76	0.04	2.3	0.1	28.1	0.5	52.	2.	0.20	0.02	0.32	0.01	0.322	0.003	0.54	0.13	850.	13.

SAMPLE	(U) (PPM)	(SC) (PPM)	W (PPM)	LA (PPM)	(SM) (PPM)	YO (PPM)	(LU) (PPM)	AS (PPM)	(SO) (PPM)							
KRK 3	1.2	0.3	27.1	0.5	78.	2.	24.2	0.1	2.2	0.4	0.44	0.13	18.6	1.4	1.05	0.21
KRK 4	1.8	0.6	27.8	0.4	18.	1.	25.2	0.2	2.8	0.4	0.44	0.11	36.3	0.9	2.50	0.20
KRK 5	3.1	0.8	21.7	0.4	69.	1.	29.1	0.2	3.0	0.4	0.29	0.12	9.1	0.7	0.66	0.18
KRK 6	1.8	0.6	22.0	0.4	12.	1.	35.5	0.2	2.9	0.3	0.41	0.17	5.8	0.6	0.08	0.08
KRK 7	3.2	1.0	23.3	0.4	14.	1.	33.4	0.2	2.2	0.3	0.44	0.15	9.5	1.6	0.60	0.26
KRK 8	3.7	1.2	21.5	0.5	109.	5.	41.9	0.4	3.0	0.3	0.53	0.25	4.6	0.8	0.27	0.13
KRK 9	4.4	0.7	20.1	0.4	33.	1.	25.7	0.3	2.3	0.3	0.30	0.25	11.1	0.8	0.72	0.19
KRK 10	3.0	0.9	21.0	0.5	22.	1.	38.4	0.3	2.5	0.4	0.50	0.16	15.0	1.0	0.80	0.20
KRK 11	3.0	0.5	16.1	0.4	68.	2.	34.2	0.2	2.0	0.3	0.27	0.13	17.3	1.1	0.81	0.19
KRK 12	2.1	0.3	15.8	0.4	52.	1.	34.3	0.1	2.6	0.3	0.31	0.09	37.5	1.2	0.81	0.17
KRK 13	2.6	0.6	21.7	0.3	57.	1.	38.2	0.2	3.2	0.4	0.39	0.11	22.3	0.9	0.78	0.19
KRK 14	2.6	1.0	23.9	0.5	31.	2.	36.8	0.3	2.6	0.4	0.25	0.13	1.1	0.4	0.00	0.00
KRK 15	3.0	0.9	23.7	1.1	20.	2.	36.3	0.3	2.9	0.5	0.36	0.14	1.9	0.5	0.00	0.00
KRK 16	9.7	1.3	24.8	0.4	24.	2.	35.4	0.4	2.8	0.9	0.46	0.29	47.7	2.0	0.00	0.00
KRK 17	3.1	0.9	22.3	0.4	35.	2.	37.1	0.3	3.3	0.4	0.46	0.15	10.3	1.4	0.49	0.21
KRK 18	2.6	0.6	19.6	0.2	30.	1.	35.0	0.2	2.4	0.3	0.34	0.08	9.4	0.9	0.30	0.13
KRK 19	2.1	0.3	16.4	0.1	11.	1.	33.6	0.1	2.6	0.2	0.49	0.10	10.6	0.9	0.40	0.10
KRK 20	2.4	0.8	22.5	0.3	18.	2.	32.2	0.3	2.5	0.3	0.34	0.10	4.7	1.1	0.38	0.10
KRK 21	1.3	0.4	23.1	0.4	55.	2.	36.7	0.2	2.6	0.4	0.41	0.09	12.2	1.5	0.62	0.24
KRK 22	1.6	0.4	21.7	0.4	28.	2.	34.6	0.2	3.0	1.2	0.36	0.10	7.7	1.5	0.57	0.28
KRK 23	1.5	0.3	15.0	0.3	66.	2.	35.1	0.1	2.8	0.3	0.48	0.09	15.8	1.6	0.79	0.25
KRK 25	4.7	1.1	22.6	0.5	32.	2.	27.6	0.4	2.4	0.3	0.30	0.13	20.1	2.2	0.76	0.23
KRK 26	1.6	0.5	19.5	0.2	13.	1.	35.0	0.2	1.8	0.2	0.34	0.07	10.0	1.5	0.42	0.17
KRK 28	2.0	0.6	23.5	0.7	13.	2.	36.6	0.3	2.5	0.3	0.46	0.09	3.2	0.9	0.52	0.19
KRK 29	1.8	0.3	18.2	0.6	50.	2.	33.6	0.1	1.4	0.2	0.18	0.08	5.4	0.9	0.50	0.20
KRK 30	3.4	0.9	22.8	0.6	49.	3.	35.1	0.3	1.7	0.2	0.31	0.11	11.8	1.8	0.43	0.37
KRK 31	9.2	1.3	18.5	0.3	93.	3.	38.4	0.4	2.7	0.2	0.34	0.18	43.7	1.9	0.00	0.00
KRK 32	1.3	0.3	15.4	0.4	8.	1.	33.0	0.1	2.0	0.3	0.50	0.09	16.8	0.7	0.00	0.00
KRK 33	1.8	0.7	12.7	0.2	5.	1.	35.4	0.2	1.4	0.3	0.10	0.08	6.7	1.3	0.07	0.24
KRK 34	1.9	0.6	18.3	0.3	10.	1.	32.2	0.2	1.4	0.2	0.32	0.09	3.2	0.6	0.00	0.00
KRK 35	0.7	0.3	13.1	0.3	107.	2.	30.2	0.1	1.5	0.2	0.32	0.07	7.6	1.2	0.69	0.19
KRK 36	0.5	0.3	21.7	0.8	107.	5.	44.5	0.2	2.3	0.3	0.40	0.11	12.1	1.8	0.00	0.00
KRK 37	1.0	0.4	9.0	0.3	0.	0.	33.5	0.1	1.5	0.1	0.26	0.05	11.7	0.5	0.00	0.00
KRK 38	4.8	0.8	23.1	0.3	184.	2.	35.6	0.3	3.0	0.4	0.47	0.15	18.9	1.0	0.00	0.00
KRK 39	1.9	0.7	21.8	0.6	48.	2.	39.1	0.3	2.1	0.3	0.37	0.12	3.9	1.0	0.00	0.00
KRK 40	2.3	0.3	24.1	0.2	34.	1.	37.1	0.1	2.5	0.3	0.40	0.08	7.9	1.1	0.47	0.14
KRK 41	3.0	0.9	19.3	0.4	20.	2.	32.8	0.3	2.2	0.4	0.36	0.13	7.6	0.6	0.00	0.00
KRK 42	2.4	0.8	24.7	0.5	10.	1.	37.6	0.3	2.5	0.4	0.46	0.12	5.3	0.5	0.00	0.00
KRK 43	3.0	1.1	19.9	0.4	34.	2.	33.7	0.4	2.3	0.3	0.30	0.24	4.9	0.9	0.66	0.21
KRK 44	3.3	0.4	24.8	0.8	138.	3.	37.5	0.2	3.0	0.4	0.43	0.13	20.3	1.5	0.25	0.20
KRK 45	2.5	0.5	24.1	0.4	37.	3.	33.6	0.2	1.9	0.3	0.46	0.11	10.2	0.8	0.00	0.00
KRK 46	2.3	0.8	22.4	0.5	58.	3.	32.8	0.3	2.4	0.4	0.31	0.12	3.6	0.6	0.00	0.00
KRK 47	2.4	0.4	16.9	0.4	146.	5.	33.5	0.2	2.2	0.4	0.50	0.11	14.9	0.9	0.00	0.00
KRK 48	1.0	0.3	8.1	0.2	0.	0.	37.2	0.2	1.5	0.6	0.22	0.07	10.6	1.1	0.00	0.00

SAMPLE	FB (PPM)	CS (PPM)	EA (PPM)	SC (PPM)	CE (PPM)	EU (PPM)	TH (PPM)
KRK 3	74.	7.	4.2	0.3	333.	140.	26.4
KRK 4	137.	14.	26.5	1.5	567.	78.	28.1
KRK 5	177.	43.	14.4	0.8	0.	0.	21.0
KRK 6	59.	10.	13.7	0.7	207.	51.	21.5
KRK 7	141.	12.	15.1	0.3	213.	59.	23.2
KRK 8	198.	16.	5.4	1.3	280.	79.	26.9
KRK 9	156.	16.	38.5	2.0	0.	0.	20.2
KRK 10	127.	9.	10.4	0.4	512.	64.	21.6
KRK 11	55.	6.	10.1	0.3	356.	41.	15.9
KRK 12	80.	9.	10.4	0.5	659.	86.	15.3
KRK 13	120.	11.	10.6	0.4	399.	72.	21.4
KRK 14	43.	8.	18.0	0.6	280.	88.	23.2
KRK 15	52.	9.	10.4	0.6	196.	46.	23.5
KRK 16	150.	9.	6.9	0.6	437.	59.	23.7
KRK 17	155.	13.	7.7	0.5	133.	55.	22.0
KRK 18	113.	13.	8.9	1.5	511.	102.	18.8
KRK 19	97.	13.	6.9	0.5	111.	44.	16.5
KRK 20	136.	14.	19.9	0.6	337.	95.	21.6
KRK 21	135.	49.	18.8	0.3	0.	0.	22.3
KRK 22	38.	8.	8.9	0.4	409.	67.	20.5
KRK 23	74.	15.	10.0	0.5	223.	64.	14.6
KRK 25	59.	7.	10.8	0.5	228.	55.	21.8
KRK 26	34.	8.	9.4	0.5	336.	118.	18.9
KRK 28	57.	14.	9.4	0.7	0.	0.	22.9
KRK 29	34.	16.	11.8	0.6	487.	233.	17.7
KRK 30	192.	18.	58.2	0.5	487.	160.	22.2
KRK 31	59.	17.	9.5	0.5	0.	0.	18.3
KRK 32	102.	23.	1.1	1.1	0.	0.	18.6
KRK 33	66.	9.	27.6	0.3	0.	0.	12.7
KRK 34	51.	13.	7.0	0.5	0.	0.	17.4
KRK 35	88.	15.	8.4	0.4	0.	0.	12.9
KRK 36	111.	23.	6.8	0.7	0.	0.	21.1
KRK 37	39.	9.	4.4	0.2	0.	0.	8.6
KRK 38	156.	24.	17.4	1.4	0.	0.	22.7
KRK 39	117.	11.	9.8	0.3	470.	159.	23.1
KRK 40	130.	10.	5.0	0.5	473.	97.	23.0
KRK 41	54.	10.	7.3	0.5	434.	114.	16.4
KRK 42	154.	10.	7.4	0.6	249.	47.	23.8
KRK 43	107.	8.	7.2	0.4	621.	75.	15.4
KRK 44	174.	12.	13.6	0.4	487.	79.	23.6
KRK 45	147.	10.	7.8	0.4	235.	48.	23.2
KRK 46	88.	12.	8.6	0.7	0.	0.	20.9
KRK 47	146.	15.	6.3	1.3	0.	0.	21.3
KRK 48	16.	3.	3.5	0.2	106.	34.	6.1

SAMPLE	HF (PPM)	TA (PPM)	CR (PPM)	FE (2)	CC (PPM)	NI (PPM)	SB (PPM)							
KRK 3	3.9	0.3	0.07	0.04	193.	7.	5.45	0.03	22.0	0.3	77.	24.	1.08	0.16
KRK 4	4.6	0.4	0.74	0.13	576.	12.	6.96	0.06	46.5	1.7	418.	74.	2.34	0.30
KRK 5	5.2	0.5	0.38	0.08	297.	14.	5.37	0.06	27.2	0.6	237.	79.	0.00	0.00
KRK 6	4.1	0.5	0.73	0.12	260.	13.	5.66	0.06	32.6	0.5	0.	0.	0.00	0.00
KRK 7	3.4	0.3	0.66	0.06	255.	11.	5.37	0.04	31.6	0.2	173.	33.	1.07	0.19
KRK 8	6.7	0.5	0.45	0.15	271.	13.	5.11	0.05	16.2	0.5	193.	61.	0.00	0.00
KRK 9	3.4	0.4	0.87	0.13	373.	16.	4.86	0.06	31.4	0.5	286.	57.	0.23	0.10
KRK 10	3.9	0.3	0.94	0.06	273.	7.	5.81	0.04	31.9	0.3	294.	50.	0.65	0.13
KRK 11	4.5	0.2	0.65	0.06	315.	6.	4.42	0.02	22.8	0.2	142.	27.	0.63	0.08
KRK 12	4.8	0.3	0.79	0.05	355.	9.	4.25	0.04	16.6	0.4	0.	0.	0.50	0.10
KRK 13	3.7	0.3	0.81	0.05	292.	9.	5.28	0.04	31.3	0.3	0.	0.	0.48	0.19
KRK 14	3.7	0.4	0.42	0.08	308.	15.	5.25	0.06	31.5	1.8	0.	0.	0.00	0.00
KRK 15	2.9	0.4	0.82	0.11	244.	11.	5.63	0.05	26.2	0.4	156.	44.	0.27	0.12
KRK 16	3.4	0.2	0.75	0.07	259.	6.	5.63	0.03	26.6	0.2	220.	35.	0.35	0.16
KRK 17	3.9	0.4	0.67	0.10	353.	13.	5.39	0.18	31.9	0.5	315.	67.	0.00	0.00
KRK 18	3.2	0.9	0.57	0.05	240.	12.	4.89	0.06	22.0	0.5	164.	50.	0.00	0.00
KRK 19	3.3	0.4	0.63	0.20	233.	12.	5.07	0.05	22.8	0.5	245.	50.	0.31	0.12
KRK 20	3.3	0.9	0.60	0.05	277.	11.	4.96	0.17	31.9	0.4	0.	0.	0.37	0.13
KRK 21	3.1	0.2	0.52	0.06	256.	11.	5.28	0.04	31.0	0.3	266.	39.	0.36	0.10
KRK 22	5.3	1.1	0.80	0.12	297.	10.	5.30	0.05	31.1	0.4	284.	54.	0.33	0.13
KRK 23	5.6	0.5	0.88	0.10	310.	12.	4.31	0.05	20.6	0.4	0.	0.	0.31	0.11
KRK 25	3.2	0.3	0.46	0.05	229.	9.	5.51	0.03	36.7	0.2	384.	49.	0.23	0.07
KRK 26	2.3	0.2	0.33	0.06	487.	16.	4.88	0.05	36.8	0.4	226.	36.	0.49	0.11
KRK 28	3.6	0.3	0.71	0.13	235.	8.	5.36	0.03	36.8	0.6	126.	22.	0.22	0.04
KRK 29	2.9	1.4	0.35	0.12	1986.	38.	5.72	0.07	44.7	0.6	1133.	109.	0.27	0.13
KRK 30	3.5	0.7	0.62	0.07	279.	10.	5.29	0.03	31.7	0.3	140.	38.	0.46	0.08
KRK 31	4.0	0.5	0.58	0.05	474.	24.	5.10	0.06	22.8	0.5	112.	39.	1.00	0.18
KRK 32	3.0	0.5	0.59	0.05	267.	20.	4.84	0.05	22.0	0.4	66.	29.	0.24	0.12
KRK 33	1.8	0.5	0.26	0.04	2088.	17.	2.95	0.02	22.4	0.2	366.	39.	0.28	0.07
KRK 34	2.2	0.4	0.19	0.05	371.	21.	4.38	0.06	31.8	0.4	309.	75.	0.54	0.17
KRK 35	2.7	0.4	0.61	0.10	247.	16.	3.43	0.05	19.7	0.4	0.	0.	0.52	0.16
KRK 36	3.5	1.4	0.40	0.05	277.	18.	4.80	0.06	27.8	0.5	0.	0.	0.62	0.18
KRK 37	3.2	0.3	0.65	0.08	1126.	15.	2.96	0.13	27.4	0.3	401.	52.	0.32	0.09
KRK 38	3.8	0.5	0.16	0.07	344.	9.	4.99	0.07	25.0	0.6	310.	87.	0.58	0.21
KRK 39	3.4	0.3	0.67	0.08	257.	10.	5.70	0.04	26.8	0.3	74.	21.	0.45	0.10
KRK 40	3.6	0.3	0.63	0.06	258.	7.	5.86	0.03	26.9	0.2	152.	32.	0.74	0.15
KRK 41	3.3	0.5	0.53	0.11	200.	13.	4.83	0.05	31.0	0.5	119.	37.	0.69	0.15
KRK 42	3.5	0.3	0.74	0.07	226.	6.	3.09	0.03	26.6	0.2	181.	31.	0.36	0.09
KRK 43	3.8	0.3	0.60	0.07	210.	6.	5.03	0.03	27.0	0.3	110.	28.	0.25	0.07
KRK 44	3.5	0.3	0.49	0.17	242.	7.	5.30	0.03	22.9	0.3	112.	28.	0.48	0.09
KRK 45	2.9	0.3	0.51	0.08	268.	7.	5.37	0.03	30.4	0.3	165.	41.	0.25	0.12
KRK 46	2.9	0.5	0.47	0.10	258.	17.	5.02	0.06	27.1	0.6	0.	0.	0.59	0.16
KRK 47	3.3	0.5	0.70	0.12	266.	13.	4.75	0.05	27.7	0.4	0.	0.	0.30	0.11
KRK 48	3.1	0.4	0.40	0.11	1066.	10.	2.76	0.02	22.7	0.2	550.	33.	0.11	0.04

SAMPLE	AL (X)	MG (X)	CA (X)	V (PPM)	TI (X)	(NA) (X)	NA (X)	K (X)	MN (PPM)					
LER 1	0.00	0.00	0.0	0.0	0.0	0.00	0.211	0.003	1.47	0.07	1431.	10.		
LER 2	0.00	0.00	0.0	0.0	0.0	0.00	0.618	0.006	1.65	0.08	1435.	8.		
LER 3	0.00	0.00	0.0	0.0	0.0	0.00	0.926	0.007	2.32	0.10	1296.	7.		
LER 4	0.00	0.00	0.0	0.0	0.0	0.00	0.583	0.005	2.22	0.08	1020.	6.		
LER 5	0.00	0.00	0.0	0.0	0.0	0.00	0.286	0.004	1.78	0.08	1682.	10.		
LER 6	0.00	0.00	0.0	0.0	0.0	0.00	0.273	0.004	1.73	0.08	1787.	10.		
LER 7	0.00	0.00	0.0	0.0	0.0	0.00	1.018	0.010	2.40	0.12	963.	7.		
LER 8	8.76	0.08	2.9	0.5	150.	0.04	0.850	0.010	2.26	0.10	539.	20.		
LER 9	7.16	0.07	2.1	0.3	131.	0.04	0.58	0.03	0.600	0.010	3.45	0.29	2925.	30.
LER 10	7.37	0.07	2.9	0.3	142.	0.04	0.54	0.02	0.490	0.010	3.22	0.26	1624.	23.
LER 11	0.00	0.00	0.0	0.0	0.0	0.00	0.793	0.008	1.82	0.11	771.	5.		
LER 12	0.00	0.00	0.0	0.0	0.0	0.00	0.497	0.006	2.66	0.12	585.	4.		
LER 13	0.00	0.00	0.0	0.0	0.0	0.00	0.571	0.007	2.52	0.12	890.	6.		
LER 14	0.00	0.00	0.0	0.0	0.0	0.00	0.673	0.007	2.58	0.10	801.	5.		
LER 15	0.00	0.00	0.0	0.0	0.0	0.00	0.498	0.006	2.85	0.13	870.	6.		
LER 16	0.00	0.00	0.0	0.0	0.0	0.00	1.071	0.011	2.70	0.12	752.	5.		
LER 17	0.00	0.00	0.0	0.0	0.0	0.00	1.427	0.013	1.52	0.10	936.	7.		
LER 18	0.00	0.00	0.0	0.0	0.0	0.00	0.575	0.007	2.52	0.12	1024.	7.		
LER 19	0.00	0.00	0.0	0.0	0.0	0.00	0.570	0.007	2.57	0.12	1037.	8.		
LER 20	0.00	0.00	0.0	0.0	0.0	0.00	0.705	0.008	3.08	0.13	869.	7.		
LER 21	0.00	0.00	0.0	0.0	0.0	0.00	0.526	0.005	1.99	0.08	1223.	8.		
LER 22	0.00	0.00	0.0	0.0	0.0	0.00	0.459	0.005	2.24	0.10	1535.	9.		
LER 23	0.00	0.00	0.0	0.0	0.0	0.00	0.558	0.005	2.26	0.09	1219.	7.		
LER 24	0.00	0.00	0.0	0.0	0.0	0.00	0.413	0.005	2.32	0.10	1796.	10.		
LER 25	0.00	0.00	0.0	0.0	0.0	0.00	0.499	0.005	2.32	0.10	1668.	9.		
LER 26	0.00	0.00	0.0	0.0	0.0	0.00	0.494	0.005	2.28	0.09	1377.	8.		
LER 27	0.00	0.00	0.0	0.0	0.0	0.00	1.022	0.008	2.55	0.09	833.	5.		
LER 28	0.00	0.00	0.0	0.0	0.0	0.00	0.372	0.004	2.31	0.09	1221.	7.		
LER 29	0.00	0.00	0.0	0.0	0.0	0.00	0.842	0.007	2.12	0.09	1082.	7.		
LER 30	0.00	0.00	0.0	0.0	0.0	0.00	0.651	0.006	2.02	0.08	1199.	7.		
LER 31	0.00	0.00	0.0	0.0	0.0	0.00	0.271	0.004	1.78	0.09	1232.	7.		
LER 32	0.00	0.00	0.0	0.0	0.0	0.00	0.281	0.004	1.76	0.10	1562.	8.		
LER 33	0.00	0.00	0.0	0.0	0.0	0.00	0.199	0.003	1.36	0.06	402.	2.		
LER 34	0.00	0.00	0.0	0.0	0.0	0.00	0.250	0.004	1.68	0.09	1488.	8.		
LER 35	0.00	0.00	0.0	0.0	0.0	0.00	1.017	0.008	1.81	0.08	706.	4.		
LER 36	0.00	0.00	0.0	0.0	0.0	0.00	1.005	0.006	2.89	0.08	444.	3.		
LER 37	0.00	0.00	0.0	0.0	0.0	0.00	1.003	0.006	2.36	0.08	950.	6.		
LER 38	0.00	0.00	0.0	0.0	0.0	0.00	0.835	0.005	3.05	0.08	386.	3.		
LER 39	0.00	0.00	0.0	0.0	0.0	0.00	1.120	0.007	2.81	0.08	360.	3.		
LER 40	9.97	0.07	1.4	0.4	19.	0.03	0.650	0.010	2.17	0.11	240.	10.		
LER 41	0.00	0.00	0.0	0.0	0.0	0.00	0.604	0.007	2.44	0.11	1077.	8.		
LER 42	0.00	0.00	0.0	0.0	0.0	0.00	0.274	0.005	2.56	0.12	943.	7.		
LER 43	0.00	0.00	0.0	0.0	0.0	0.00	0.631	0.007	2.34	0.11	1292.	9.		
LER 44	0.00	0.00	0.0	0.0	0.0	0.00	0.408	0.006	2.50	0.11	1213.	9.		
LER 45	0.00	0.00	0.0	0.0	0.0	0.00	0.816	0.008	1.95	0.10	835.	6.		
LER 46	0.00	0.00	0.0	0.0	0.0	0.00	0.238	0.005	2.88	0.12	996.	7.		
LER 47	0.00	0.00	0.0	0.0	0.0	0.00	0.841	0.009	2.48	0.11	1172.	8.		
LER 48	0.00	0.00	0.0	0.0	0.0	0.00	0.372	0.006	1.63	0.10	1380.	10.		
LER 49	0.00	0.00	0.0	0.0	0.0	0.00	0.310	0.005	2.52	0.11	812.	6.		
LER 50	0.00	0.00	0.0	0.0	0.0	0.00	0.639	0.005	1.66	0.06	596.	3.		
LER 51	0.00	0.00	0.0	0.0	0.0	0.00	0.362	0.003	2.33	0.07	595.	3.		
LER 52	0.00	0.00	0.0	0.0	0.0	0.00	0.772	0.005	2.05	0.07	774.	5.		
LER 53	0.00	0.00	0.0	0.0	0.0	0.00	0.304	0.003	2.82	0.07	991.	6.		
LER 54	0.00	0.00	0.0	0.0	0.0	0.00	0.332	0.003	2.47	0.07	949.	5.		
LER 55	0.00	0.00	0.0	0.0	0.0	0.00	0.403	0.004	2.32	0.07	1002.	6.		
LER 56	0.00	0.00	0.0	0.0	0.0	0.00								

SAMPLE	(U) (PPM)	(SC) (PPM)	(W) (PPM)	LA (PPM)	(SM) (PPM)	YB (PPM)	(LU) (PPM)	AS (PPM)	(SB) (PPM)
LER 1	0.0	0.0	0.0	0.0	0.0	2.4	0.22	0.31	0.03
LER 2	0.0	0.0	0.0	0.0	0.0	2.9	0.22	0.37	0.02
LER 3	0.0	0.0	0.0	0.0	0.0	3.1	0.3	0.47	0.03
LER 4	0.0	0.0	0.0	0.0	0.0	1.9	0.2	0.35	0.02
LER 5	0.0	0.0	0.0	0.0	0.0	3.0	0.2	0.35	0.02
LER 6	0.0	0.0	0.0	0.0	0.0	3.2	0.2	0.47	0.03
LER 7	0.0	0.0	0.0	0.0	0.0	2.7	0.3	0.35	0.05
LER 8	3.7	1.4	0.0	0.0	0.0	3.3	1.6	0.46	0.13
LER 9	1.4	0.5	0.0	0.0	0.0	2.9	0.7	0.32	0.10
LER 10	1.2	0.4	0.0	0.0	0.0	2.0	0.6	0.26	0.08
LER 11	0.0	0.0	0.0	0.0	0.0	1.6	0.3	0.22	0.04
LER 12	0.0	0.0	0.0	0.0	0.0	1.9	0.3	0.32	0.05
LER 13	0.0	0.0	0.0	0.0	0.0	2.7	0.3	0.38	0.05
LER 14	0.0	0.0	0.0	0.0	0.0	3.1	0.4	0.28	0.05
LER 15	0.0	0.0	0.0	0.0	0.0	2.4	0.3	0.17	0.04
LER 16	0.0	0.0	0.0	0.0	0.0	1.8	0.3	0.35	0.05
LER 17	0.0	0.0	0.0	0.0	0.0	1.9	0.3	0.34	0.04
LER 18	0.0	0.0	0.0	0.0	0.0	3.2	0.4	0.28	0.05
LER 19	0.0	0.0	0.0	0.0	0.0	3.3	0.3	0.33	0.04
LER 20	0.0	0.0	0.0	0.0	0.0	3.1	0.4	0.33	0.05
LER 21	0.0	0.0	0.0	0.0	0.0	2.4	0.2	0.38	0.03
LER 22	0.0	0.0	0.0	0.0	0.0	3.7	0.3	0.46	0.03
LER 23	0.0	0.0	0.0	0.0	0.0	3.5	0.3	0.44	0.03
LER 24	0.0	0.0	0.0	0.0	0.0	4.1	0.3	0.50	0.03
LER 25	0.0	0.0	0.0	0.0	0.0	4.1	0.3	0.53	0.03
LER 26	0.0	0.0	0.0	0.0	0.0	3.9	0.3	0.47	0.03
LER 27	0.0	0.0	0.0	0.0	0.0	3.5	0.3	0.35	0.03
LER 28	0.0	0.0	0.0	0.0	0.0	3.3	0.3	0.33	0.02
LER 29	0.0	0.0	0.0	0.0	0.0	2.4	0.4	0.32	0.03
LER 30	0.0	0.0	0.0	0.0	0.0	3.1	0.3	0.42	0.03
LER 31	0.0	0.0	0.0	0.0	0.0	3.4	0.3	0.48	0.03
LER 32	0.0	0.0	0.0	0.0	0.0	4.0	0.3	0.51	0.03
LER 33	0.0	0.0	0.0	0.0	0.0	2.5	0.2	0.33	0.02
LER 34	0.0	0.0	0.0	0.0	0.0	3.4	0.3	0.50	0.03
LER 35	0.0	0.0	0.0	0.0	0.0	2.0	0.2	0.32	0.02
LER 36	0.0	0.0	0.0	0.0	0.0	3.7	0.3	0.55	0.10
LER 37	0.0	0.0	0.0	0.0	0.0	2.9	0.7	0.38	0.09
LER 38	0.0	0.0	0.0	0.0	0.0	3.1	0.7	0.47	0.10
LER 39	0.0	0.0	0.0	0.0	0.0	2.8	0.8	0.34	0.10
LER 40	5.5	1.1	0.0	0.0	0.0	2.6	0.3	0.33	0.04
LER 41	0.0	0.0	0.0	0.0	0.0	2.4	0.3	0.40	0.04
LER 42	0.0	0.0	0.0	0.0	0.0	2.2	0.3	0.35	0.04
LER 43	0.0	0.0	0.0	0.0	0.0	2.6	0.3	0.37	0.04
LER 44	0.0	0.0	0.0	0.0	0.0	2.6	0.3	0.23	0.04
LER 45	0.0	0.0	0.0	0.0	0.0	4.2	0.4	0.60	0.05
LER 46	0.0	0.0	0.0	0.0	0.0	2.8	0.3	0.42	0.05
LER 47	0.0	0.0	0.0	0.0	0.0	2.2	0.3	0.32	0.04
LER 48	0.0	0.0	0.0	0.0	0.0	4.1	0.3	0.33	0.04
LER 49	0.0	0.0	0.0	0.0	0.0	4.1	0.7	0.53	0.09
LER 50	0.0	0.0	0.0	0.0	0.0	4.6	0.6	0.62	0.09
LER 51	0.0	0.0	0.0	0.0	0.0	1.4	0.6	0.23	0.08
LER 52	0.0	0.0	0.0	0.0	0.0	1.4	0.6	0.23	0.08
LER 53	0.0	0.0	0.0	0.0	0.0	1.4	0.6	0.23	0.08
LER 54	0.0	0.0	0.0	0.0	0.0	1.4	0.6	0.23	0.08
LER 55	0.0	0.0	0.0	0.0	0.0	1.4	0.6	0.23	0.08
LER 56	0.0	0.0	0.0	0.0	0.0	1.4	0.6	0.23	0.08

SAMPLE	RB (PPM)	ES (PPM)	EA (PPM)	SC (PPM)	CE (PPM)	EU (PPM)	TH (PPM)
LER 1	68.	20.	6.2	0.5	C.	0.	13.8
LER 2	211.	103.	3.3	0.7	0.	0.	15.6
LER 3	149.	83.	4.4	0.5	0.	0.	26.1
LER 4	160.	84.	6.0	0.8	0.	0.	18.2
LER 5	211.	102.	4.7	0.7	0.	0.	12.1
LER 6	210.	102.	5.3	0.7	0.	0.	11.9
LER 7	139.	37.	6.1	1.1	0.	0.	22.0
LER 8	0.	0.	6.6	0.1	0.	0.	18.2
LER 9	0.	0.	5.9	0.1	0.	0.	21.4
LER 10	0.	0.	5.5	0.1	0.	0.	22.0
LER 11	76.	25.	4.4	0.5	0.	0.	17.5
LER 12	171.	41.	11.3	1.4	0.	0.	19.8
LER 13	117.	32.	12.0	1.4	0.	0.	15.4
LER 14	169.	41.	12.0	1.4	0.	0.	18.3
LER 15	177.	43.	12.4	1.5	0.	0.	15.7
LER 16	159.	38.	8.6	1.1	0.	0.	14.7
LER 17	135.	35.	5.7	1.0	0.	0.	18.8
LER 18	168.	41.	8.5	1.2	0.	0.	20.5
LER 19	163.	40.	5.1	1.2	0.	0.	20.4
LER 20	197.	47.	8.2	1.2	0.	0.	21.7
LER 21	98.	34.	5.8	0.9	0.	0.	15.4
LER 22	90.	34.	5.1	1.2	0.	0.	20.5
LER 23	88.	34.	6.0	0.9	0.	0.	17.6
LER 24	163.	51.	10.9	1.2	0.	0.	20.6
LER 25	110.	39.	5.7	1.2	0.	0.	15.5
LER 26	149.	46.	7.1	1.0	0.	0.	16.7
LER 27	150.	48.	6.6	1.0	0.	0.	21.0
LER 28	59.	28.	6.0	0.5	0.	0.	14.7
LER 29	133.	44.	6.5	1.0	0.	0.	16.5
LER 30	96.	37.	6.2	1.0	0.	0.	16.5
LER 31	186.	90.	7.5	0.7	0.	0.	14.4
LER 32	274.	127.	7.4	0.7	0.	0.	14.4
LER 33	188.	84.	4.6	0.5	0.	0.	10.6
LER 34	200.	120.	7.5	0.5	0.	0.	12.8
LER 35	181.	88.	3.1	0.6	0.	0.	11.5
LER 36	114.	44.	6.0	1.2	0.	0.	20.4
LER 37	67.	36.	3.6	1.2	0.	0.	21.3
LER 38	62.	36.	9.5	1.6	0.	0.	21.5
LER 39	163.	58.	7.1	1.4	0.	0.	23.0
LER 40	0.	0.	10.5	0.2	0.	0.	23.0
LER 41	161.	40.	9.8	1.2	0.	0.	22.2
LER 42	179.	44.	10.7	1.4	0.	0.	22.1
LER 43	129.	34.	5.2	1.2	0.	0.	20.4
LER 44	173.	43.	10.4	1.2	0.	0.	22.0
LER 45	124.	32.	5.1	0.5	0.	0.	15.1
LER 46	217.	53.	12.3	1.6	0.	0.	25.5
LER 47	163.	41.	7.2	1.1	0.	0.	21.5
LER 48	84.	27.	6.3	1.0	0.	0.	16.2
LER 49	195.	47.	14.3	1.6	0.	0.	20.5
LER 50	67.	36.	3.8	1.1	0.	0.	16.1
LER 51	158.	56.	5.4	1.2	0.	0.	20.3
LER 52	83.	39.	3.8	1.1	0.	0.	17.8
LER 53	35.	33.	7.9	1.4	0.	0.	22.2
LER 54	85.	42.	9.4	1.6	0.	0.	20.2
LER 55	44.	34.	7.1	1.3	0.	0.	18.1
LER 56							

SAMPLE	HF (PPM)	(TA) (PPM)	CR (PPM)	FE (1)	CC (PPM)	(NI) (PPM)	SD (PPM)							
LER 1	5.4	0.6	0.48	0.52	596.	32.	3.81	0.11	33.7	0.9	0.	0.	0.00	0.00
LER 2	5.1	0.4	0.79	0.38	175.	10.	3.91	0.09	27.3	0.7	0.	0.	0.00	0.00
LFR 3	4.8	0.5	0.53	0.42	82.	8.	5.47	0.12	25.1	0.7	0.	0.	0.00	0.00
LER 4	3.6	0.4	0.56	0.17	350.	18.	4.30	0.10	22.9	0.8	0.	0.	0.00	0.00
LER 5	5.6	0.4	0.93	0.17	481.	24.	3.22	0.08	27.8	0.7	0.	0.	0.00	0.00
LER 6	6.4	0.5	0.74	0.35	182.	10.	3.32	0.08	25.9	0.6	0.	0.	0.00	0.00
LER 7	4.5	0.5	0.59	0.51	375.	18.	5.02	0.12	26.9	1.1	0.	0.	0.00	0.00
LER 8	6.4	1.0	0.13	0.00	190.	20.	4.33	0.85	10.1	0.2	0.	0.	0.00	0.00
LER 9	3.7	0.8	0.02	0.00	550.	47.	5.60	1.00	65.8	0.5	0.	0.	0.00	0.00
LER 10	4.7	1.0	0.02	0.00	781.	62.	5.56	0.97	65.5	0.5	0.	0.	0.00	0.00
LER 11	3.8	0.4	0.40	0.42	774.	35.	4.32	0.10	22.2	1.0	0.	0.	0.00	0.00
LER 12	3.7	0.4	0.44	0.42	217.	11.	4.32	0.10	24.4	0.7	0.	0.	0.00	0.00
LER 13	4.6	0.5	0.58	0.48	275.	12.	4.39	0.11	26.6	0.8	0.	0.	0.00	0.00
LER 14	4.8	0.5	0.32	0.51	218.	11.	4.24	0.10	25.2	0.7	0.	0.	0.00	0.00
LER 15	4.1	0.4	0.89	0.50	224.	12.	4.39	0.11	27.4	0.9	0.	0.	0.00	0.00
LER 16	5.7	0.5	0.70	0.46	123.	7.	3.54	0.05	12.7	0.8	0.	0.	0.00	0.00
LFR 17	3.6	0.4	0.71	0.42	367.	18.	4.56	0.11	26.6	0.9	0.	0.	0.00	0.00
LER 18	5.2	0.5	0.49	0.47	368.	18.	4.84	0.12	29.7	1.0	0.	0.	0.00	0.00
LER 19	5.2	0.5	0.45	0.47	342.	16.	4.91	0.12	27.0	1.0	0.	0.	0.00	0.00
LER 20	4.6	0.5	0.64	0.53	351.	17.	5.27	0.13	25.7	1.3	0.	0.	0.00	0.00
LER 21	3.8	0.5	1.19	0.51	587.	37.	5.06	0.13	35.9	0.9	0.	0.	0.00	0.00
LER 22	6.6	0.6	2.05	0.67	241.	17.	5.15	0.13	35.1	0.9	0.	0.	0.00	0.00
LER 23	7.6	0.6	0.77	0.52	241.	17.	4.70	0.12	26.8	0.8	0.	0.	0.00	0.00
LER 24	5.6	0.6	1.09	0.59	272.	19.	6.63	0.16	38.1	1.1	0.	0.	0.00	0.00
LER 25	6.7	0.6	1.86	0.67	231.	16.	5.02	0.13	35.5	1.0	0.	0.	0.00	0.00
LER 26	6.6	0.6	1.01	0.46	234.	16.	4.56	0.12	32.5	0.8	0.	0.	0.00	0.00
LER 27	5.6	0.6	1.26	0.55	314.	21.	5.24	0.12	36.8	1.1	0.	0.	0.00	0.00
LER 28	2.6	0.4	0.45	0.75	291.	19.	4.07	0.10	26.1	0.7	0.	0.	0.00	0.00
LER 29	5.5	0.6	1.19	0.56	483.	31.	5.28	0.13	35.7	1.1	0.	0.	0.00	0.00
LFR 30	6.4	0.6	0.79	0.48	208.	15.	5.03	0.13	27.7	0.7	0.	0.	0.00	0.00
LER 31	6.3	0.5	0.48	0.44	202.	9.	3.66	0.08	34.1	0.7	0.	0.	0.00	0.00
LER 32	6.5	0.5	0.73	0.48	212.	10.	3.74	0.08	32.2	0.7	0.	0.	0.00	0.00
LER 33	4.5	0.5	0.89	0.41	235.	10.	3.27	0.17	16.3	0.4	0.	0.	0.00	0.00
LER 34	7.7	2.0	1.30	0.50	200.	11.	3.31	0.08	24.8	0.5	0.	0.	0.00	0.00
LFR 35	5.1	0.4	0.61	0.32	214.	12.	2.96	0.07	17.0	0.5	0.	0.	0.00	0.00
LER 36	7.5	1.2	0.78	0.67	339.	41.	5.33	0.24	34.4	1.5	0.	0.	0.00	0.00
LER 37	6.0	1.1	0.62	0.65	390.	46.	5.29	0.24	32.9	1.3	0.	0.	0.00	0.00
LER 38	6.8	1.2	1.17	0.73	281.	25.	5.51	0.25	32.9	1.5	0.	0.	0.00	0.00
LER 39	6.6	1.2	1.79	0.68	244.	32.	6.01	0.27	32.2	1.5	0.	0.	0.00	0.00
LER 40	5.4	0.8	0.27	0.60	345.	27.	4.50	0.80	40.0	0.5	0.	0.	0.00	0.00
LER 41	4.5	0.5	1.01	0.49	27.7.	14.	4.99	0.12	30.5	0.8	0.	0.	0.00	0.00
LER 42	2.8	0.4	1.19	0.53	221.	12.	5.02	0.12	26.3	0.9	0.	0.	0.00	0.00
LER 43	4.3	0.5	0.78	0.46	239.	12.	4.64	0.11	27.2	0.8	0.	0.	0.00	0.00
LER 44	3.4	0.4	1.08	0.50	248.	13.	5.13	0.12	31.2	0.9	0.	0.	0.00	0.00
LER 45	3.7	0.4	0.31	0.37	157.	10.	3.32	0.08	21.2	0.6	0.	0.	0.00	0.00
LER 46	4.4	0.5	0.79	0.56	387.	19.	6.97	0.16	45.2	1.3	0.	0.	0.00	0.00
LER 47	4.4	0.5	1.24	0.61	366.	15.	4.82	0.12	31.8	0.9	0.	0.	0.00	0.00
LER 48	4.0	0.4	1.36	0.52	712.	32.	4.19	0.10	35.0	1.0	0.	0.	0.00	0.00
LER 49	3.6	0.4	0.82	0.45	216.	11.	4.47	0.11	24.5	0.7	0.	0.	0.00	0.00
LER 51	7.1	1.2	2.16	0.55	210.	28.	5.39	0.24	25.9	1.2	0.	0.	0.00	0.00
LER 52	6.6	1.2	2.17	0.92	320.	35.	5.35	0.24	25.3	1.1	0.	0.	0.00	0.00
LER 53	6.5	1.1	0.50	0.65	329.	40.	5.32	0.24	24.6	1.8	0.	0.	0.00	0.00
LER 54	3.5	1.0	0.05	0.35	331.	40.	5.50	0.25	19.1	1.4	0.	0.	0.00	0.00
LER 55	3.8	1.0	2.11	0.35	268.	34.	5.33	0.24	19.1	1.7	0.	0.	0.00	0.00
LFR 56	3.6	0.9	0.07	0.00	267.	33.	4.48	0.20	22.9	1.4	0.	0.	0.00	0.00

SAMPLE	AL (%)	MG (%)	CA (%)	V (PPM)	TI (%)	(NA) (%)	NA (%)	K (%)	MN (PPM)
PHL 1	0.00	0.00	0.0	0.0	0.0	0.00	0.214	1.26	739.
PHL 2	7.81	0.06	1.5	0.3	7.9	0.3	0.507	2.19	765.
PHL 3	7.57	0.06	1.5	0.3	7.8	0.3	0.617	2.11	742.
PHL 4	7.67	0.06	2.1	0.3	8.5	0.3	0.938	1.51	1211.
PHL 5	7.68	0.06	1.6	0.3	8.8	0.3	0.608	1.78	865.
PHL 7	0.00	0.00	0.0	0.0	0.0	0.0	0.355	1.80	1267.
PHL 8	0.00	0.00	0.0	0.0	0.0	0.0	0.859	1.07	1463.
PHL 9	0.00	0.00	0.0	0.0	0.0	0.0	0.385	1.92	1884.
PHL 10	0.00	0.00	0.0	0.0	0.0	0.0	0.518	2.18	1622.
PHL 11	0.00	0.00	0.0	0.0	0.0	0.0	0.180	1.66	2616.
PHL 12	0.00	0.00	0.0	0.0	0.0	0.0	0.333	1.46	2580.
PHL 13	0.00	0.00	0.0	0.0	0.0	0.0	0.726	1.93	959.
PHL 14	5.81	0.05	0.6	0.2	11.7	0.3	0.286	1.44	1890.
PHL 18	7.15	0.06	1.6	0.3	10.9	0.3	0.646	2.05	871.
PHL 23	0.00	0.00	0.0	0.0	0.0	0.0	1.149	2.13	637.
PHL 24	0.00	0.00	0.0	0.0	0.0	0.0	0.498	2.19	881.

SAMPLE	(U) (PPM)	(SC) (PPM)	W (PPM)	LA (PPM)	(SN) (PPM)	YB (PPM)	(LU) (PPM)	AS (PPM)	(SB) (PPM)
PHL 1	0.0	0.0	0.0	21.	3.	40.7	0.38	24.1	0.00
PHL 2	22.5	0.8	20.5	31.	1.	32.9	0.451	3.3	0.75
PHL 3	22.7	0.8	19.5	32.	1.	32.2	0.34	3.9	0.44
PHL 4	1.5	0.3	21.7	89.	2.	31.6	0.43	7.1	0.49
PHL 5	22.5	0.7	20.1	26.	1.	32.9	0.39	4.0	0.47
PHL 7	0.0	0.0	0.0	28.	4.	35.1	0.41	10.3	0.00
PHL 8	0.0	0.0	0.0	16.	2.	32.6	0.36	10.5	0.00
PHL 9	0.0	0.0	0.0	25.	4.	32.1	0.37	7.8	0.00
PHL 10	0.0	0.0	0.0	7.	1.	33.9	0.32	4.4	0.00
PHL 11	0.0	0.0	0.0	9.	2.	30.6	0.46	29.0	0.00
PHL 12	0.0	0.0	0.0	15.	2.	38.9	0.43	22.6	0.00
PHL 13	0.0	0.0	0.0	0.	1.	34.6	0.5	16.2	0.00
PHL 14	22.3	0.6	16.9	128.	2.	40.3	0.50	20.2	0.80
PHL 18	22.4	0.9	19.0	47.	1.	30.7	0.30	4.0	0.78
PHL 23	0.0	0.0	0.0	23.	3.	27.8	0.32	15.1	0.00
PHL 24	0.0	0.0	0.0	24.	3.	33.5	0.32	4.8	0.00

SAMPLE		RB (PPM)		CS (PPM)		(EA) (PPM)		SC (PPM)		CE (PPM)		EU (PPM)		TH (PPM)	
PHL 1	105.	43.	8.4	1.1	C.	15.1	C.1	65.3	2.2	1.42	0.13	10.8	C.2		
PHL 2	123.	8.	8.7	0.2	451.	64.	15.2	C.1	72.1	1.5	1.27	0.06	8.1	0.2	
PHL 3	110.	14.	8.2	0.5	215.	70.	19.3	C.1	72.5	2.3	1.12	0.06	8.5	0.4	
PHL 4	99.	15.	14.5	1.2	415.	144.	21.8	C.1	73.1	2.8	1.26	0.10	8.1	0.4	
PHL 5	69.	14.	6.1	0.5	543.	125.	15.6	C.1	73.4	2.8	1.23	0.11	8.5	0.4	
PHL 7	108.	49.	10.9	1.4	0.	0.	24.6	C.1	73.7	2.4	1.38	0.13	13.0	1.0	
PHL 8	82.	42.	11.9	1.2	0.	0.	20.6	C.1	71.2	2.3	1.44	0.13	13.8	1.0	
PHL 9	121.	22.	7.2	1.1	0.	0.	20.7	C.1	68.5	2.3	1.26	0.12	11.8	0.5	
PHL 10	159.	63.	10.7	1.4	0.	0.	21.8	C.1	68.1	2.4	1.37	0.13	11.4	0.9	
PHL 11	127.	55.	11.1	1.4	0.	0.	20.5	C.1	61.7	2.7	1.81	0.16	12.9	1.0	
PHL 12	150.	61.	11.8	1.4	0.	0.	19.0	C.1	68.4	2.6	2.03	0.17	13.1	1.0	
PHL 13	167.	66.	12.2	1.5	0.	0.	22.5	C.1	71.1	2.4	1.40	0.13	10.7	0.9	
PHL 14	67.	18.	5.1	0.3	1157.	94.	16.6	C.1	50.5	3.1	1.55	0.05	10.1	0.3	
PHL 18	118.	13.	9.6	0.5	0.	0.	15.1	C.1	65.5	2.5	1.05	0.08	7.6	0.4	
PHL 23	188.	71.	7.1	1.1	0.	0.	21.3	C.1	65.7	2.3	1.19	0.12	11.5	0.9	
PHL 24	106.	50.	12.1	1.5	0.	0.	22.8	C.1	76.0	2.4	1.25	0.12	12.8	1.0	

SAMPLE		HF (PPM)		(TA) (PPM)		CR (PPM)		FE (%)		CC (PPM)		(NI) (PPM)		SD (PPM)
PHL	1	4.2	0.5	0.32	0.30	154.	13.	3.48	0.10	17.2	0.6	0.	0.	0.00
PHL	2	4.4	0.2	0.72	0.07	232.	6.	4.73	0.03	23.5	0.2	125.	21.	0.34
PHL	3	4.7	0.4	0.61	0.05	233.	11.	5.31	0.05	23.9	0.4	109.	29.	0.83
PHL	4	4.1	0.5	0.59	0.09	421.	16.	5.61	0.06	23.1	0.5	258.	70.	0.43
PHL	5	5.0	0.4	0.40	0.06	241.	12.	4.78	0.05	23.2	0.4	0.	0.	0.27
PHL	7	0.0	0.0	0.72	0.41	262.	17.	5.95	0.17	23.0	1.1	0.	0.	0.00
PHL	8	6.0	0.6	0.46	0.36	278.	17.	5.66	0.16	23.2	0.9	0.	0.	0.00
PHL	9	4.3	0.6	0.60	0.37	243.	16.	5.62	0.16	23.1	1.0	0.	0.	0.00
PHL	10	4.1	0.6	0.62	0.38	228.	15.	5.44	0.15	23.5	0.9	0.	0.	0.00
PHL	11	5.4	0.6	0.69	0.40	330.	20.	5.79	0.16	23.4	1.2	0.	0.	0.00
PHL	12	5.2	0.6	0.90	0.40	302.	19.	5.43	0.15	23.6	1.3	0.	0.	0.00
PHL	13	4.2	0.6	1.27	0.43	224.	15.	5.24	0.15	23.8	0.9	0.	0.	0.00
PHL	14	6.8	0.3	0.79	0.17	243.	8.	4.40	0.03	23.5	0.3	167.	35.	0.58
PHL	18	4.5	0.4	0.61	0.05	225.	11.	4.81	0.05	23.8	1.6	145.	34.	0.60
PHL	23	5.3	0.6	0.39	0.35	199.	14.	4.25	0.14	23.5	0.7	0.	0.	0.00
PHL	24	4.1	0.6	0.68	0.35	267.	17.	5.45	0.15	23.5	0.9	0.	0.	0.00

SAMPLE	AL (%)	NG (%)	CA (%)	V (PPM)	TI (%)	(NA) (%)	NA (%)	K (%)	MN (PPM)									
TIR 1	7.67	0.06	1.8	0.3	3.7	0.2	120.	4.	0.46	0.02	0.59	0.02	1.038	0.006	2.13	0.28	961.	14.
TIR 2	7.83	0.06	2.4	0.3	3.3	0.2	129.	4.	0.47	0.03	1.00	0.02	1.054	0.006	3.56	0.37	830.	14.
TIP 3	8.47	0.06	2.5	0.3	0.4	0.1	127.	4.	0.56	0.03	0.56	0.02	1.017	0.007	2.85	0.42	726.	13.
TIR 4	8.07	0.06	2.3	0.3	1.6	0.1	116.	4.	0.51	0.03	1.23	0.03	1.334	0.008	3.16	0.46	816.	14.
TIR 5	8.29	0.06	2.3	0.3	1.0	0.1	139.	4.	0.55	0.03	0.92	0.02	1.018	0.010	3.06	0.15	734.	13.
TIR 6	8.52	0.06	2.4	0.3	1.9	0.2	152.	4.	0.50	0.03	1.00	0.03	1.014	0.004	2.94	0.15	750.	15.
TIR 7	7.26	0.06	1.5	0.3	7.6	0.3	107.	4.	0.44	0.03	0.60	0.02	0.672	0.003	2.18	0.15	902.	15.
TIR 8	8.32	0.06	2.3	0.3	1.1	0.1	134.	4.	0.45	0.03	1.14	0.02	1.218	0.004	2.55	0.15	726.	13.
TIR 9	8.58	0.06	2.7	0.3	0.9	0.1	126.	4.	0.51	0.03	1.26	0.03	1.251	0.004	2.61	0.19	805.	14.
TIR 10	7.30	0.06	2.4	0.3	5.7	0.2	119.	4.	0.46	0.03	0.86	0.02	0.914	0.004	2.51	0.18	856.	14.
TIR 11	8.08	0.06	2.6	0.3	0.8	0.1	121.	4.	0.56	0.03	1.09	0.02	1.119	0.006	2.73	0.22	818.	14.
TIR 12	8.37	0.06	1.7	0.3	1.9	0.1	127.	4.	0.45	0.03	0.57	0.02	1.031	0.006	2.11	0.20	722.	13.
TIR 13	8.14	0.06	2.3	0.3	2.1	0.1	134.	4.	0.45	0.02	1.01	0.02	1.051	0.004	2.77	0.23	676.	12.
TIR 14	7.66	0.05	2.2	0.3	1.7	0.1	121.	4.	0.45	0.02	0.59	0.02	1.033	0.005	2.80	0.27	604.	11.
TIR 15	7.66	0.05	2.2	0.3	1.2	0.1	122.	4.	0.44	0.02	1.00	0.02	1.096	0.005	2.78	0.29	763.	12.
TIP 16	8.59	0.06	2.3	0.3	0.6	0.1	124.	4.	0.55	0.02	1.18	0.02	1.257	0.008	2.63	0.40	606.	11.
TIR 17	8.33	0.06	2.6	0.3	2.2	0.1	125.	4.	0.55	0.02	1.11	0.02	1.125	0.003	2.97	0.13	569.	12.
TIR 18	7.82	0.06	2.0	0.3	0.7	0.1	127.	4.	0.47	0.03	1.01	0.02	0.959	0.002	2.65	0.08	839.	14.
TIR 19	8.34	0.06	2.4	0.3	0.7	0.1	132.	4.	0.51	0.02	0.90	0.02	0.930	0.002	2.77	0.09	787.	13.
TIR 20	7.19	0.06	1.3	0.3	7.1	0.2	110.	3.	0.43	0.02	0.84	0.02	0.882	0.006	2.06	0.07	980.	14.
TIR 26	9.16	0.06	3.0	0.3	5.8	0.2	177.	4.	0.56	0.03	0.71	0.02	0.683	0.001	3.23	0.07	997.	16.
TIR 31	7.87	0.06	2.5	0.3	3.0	0.2	123.	4.	0.47	0.03	1.05	0.02	1.058	0.002	2.95	0.12	777.	14.
TIR 32	7.58	0.06	2.5	0.3	1.4	0.1	129.	3.	0.45	0.02	1.03	0.02	1.043	0.003	2.77	0.14	748.	13.
TIR 33	8.59	0.06	2.1	0.3	2.4	0.2	143.	4.	0.54	0.03	0.77	0.02	0.797	0.002	2.99	0.08	978.	15.
TIR 34	8.23	0.06	2.0	0.3	2.0	0.1	131.	4.	0.54	0.03	1.09	0.02	1.142	0.003	2.86	0.16	784.	14.
TIR 35	8.44	0.06	2.2	0.3	1.4	0.1	128.	4.	0.48	0.03	1.10	0.02	1.108	0.003	2.55	0.14	657.	13.
TIR 36	8.40	0.06	1.3	0.3	1.0	0.1	131.	4.	0.47	0.02	0.89	0.02	0.969	0.003	2.94	0.15	588.	13.
TIR 37	8.25	0.06	1.8	0.3	3.4	0.2	137.	4.	0.54	0.03	1.03	0.03	1.122	0.007	2.63	0.24	863.	16.
TIR 38	7.01	0.06	3.0	0.3	10.7	0.2	124.	4.	0.43	0.03	0.42	0.02	0.406	0.002	2.80	0.19	1455.	20.
TIR 39	8.20	0.06	1.8	0.3	3.3	0.2	132.	4.	0.46	0.02	0.80	0.02	0.823	0.003	3.31	0.16	766.	14.
TIR 40	8.50	0.06	2.3	0.3	1.0	0.1	127.	4.	0.51	0.02	1.08	0.02	1.096	0.003	3.09	0.16	679.	13.
TIR 41	7.61	0.07	2.6	0.3	5.7	0.3	117.	4.	0.48	0.02	0.59	0.03	0.553	0.003	2.71	0.11	758.	16.
TIR 42	7.92	0.06	2.3	0.3	2.3	0.2	122.	4.	0.51	0.02	1.15	0.03	1.157	0.004	2.34	0.17	562.	13.
TIR 43	7.93	0.06	2.0	0.3	2.5	0.2	133.	4.	0.47	0.02	0.92	0.02	0.937	0.004	2.61	0.17	840.	15.
TIR 44	8.33	0.06	2.0	0.3	1.6	0.1	128.	4.	0.45	0.02	0.73	0.02	0.767	0.003	3.12	0.17	633.	12.
TIR 45	8.78	0.06	2.5	0.3	0.6	0.1	125.	4.	0.55	0.02	1.17	0.02	1.229	0.004	2.94	0.21	692.	13.
TIR 56	7.79	0.06	2.6	0.3	8.8	0.3	145.	4.	0.40	0.02	0.38	0.02	0.373	0.001	2.84	0.07	781.	14.
TIR 57	7.52	0.06	2.6	0.3	8.4	0.3	137.	4.	0.45	0.02	0.40	0.02	0.408	0.001	2.78	0.07	1201.	17.
TIR 58	8.21	0.06	2.8	0.3	7.7	0.3	165.	4.	0.46	0.02	0.97	0.02	0.973	0.004	2.12	0.44	977.	15.
TIR 59	7.28	0.06	2.8	0.3	8.8	0.3	132.	4.	0.43	0.02	0.38	0.02	0.426	0.001	2.80	0.07	1260.	17.
TIR 60	7.54	0.06	2.4	0.3	11.0	0.3	137.	4.	0.43	0.02	0.28	0.02	0.312	0.002	2.42	0.10	819.	13.
TIR 61	7.38	0.06	2.9	0.3	8.8	0.3	126.	4.	0.42	0.02	0.43	0.02	0.456	0.008	2.84	0.14	1180.	16.
TIR 62	7.55	0.06	3.1	0.3	8.2	0.3	137.	4.	0.46	0.02	0.42	0.02	0.445	0.006	2.57	0.13	1151.	17.
TIR 70	6.39	0.07	2.7	0.3	13.6	0.4	145.	4.	0.42	0.03	0.36	0.02	0.351	0.001	2.04	0.09	1009.	19.
TIR 73	7.61	0.06	2.8	0.3	3.4	0.2	125.	4.	0.46	0.02	1.01	0.02	1.033	0.005	2.48	0.26	703.	13.
TIR 74	7.81	0.06	2.6	0.3	4.2	0.2	123.	4.	0.46	0.02	0.98	0.02	1.037	0.006	2.65	0.29	664.	14.
TIR 75	8.41	0.06	2.7	0.3	0.9	0.1	135.	4.	0.45	0.02	1.05	0.02	1.076	0.020	2.67	0.31	712.	12.
TIR 76	9.37	0.06	1.2	0.3	0.3	0.1	146.	4.	0.57	0.02	0.43	0.02	0.457	0.003	2.28	0.15	939.	14.
TIR 77	8.09	0.06	2.4	0.3	12.0	0.4	151.	4.	0.44	0.02	0.33	0.02	0.346	0.002	2.45	0.12	1053.	16.
TIR 79	8.60	0.06	1.4	0.3	7.9	0.3	119.	3.	0.45	0.02	1.04	0.02	1.136	0.007	2.65	0.29	885.	14.
TIR 80	7.71	0.06	1.9	0.3	8.2	0.3	130.	4.	0.46	0.02	1.07	0.02	1.167	0.007	2.81	0.38	1005.	15.
TIR 81	8.15	0.06	2.1	0.3	6.6	0.3	152.	4.	0.45	0.02	1.24	0.02	1.242	0.004	2.22	0.36	586.	15.
TIR 82	7.60	0.06	1.9	0.3	10.2	0.3	132.	4.	0.46	0.02	0.52	0.02	0.931	0.003	2.81	0.16	1049.	15.
TIR 83	7.49	0.06	1.4	0.2	2.3	0.1	44.	3.	0.38	0.02	0.64	0.02	0.708	0.003	1.63	0.12	780.	12.
TIR 84	6.77	0.05	1.5	0.2	7.3	0.3	112.	3.	0.43	0.02	1.29	0.02	1.370	0.004	2.09	0.16	666.	14.
TIR 85	7.43	0.05	2.1	0.2	4.6	0.2	116.	3.	0.45	0.02	0.89	0.02	0.939	0.002	2.56	0.10	638.	11.
TIR 86	7.39	0.06	2.9	0.2	8.3	0.3	126.	4.	0.44	0.02	0.45	0.02	0.476	0.001	2.64	0.07	1177.	16.
TIR 87	8.40	0.06	2.8	0.3	8.0	0.3	170.	4.	0.35	0.02	0.42	0.02	0.461	0.001	2.63	0.08	579.	15.
TIR 88	7.22	0.06	2.6	0.3	15.2	0.4	138.	4.	0.35	0.02	0.25	0.02	0.247	0.001	2.63	0.06	596.	15.

SAMPLE	(U) (PPM)	(SC) (PPM)	(PFM)	W (PPM)	LA (PPM)	(SN) (PPM)	YB (PPM)	(LU) (PPM)	AS (PPM)	(SB) (PPM)					
TIR 1	0.9	0.4	20.7	0.4	159.	36.3	0.2	3.1	0.4	0.45	0.10	8.9	1.6	0.53	0.24
TIR 2	1.7	0.4	20.7	0.4	131.	37.1	0.2	2.6	0.4	0.43	0.23	9.1	1.5	0.60	0.00
TIR 3	3.1	1.3	21.4	0.4	190.	43.5	0.5	2.6	0.4	0.46	0.15	5.8	1.3	0.61	0.21
TIR 4	1.1	0.4	20.6	0.4	144.	43.1	0.2	2.8	0.4	0.47	0.11	5.3	0.8	0.60	0.00
TIR 5	2.3	0.5	21.0	0.4	254.	42.4	0.2	2.9	0.5	0.10	0.17	13.9	1.2	0.80	0.23
TIR 6	3.2	1.2	20.7	0.4	256.	40.3	0.4	2.9	0.4	0.10	0.18	21.2	1.6	0.60	0.00
TIR 7	0.0	0.0	17.6	0.4	112.	34.4	0.1	2.2	0.4	0.45	0.11	8.9	1.2	0.63	0.25
TIR 8	1.3	0.5	20.7	0.4	108.	44.4	0.2	3.1	0.5	0.22	0.12	11.9	1.5	0.66	0.26
TIR 9	1.0	0.4	20.4	0.4	149.	40.7	0.2	2.4	0.4	0.38	0.13	8.9	1.2	0.60	0.00
TIR 10	1.6	0.5	19.5	0.4	99.	22.6	0.2	1.8	0.3	0.31	0.14	12.6	1.5	0.66	0.23
TIR 11	0.9	0.4	21.3	0.4	207.	42.5	0.2	2.8	0.5	0.85	0.42	8.4	1.5	0.70	0.27
TIR 12	3.9	1.3	20.5	0.4	96.	41.2	0.4	3.1	0.4	0.39	0.15	4.3	1.2	0.60	0.00
TIR 13	2.1	0.5	20.1	0.4	101.	37.3	0.2	2.5	0.3	0.42	0.10	8.2	1.1	0.56	0.19
TIR 14	2.0	0.8	20.6	0.7	128.	35.6	0.3	2.3	0.3	0.14	0.10	8.4	1.4	0.63	0.22
TIR 15	0.0	0.0	20.3	0.4	94.	38.4	0.0	2.3	0.3	0.52	0.08	5.3	0.6	0.60	0.00
TIR 16	0.6	0.2	21.1	0.4	67.	45.3	0.1	3.0	0.3	0.54	0.13	10.1	1.8	0.93	0.25
TIR 17	2.4	0.8	20.5	0.4	51.	38.6	0.3	2.2	0.4	0.40	0.15	6.5	0.6	0.60	0.00
TIR 18	1.6	0.4	20.1	0.7	40.	33.7	0.2	2.0	0.4	0.46	0.16	10.4	1.3	0.61	0.25
TIR 19	2.5	1.2	21.3	0.6	73.	42.9	0.4	2.2	0.4	0.33	0.20	7.5	0.9	0.60	0.00
TIR 20	2.7	1.0	17.8	0.3	24.	32.0	0.3	2.2	0.4	0.32	0.15	7.1	0.5	0.60	0.00
TIR 26	1.3	0.4	26.8	0.4	14.	32.0	0.2	2.6	0.4	0.48	0.14	5.3	0.5	0.60	0.00
TIR 31	3.1	1.2	19.6	0.4	51.	22.2	0.4	2.4	0.5	0.09	0.16	8.3	1.3	0.92	0.28
TIR 32	1.3	0.3	20.3	0.4	63.	27.0	0.1	2.5	0.2	0.23	0.08	10.4	1.4	0.56	0.25
TIR 33	1.4	0.3	21.6	0.4	64.	42.1	0.2	2.2	0.3	0.38	0.15	9.4	1.0	0.60	0.00
TIR 34	0.0	0.0	19.9	0.4	119.	35.3	0.1	2.3	0.4	0.24	0.09	11.6	1.3	0.86	0.27
TIR 35	1.8	0.4	20.2	0.4	79.	40.8	0.2	3.0	0.4	0.43	0.14	10.7	1.5	0.88	0.26
TIR 36	2.6	0.6	19.7	0.4	165.	37.5	0.2	2.8	0.3	0.23	0.10	8.5	0.6	0.56	0.14
TIR 37	0.0	0.0	21.2	0.4	53.	36.4	0.7	2.1	0.3	0.40	0.08	8.1	2.1	0.60	0.00
TIR 38	1.2	0.4	21.1	0.4	15.	29.4	0.1	1.7	0.4	0.35	0.12	20.5	1.5	0.60	0.00
TIR 39	1.8	0.5	21.4	0.4	82.	33.1	0.3	1.6	0.2	0.41	0.14	4.4	1.0	0.60	0.00
TIR 40	0.9	0.2	20.0	0.4	84.	38.6	0.1	2.4	0.3	0.33	0.12	6.4	1.2	0.60	0.00
TIR 41	1.8	0.5	19.6	0.7	68.	36.3	0.2	1.9	0.4	0.18	0.15	6.3	1.3	0.81	0.29
TIR 42	1.3	0.4	19.4	0.4	141.	35.2	0.2	1.7	0.4	0.08	0.10	6.7	1.2	0.60	0.00
TIR 43	0.0	0.0	20.0	0.4	142.	35.5	0.1	3.1	0.4	0.09	0.10	10.8	1.3	0.80	0.26
TIR 44	1.3	0.4	20.1	0.4	158.	35.9	0.2	1.9	0.4	0.32	0.13	5.1	0.9	0.60	0.00
TIR 45	2.8	1.2	20.8	0.4	124.	44.4	0.4	2.6	0.4	0.30	0.17	8.1	1.3	0.60	0.21
TIR 56	1.5	0.6	22.1	0.4	45.	36.4	0.2	2.2	0.3	0.26	0.13	3.6	0.4	0.60	0.00
TIR 57	2.5	1.2	22.0	0.4	23.	36.3	0.3	1.9	0.4	0.26	0.16	9.4	1.0	0.60	0.00
TIR 58	1.4	0.4	24.5	0.4	58.	31.1	0.2	2.0	0.3	0.25	0.11	3.1	0.6	0.60	0.00
TIR 59	1.3	0.3	22.3	0.4	19.	31.6	0.1	1.9	0.3	0.26	0.10	9.6	1.1	0.60	0.00
TIR 60	1.7	0.6	22.4	0.4	16.	32.2	0.2	2.2	0.3	0.35	0.10	4.4	0.4	0.60	0.00
TIR 61	0.9	0.2	21.6	0.4	39.	26.7	0.1	1.8	0.3	0.36	0.09	8.3	1.2	0.60	0.00
TIR 62	2.4	0.8	21.9	0.4	50.	28.7	0.3	1.3	0.2	0.31	0.14	6.6	1.0	0.60	0.00
TIR 70	2.4	0.5	20.1	0.4	87.	26.7	0.2	1.4	0.2	0.27	0.09	22.3	0.9	0.60	0.00
TIR 73	2.1	0.7	19.1	0.4	111.	34.8	0.3	2.6	0.3	0.44	0.13	11.6	1.3	0.66	0.19
TIR 74	2.0	0.4	20.1	0.4	102.	36.4	0.2	2.4	0.4	0.49	0.11	10.7	1.7	0.62	0.26
TIR 75	5.1	1.5	20.7	0.4	130.	42.3	0.5	2.8	0.8	0.36	0.14	11.6	1.6	0.60	0.00
TIR 76	1.1	0.3	22.6	0.4	32.	35.5	0.1	3.6	1.0	0.58	0.10	8.2	1.3	1.56	0.28
TIR 77	1.7	0.7	23.0	0.4	17.	24.4	0.2	1.4	0.2	0.38	0.10	6.4	0.6	0.60	0.00
TIR 79	1.6	0.5	21.2	0.4	11.	22.7	0.3	2.4	0.3	0.35	0.09	3.3	1.2	0.60	0.00
TIR 80	0.9	0.4	21.8	0.4	10.	34.4	0.2	2.2	0.3	0.37	0.07	3.8	0.8	0.60	0.00
TIR 81	1.3	0.6	21.8	0.4	12.	33.2	0.2	3.5	1.4	0.21	0.10	26.5	1.1	0.60	0.00
TIR 82	1.6	0.6	20.8	0.4	0.	33.3	0.2	2.0	0.4	0.25	0.10	4.6	0.6	0.60	0.00
TIR 83	0.0	0.0	17.1	0.4	125.	24.1	0.1	2.9	0.8	0.50	0.11	4.2	0.9	0.60	0.00
TIR 84	0.0	0.0	18.2	0.4	25.	32.2	0.1	2.6	1.1	0.39	0.06	5.6	0.6	0.60	0.00
TIR 85	2.3	0.5	18.9	0.4	67.	33.4	0.2	2.4	0.3	0.24	0.09	8.9	0.8	0.60	0.00
TIR 86	1.7	0.7	21.7	0.4	24.	24.1	0.2	1.9	0.3	0.27	0.13	2.8	0.3	0.60	0.00
TIR 87	1.1	0.4	25.9	1.0	18.	33.6	0.1	2.1	0.4	0.04	0.01	2.2	0.3	0.60	0.00
TIR 88	0.8	0.3	21.0	0.4	0.	30.1	0.1	1.4	0.3	0.17	0.06	2.8	1.1	0.60	0.00

SAMPLE	RB (PPM)	CS (PPM)	(EA) (PPM)	SC (PPM)	CE (PPM)	EU (PPM)	TH (PPM)							
TIR 1	102.	12.	4.7	0.3	276.	81.	15.4	C.1	75.1	4.2	1.44	0.08	8.2	0.3
TIR 2	69.	6.	6.5	0.3	260.	73.	15.8	C.1	71.8	1.7	1.13	0.05	9.5	0.3
TIR 3	144.	14.	6.6	0.4	0.	0.	20.5	C.1	82.5	2.4	0.94	0.17	9.8	0.4
TIR 4	128.	11.	6.0	0.3	259.	67.	15.5	C.1	85.7	3.3	1.03	0.05	9.9	0.3
TIR 5	145.	13.	6.9	0.6	207.	50.	20.8	C.1	85.3	2.7	1.08	0.06	10.6	0.3
TIR 6	140.	9.	6.4	0.4	315.	49.	20.7	C.1	85.6	3.3	1.15	0.06	11.2	0.3
TIR 7	84.	9.	6.5	1.7	272.	61.	17.7	C.1	85.6	2.6	1.08	0.11	8.9	0.4
TIR 8	76.	8.	7.3	0.6	160.	45.	21.2	C.1	81.8	2.6	0.94	0.09	11.2	0.5
TIR 9	135.	8.	6.3	0.3	127.	26.	20.7	C.1	85.8	2.9	1.03	0.06	11.2	0.3
TIR 10	89.	10.	4.7	0.5	0.	0.	19.7	C.1	62.5	2.6	0.81	0.07	7.4	0.4
TIR 11	114.	25.	5.0	0.6	194.	67.	20.6	C.1	91.3	6.4	1.10	0.06	11.0	0.5
TIR 12	102.	15.	6.1	0.6	279.	138.	20.8	C.1	81.5	5.7	1.14	0.10	9.8	0.5
TIR 13	117.	7.	7.4	0.7	130.	31.	20.2	C.2	72.3	2.9	1.30	0.06	9.9	0.3
TIR 14	118.	10.	6.6	0.5	172.	70.	19.9	C.1	70.0	2.4	1.00	0.08	8.6	0.4
TIR 15	128.	12.	6.6	0.3	205.	70.	20.0	C.1	76.0	2.7	1.05	0.06	8.9	0.4
TIR 16	156.	15.	6.3	0.6	0.	0.	20.8	C.1	84.4	2.7	0.99	0.08	9.6	0.5
TIR 17	131.	7.	6.0	0.6	327.	42.	20.6	C.1	80.7	2.7	1.07	0.06	10.6	0.2
TIR 18	60.	8.	6.7	0.6	114.	34.	20.5	C.1	67.7	2.6	1.04	0.06	8.6	0.4
TIR 19	143.	7.	6.9	0.4	251.	40.	21.1	C.1	82.2	1.3	1.16	0.06	11.5	0.2
TIR 20	71.	9.	4.8	0.5	534.	78.	18.4	C.1	61.8	2.2	1.34	0.10	7.9	0.4
TIR 26	145.	14.	7.9	0.4	127.	56.	26.5	C.1	77.1	2.7	1.22	0.11	9.4	0.5
TIR 31	124.	7.	7.0	0.3	331.	44.	15.5	C.1	67.6	2.7	0.99	0.05	8.9	0.3
TIR 32	58.	6.	6.3	0.5	229.	56.	20.0	C.1	72.4	4.9	1.14	0.09	9.5	0.5
TIR 33	143.	15.	7.5	0.4	245.	77.	21.3	C.1	82.4	5.7	1.27	0.11	10.2	0.5
TIR 34	128.	8.	6.8	0.4	312.	88.	20.3	C.1	71.6	2.8	1.05	0.05	10.1	0.3
TIR 35	142.	12.	5.9	0.5	311.	86.	20.4	C.1	77.9	2.4	1.18	0.07	9.3	0.4
TIR 36	123.	7.	6.5	0.3	161.	30.	18.9	C.1	77.5	2.9	1.33	0.16	10.0	0.3
TIR 37	132.	13.	5.0	0.6	326.	61.	21.0	C.1	84.0	6.2	1.19	0.10	9.2	0.5
TIR 38	87.	12.	4.9	0.5	379.	53.	20.9	C.1	85.0	3.0	0.98	0.11	7.2	0.4
TIR 39	131.	12.	7.5	0.6	0.	0.	21.0	C.1	65.8	2.6	1.08	0.09	9.0	0.5
TIR 40	144.	13.	6.3	1.1	305.	61.	20.4	C.1	82.2	5.6	0.89	0.23	9.7	0.4
TIR 41	122.	8.	5.1	0.4	286.	48.	15.7	C.1	81.3	4.3	1.12	0.19	9.6	0.3
TIR 42	112.	7.	6.2	0.4	405.	46.	15.2	C.1	68.6	2.7	1.24	0.05	9.6	0.3
TIR 43	126.	14.	5.2	0.5	334.	70.	20.0	C.1	70.2	2.3	1.11	0.31	8.5	0.4
TIR 44	154.	35.	8.8	0.3	185.	42.	15.7	C.1	74.1	2.7	0.93	0.05	9.2	0.4
TIR 45	137.	12.	6.4	0.6	0.	0.	20.5	C.1	89.4	5.3	0.99	0.10	10.2	0.5
TIR 56	145.	13.	7.6	0.4	299.	66.	23.8	C.1	67.2	5.6	0.96	0.08	7.2	0.4
TIR 57	127.	13.	6.0	0.5	525.	75.	22.2	C.1	68.5	2.5	1.40	0.10	7.0	0.4
TIR 58	153.	7.	8.9	0.6	301.	50.	24.0	C.1	68.4	2.8	1.05	0.16	7.5	0.2
TIR 59	99.	10.	6.7	0.4	475.	88.	21.5	C.1	62.5	2.3	1.19	0.07	7.6	0.4
TIR 60	128.	12.	8.5	0.6	440.	64.	21.8	C.1	67.1	5.8	1.35	0.07	7.8	0.4
TIR 61	116.	27.	6.5	0.5	0.	0.	21.9	C.1	85.4	2.9	1.18	0.07	7.4	0.4
TIR 62	132.	15.	5.6	0.6	483.	100.	21.6	C.1	68.6	2.9	1.16	0.07	7.1	0.4
TIR 70	85.	9.	4.7	0.5	516.	82.	20.1	C.1	55.7	1.7	1.21	0.05	6.7	0.2
TIR 73	98.	7.	4.7	0.3	397.	48.	18.8	C.0	65.6	1.4	1.25	0.05	9.4	0.2
TIR 74	104.	17.	4.0	0.6	249.	71.	19.5	C.1	72.1	3.3	1.22	0.07	8.3	0.5
TIR 75	122.	12.	6.3	0.5	131.	54.	20.8	C.1	86.4	6.5	1.26	0.07	9.8	0.5
TIR 76	104.	14.	6.9	0.4	0.	0.	23.2	C.1	86.5	2.9	2.12	0.08	10.2	0.6
TIR 77	132.	8.	6.8	0.6	626.	60.	22.5	C.1	64.0	1.2	1.27	0.06	8.8	0.2
TIR 79	41.	7.	4.5	0.4	433.	58.	21.1	C.1	67.4	2.8	1.59	0.07	7.4	0.5
TIR 80	104.	15.	3.8	0.6	788.	147.	21.9	C.1	67.6	2.8	1.48	0.07	8.0	0.6
TIR 81	82.	7.	4.2	0.4	506.	66.	22.0	C.1	69.0	1.7	1.53	0.07	9.1	0.3
TIR 82	87.	12.	4.1	0.3	219.	84.	20.5	C.1	67.2	2.9	1.26	0.06	7.5	0.5
TIR 83	20.	6.	2.3	0.1	191.	52.	16.8	C.1	87.0	4.5	1.35	0.06	5.5	0.5
TIR 84	49.	6.	3.2	0.3	402.	65.	16.3	C.1	62.3	2.5	1.36	0.06	8.6	0.5
TIR 85	106.	12.	5.6	0.6	0.	0.	15.4	C.1	65.6	4.9	1.19	0.06	7.8	0.4
TIR 86	100.	12.	7.0	0.6	0.	0.	22.0	C.1	61.5	2.8	1.22	0.06	7.5	0.5
TIR 87	140.	20.	6.7	0.6	0.	0.	22.0	C.1	65.8	3.1	1.19	0.07	7.8	0.6
TIR 88	115.	8.	7.2	0.4	179.	31.	21.3	C.1	56.0	1.6	1.28	0.04	7.2	0.3

SAMPLE	HF (PPM)	(TA) (PPM)	CR (PPM)	FE (1)	CC (PPM)	(NI) (PPM)	SB (PPM)							
TIR 1	5.5	0.4	0.48	0.08	294.	10.	4.96	0.04	20.9	1.3	42.	14.	0.44	0.22
TIR 2	5.2	0.3	0.46	0.06	362.	9.	4.96	0.03	20.4	0.2	0.	0.	0.34	0.09
TIR 3	6.5	0.4	0.53	0.06	294.	11.	5.07	0.04	18.7	0.3	0.	0.	0.85	0.15
TIR 4	6.3	0.7	0.49	0.06	387.	9.	4.99	0.02	21.5	0.3	129.	31.	0.15	0.06
TIR 5	5.2	0.4	0.18	0.05	502.	15.	5.34	0.05	19.4	0.6	202.	58.	0.85	0.16
TIR 6	6.3	0.3	0.36	0.05	504.	10.	5.37	0.02	20.4	0.3	0.	0.	0.27	0.08
TIR 7	4.6	0.4	0.58	0.11	358.	14.	4.58	0.05	21.7	0.5	126.	35.	0.48	0.13
TIR 8	6.1	0.6	0.57	0.11	334.	15.	5.32	0.06	24.6	0.5	166.	60.	1.04	0.17
TIR 9	6.2	0.3	0.53	0.06	245.	7.	5.09	0.02	21.5	0.3	76.	25.	0.35	0.07
TIR 10	4.8	0.5	0.14	0.07	392.	14.	4.81	0.05	26.8	0.5	0.	0.	0.60	0.15
TIR 11	6.5	0.6	0.29	0.11	756.	22.	5.38	0.06	25.2	0.6	0.	0.	1.31	0.18
TIR 12	7.3	0.6	0.34	0.06	295.	13.	5.23	0.05	21.2	0.4	0.	0.	0.36	0.11
TIR 13	5.4	0.3	0.73	0.06	374.	12.	5.21	0.03	26.2	0.3	0.	0.	0.59	0.10
TIR 14	5.6	0.4	0.43	0.05	366.	12.	5.13	0.05	22.5	0.4	0.	0.	0.89	0.15
TIR 15	5.1	0.4	0.53	0.05	486.	13.	5.12	0.05	26.5	0.4	38.	17.	0.59	0.13
TIR 16	6.2	0.5	0.64	0.25	282.	12.	5.22	0.05	23.1	0.4	0.	0.	0.71	0.14
TIR 17	6.1	0.3	0.90	0.20	294.	7.	5.11	0.02	23.0	0.2	138.	31.	0.56	0.07
TIR 18	5.8	0.5	0.56	0.12	299.	12.	5.21	0.05	29.4	0.5	176.	45.	0.59	0.14
TIR 19	5.9	0.3	0.77	0.07	685.	6.	5.40	0.03	28.1	0.3	189.	26.	0.64	0.30
TIR 20	5.1	0.4	0.53	0.10	166.	10.	4.74	0.05	21.4	0.4	0.	0.	0.45	0.14
TIR 26	2.9	0.3	0.81	0.26	261.	13.	4.19	0.06	31.8	0.5	0.	0.	0.32	0.17
TIR 31	5.5	0.3	0.68	0.16	258.	8.	5.00	0.10	26.4	0.3	89.	27.	0.26	0.07
TIR 32	4.6	0.4	0.66	0.12	270.	13.	5.04	0.05	24.4	0.4	0.	0.	0.29	0.10
TIR 33	4.9	0.5	0.23	0.12	233.	12.	5.28	0.05	26.2	0.5	0.	0.	0.56	0.17
TIR 34	5.0	0.3	0.66	0.07	255.	7.	5.06	0.03	22.2	0.3	136.	54.	0.84	0.13
TIR 35	4.9	0.4	0.37	0.05	355.	13.	5.09	0.05	22.9	0.4	0.	0.	1.00	0.14
TIR 36	6.4	0.3	0.28	0.04	178.	5.	4.84	0.02	17.5	0.3	0.	0.	0.30	0.06
TIR 37	4.7	0.4	0.30	0.07	265.	12.	5.07	0.05	22.9	1.8	91.	38.	0.85	0.16
TIR 38	2.9	0.4	0.53	0.06	467.	15.	5.68	0.06	35.6	0.5	239.	39.	0.66	0.16
TIR 39	4.8	0.5	0.45	0.10	245.	11.	5.18	0.05	25.5	0.5	284.	71.	0.94	0.16
TIR 40	6.3	0.5	0.38	0.05	410.	13.	5.25	0.05	25.5	0.5	0.	0.	0.49	0.15
TIR 41	4.9	0.3	0.72	0.06	393.	9.	4.95	0.03	25.4	0.3	158.	41.	0.66	0.11
TIR 42	5.6	0.3	0.49	0.06	229.	6.	4.76	0.03	16.5	0.3	69.	23.	0.38	0.06
TIR 43	4.1	0.3	0.15	0.23	254.	11.	5.08	0.05	22.1	0.5	0.	0.	1.04	0.17
TIR 44	4.6	0.4	0.06	0.06	280.	10.	4.83	0.05	21.3	0.5	147.	54.	0.59	0.16
TIR 45	7.0	0.5	0.53	0.10	294.	12.	5.21	0.05	22.4	0.5	0.	0.	0.39	0.19
TIR 56	2.0	0.3	0.47	0.05	366.	12.	5.26	0.05	22.2	0.5	270.	64.	0.82	0.17
TIR 57	2.6	0.3	0.47	0.07	488.	14.	5.82	0.05	27.6	0.5	480.	91.	0.69	0.17
TIR 58	3.2	0.3	0.51	0.08	351.	7.	5.56	0.03	22.5	0.3	137.	24.	0.49	0.08
TIR 59	2.6	0.4	0.22	0.06	417.	15.	5.91	0.05	35.5	0.5	443.	222.	0.59	0.13
TIR 60	3.4	0.3	0.40	0.06	265.	12.	5.47	0.05	25.9	0.4	102.	43.	0.49	0.14
TIR 61	2.6	0.3	0.49	0.12	414.	15.	5.84	0.05	25.3	0.5	210.	40.	0.63	0.14
TIR 62	2.0	0.3	0.27	0.11	457.	16.	5.85	0.06	41.4	0.6	467.	94.	0.72	0.14
TIR 70	2.4	0.2	0.38	0.07	1639.	13.	4.48	0.02	46.4	0.3	467.	45.	0.36	0.08
TIR 73	5.4	0.3	0.25	0.05	472.	9.	4.84	0.03	21.0	0.2	84.	21.	0.34	0.08
TIR 74	5.1	0.5	0.51	0.15	547.	20.	5.01	0.06	22.4	0.6	0.	0.	0.86	0.16
TIR 75	5.9	0.5	0.18	0.07	355.	14.	5.21	0.05	23.3	0.5	0.	0.	0.54	0.12
TIR 76	6.4	0.5	1.23	0.15	205.	12.	5.55	0.06	27.5	0.5	0.	0.	0.49	0.20
TIR 77	2.7	0.2	0.54	0.16	288.	7.	5.16	0.02	22.7	0.2	90.	16.	0.20	0.08
TIR 79	3.7	0.4	0.19	0.06	205.	13.	5.29	0.05	24.1	0.4	0.	0.	0.62	0.14
TIR 80	4.5	0.5	0.49	0.05	213.	13.	5.50	0.22	25.4	0.5	0.	0.	0.80	0.15
TIR 81	4.5	0.3	0.66	0.07	212.	6.	5.45	0.03	21.4	0.2	215.	64.	0.67	0.07
TIR 82	2.9	0.2	0.33	0.06	193.	12.	5.21	0.05	25.6	0.4	77.	34.	0.95	0.15
TIR 83	5.9	0.5	0.06	0.06	35.	6.	4.15	0.05	4.4	0.4	0.	0.	0.70	0.12
TIR 84	4.7	0.4	0.56	0.10	230.	14.	4.60	0.05	22.3	0.4	0.	0.	0.21	0.05
TIR 85	5.4	0.5	0.39	0.06	240.	11.	4.72	0.04	24.7	0.4	123.	38.	0.88	0.14
TIR 86	3.1	0.3	0.36	0.07	404.	16.	5.74	0.05	38.6	0.5	363.	115.	0.38	0.15
TIR 87	3.4	0.3	0.40	0.07	304.	16.	6.03	0.06	33.5	0.5	95.	39.	0.54	0.15
TIR 88	2.8	0.3	0.51	0.07	334.	8.	5.13	0.03	37.7	0.3	211.	56.	0.53	0.07

SAMPLE	AL (%)	MG (%)	CA (%)	V (PPM)	TI (%)	(NA) (%)	NA (%)	K (%)	PN (PPM)
VNU010	0.00	0.00	0.0	0.0	14.5	1.3	0.0	0.0	0.0
VNU011	0.00	0.00	0.0	0.0	15.6	1.4	0.0	0.0	0.0
VNU012	0.00	0.00	0.0	0.0	21.1	1.5	0.0	0.0	0.0
VNU013	0.00	0.00	0.0	0.0	20.1	1.8	0.0	0.0	0.0
VNU014	0.00	0.00	0.0	0.0	20.7	1.9	0.0	0.0	0.0
VNU015	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
VNU016	0.00	0.00	0.0	0.0	11.3	1.0	0.0	0.0	0.0
VNU101	0.00	0.00	0.0	0.0	8.9	0.8	0.0	0.0	0.0
VNU102	0.00	0.00	0.0	0.0	8.0	0.7	0.0	0.0	0.0
VNU103	0.00	0.00	0.0	0.0	10.3	0.9	0.0	0.0	0.0
VNU104	0.00	0.00	0.0	0.0	17.5	1.6	0.0	0.0	0.0
VNU105	0.00	0.00	0.0	0.0	6.0	0.5	0.0	0.0	0.0
VNU106	0.00	0.00	0.0	0.0	5.1	0.5	0.0	0.0	0.0
VNU107	0.00	0.00	0.0	0.0	5.2	0.5	0.0	0.0	0.0
VNU108	0.00	0.00	0.0	0.0	7.5	0.7	0.0	0.0	0.0
VNU111	0.00	0.00	0.0	0.0	14.4	1.3	0.0	0.0	0.0
VNU112	0.00	0.00	0.0	0.0	12.0	1.1	0.0	0.0	0.0
VNU113	0.00	0.00	0.0	0.0	17.1	1.6	0.0	0.0	0.0
VNU114	0.00	0.00	0.0	0.0	17.5	1.6	0.0	0.0	0.0
VNU115	0.00	0.00	0.0	0.0	12.8	1.2	0.0	0.0	0.0
VNU116	0.00	0.00	0.0	0.0	16.8	1.5	0.0	0.0	0.0
VNU151	0.00	0.00	0.0	0.0	14.8	1.3	0.0	0.0	0.0
VNU152	0.00	0.00	0.0	0.0	8.3	0.8	0.0	0.0	0.0
VNU153	0.00	0.00	0.0	0.0	11.9	1.1	0.0	0.0	0.0
VNU154	0.00	0.00	0.0	0.0	7.8	0.7	0.0	0.0	0.0
VNU155	0.00	0.00	0.0	0.0	1.9	0.2	0.0	0.0	0.0
VNU156	0.00	0.00	0.0	0.0	0.8	0.1	0.0	0.0	0.0
VNU157	0.00	0.00	0.0	0.0	2.1	0.2	0.0	0.0	0.0
VNU158	0.00	0.00	0.0	0.0	5.1	0.5	0.0	0.0	0.0
VNU159	0.00	0.00	0.0	0.0	4.5	0.4	0.0	0.0	0.0
VNU160	0.00	0.00	0.0	0.0	7.6	0.7	0.0	0.0	0.0
VNU201	0.00	0.00	0.0	0.0	13.7	1.2	0.0	0.0	0.0
VNU202	0.00	0.00	0.0	0.0	10.3	0.9	0.0	0.0	0.0
VNU203	0.00	0.00	0.0	0.0	7.8	0.7	0.0	0.0	0.0
VNU204	0.00	0.00	0.0	0.0	14.3	1.3	0.0	0.0	0.0
VNU205	0.00	0.00	0.0	0.0	8.6	0.8	0.0	0.0	0.0
VNU206	0.00	0.00	0.0	0.0	19.9	1.8	0.0	0.0	0.0
VNU301	0.00	0.00	0.0	0.0	13.0	1.2	0.0	0.0	0.0
VNU302	0.00	0.00	0.0	0.0	9.2	0.9	0.0	0.0	0.0
VNU303	0.00	0.00	0.0	0.0	6.5	0.6	0.0	0.0	0.0
VNU304	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
VNU401	0.00	0.00	0.0	0.0	5.6	0.5	0.0	0.0	0.0
VNU402	0.00	0.00	0.0	0.0	17.3	1.6	0.0	0.0	0.0
VNU403	0.00	0.00	0.0	0.0	14.3	1.3	0.0	0.0	0.0
VNU404	0.00	0.00	0.0	0.0	16.5	1.5	0.0	0.0	0.0
VNU405	0.00	0.00	0.0	0.0	6.2	0.6	0.0	0.0	0.0
VNU406	0.00	0.00	0.0	0.0	10.5	1.0	0.0	0.0	0.0
VNU407	0.00	0.00	0.0	0.0	11.3	1.0	0.0	0.0	0.0
VNU408	0.00	0.00	0.0	0.0	1.3	0.1	0.0	0.0	0.0
VNU409	0.00	0.00	0.0	0.0	8.9	0.8	0.0	0.0	0.0
VNU410	0.00	0.00	0.0	0.0	15.7	1.4	0.0	0.0	0.0
VNU411	0.00	0.00	0.0	0.0	5.2	0.5	0.0	0.0	0.0
VNU412	0.00	0.00	0.0	0.0	4.2	0.4	0.0	0.0	0.0
VNU413	0.00	0.00	0.0	0.0	16.4	1.5	0.0	0.0	0.0
VNU414	0.00	0.00	0.0	0.0	14.0	1.3	0.0	0.0	0.0
VNU415	0.00	0.00	0.0	0.0	13.5	1.2	0.0	0.0	0.0

SAMPLE	AL (%)	MG (%)	CA (%)	V (PPM)	TI (%)	(NA) (%)	NA (%)	K (%)	MN (PPM)
VQU416	0.00	0.00	0.0	0.0	12.6	1.1	0.0	0.0	0.0
VQU417	0.00	0.00	0.0	0.0	13.2	1.2	0.0	0.0	0.0
VQU418	0.00	0.00	0.0	0.0	13.0	1.2	0.0	0.0	0.0
VQU419	0.00	0.00	0.0	0.0	13.4	1.2	0.0	0.0	0.0
VQU420	0.00	0.00	0.0	0.0	16.1	1.5	0.0	0.0	0.0
VQU421	0.00	0.00	0.0	0.0	2.2	0.2	0.0	0.0	0.0
VQU422	0.00	0.00	0.0	0.0	15.4	1.4	0.0	0.0	0.0
VQU501	0.00	0.00	0.0	0.0	6.1	0.6	0.0	0.0	0.0
VQU502	0.00	0.00	0.0	0.0	10.1	0.9	0.0	0.0	0.0
VQU503	0.00	0.00	0.0	0.0	7.2	0.7	0.0	0.0	0.0
VQU504	0.00	0.00	0.0	0.0	11.2	1.0	0.0	0.0	0.0
VQU505	0.00	0.00	0.0	0.0	9.2	0.8	0.0	0.0	0.0
VQU506	0.00	0.00	0.0	0.0	5.6	0.5	0.0	0.0	0.0
VQU507	0.00	0.00	0.0	0.0	11.8	1.1	0.0	0.0	0.0
VQU508	0.00	0.00	0.0	0.0	10.0	0.9	0.0	0.0	0.0
VQU509	0.00	0.00	0.0	0.0	8.4	0.8	0.0	0.0	0.0
VQU510	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
VQU511	0.00	0.00	0.0	0.0	10.6	1.0	0.0	0.0	0.0
VQU512	0.00	0.00	0.0	0.0	9.3	0.8	0.0	0.0	0.0
VQU513	0.00	0.00	0.0	0.0	7.0	0.6	0.0	0.0	0.0
VQU514	0.00	0.00	0.0	0.0	9.5	0.9	0.0	0.0	0.0
VQU516	0.00	0.00	0.0	0.0	8.7	0.8	0.0	0.0	0.0
VQU517	0.00	0.00	0.0	0.0	9.9	0.9	0.0	0.0	0.0
VQU518	0.00	0.00	0.0	0.0	7.7	0.7	0.0	0.0	0.0
VQU519	0.00	0.00	0.0	0.0	7.6	0.7	0.0	0.0	0.0
VQU520	0.00	0.00	0.0	0.0	8.5	0.8	0.0	0.0	0.0
VQU521	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
VQU522	0.00	0.00	0.0	0.0	9.2	0.8	0.0	0.0	0.0
VQU523	0.00	0.00	0.0	0.0	7.1	0.6	0.0	0.0	0.0
VQU524	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
VQU525	0.00	0.00	0.0	0.0	18.8	1.8	0.0	0.0	0.0
VQU526	0.00	0.00	0.0	0.0	13.4	1.2	0.0	0.0	0.0
VQU601	0.00	0.00	0.0	0.0	15.2	0.5	0.0	0.0	0.0
VQU602	0.00	0.00	0.0	0.0	2.0	0.2	0.0	0.0	0.0
VQU603	0.00	0.00	0.0	0.0	11.0	1.0	0.0	0.0	0.0
VQU604	0.00	0.00	0.0	0.0	2.3	0.2	0.0	0.0	0.0
VQU605	0.00	0.00	0.0	0.0	1.9	0.2	0.0	0.0	0.0
VQU606	0.00	0.00	0.0	0.0	8.6	0.8	0.0	0.0	0.0
VQU607	0.00	0.00	0.0	0.0	2.2	0.2	0.0	0.0	0.0
VQU608	0.00	0.00	0.0	0.0	5.6	0.5	0.0	0.0	0.0
VQU609	0.00	0.00	0.0	0.0	11.0	1.0	0.0	0.0	0.0
VQU610	0.00	0.00	0.0	0.0	6.4	0.6	0.0	0.0	0.0
VQU611	0.00	0.00	0.0	0.0	4.1	0.4	0.0	0.0	0.0
VQU612	0.00	0.00	0.0	0.0	6.1	0.6	0.0	0.0	0.0
VQU613	0.00	0.00	0.0	0.0	6.8	0.6	0.0	0.0	0.0
VQU614	0.00	0.00	0.0	0.0	7.2	0.7	0.0	0.0	0.0
VQU615	0.00	0.00	0.0	0.0	9.2	0.8	0.0	0.0	0.0
VQU616	0.00	0.00	0.0	0.0	12.4	1.1	0.0	0.0	0.0
VQU617	0.00	0.00	0.0	0.0	3.8	0.3	0.0	0.0	0.0
VQU618	0.00	0.00	0.0	0.0	3.8	0.3	0.0	0.0	0.0
VQU619	0.00	0.00	0.0	0.0	9.1	0.8	0.0	0.0	0.0
VQU620	0.00	0.00	0.0	0.0	8.9	0.8	0.0	0.0	0.0
VQU621	0.00	0.00	0.0	0.0	9.0	0.8	0.0	0.0	0.0
VQU622	0.00	0.00	0.0	0.0	10.3	0.9	0.0	0.0	0.0
VQU623	0.00	0.00	0.0	0.0	2.4	0.2	0.0	0.0	0.0
VQU 001	0.00	0.00	0.0	0.0	20.4	2.0	0.0	0.0	0.0
VQU 002	0.00	0.00	0.0	0.0	20.4	2.0	0.0	0.0	0.0
VQU 207	0.00	0.00	0.0	0.0	20.2	2.0	0.0	0.0	0.0
VQU 208	0.00	0.00	0.0	0.0	17.1	1.7	0.0	0.0	0.0
VQU 209	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
VQU 211	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
VQU 212	0.00	0.00	0.0	0.0	19.6	2.0	0.0	0.0	0.0
VQU 213	0.00	0.00	0.0	0.0	10.1	1.0	0.0	0.0	0.0
VQU 214	0.00	0.00	0.0	0.0	14.4	1.4	0.0	0.0	0.0
MYCN	0.00	0.00	0.0	0.0	9.8	0.9	0.0	0.0	0.0

SAMPLE	(U)	(PPM)	(SC)	(PPM)	M	(PPM)	LA	(PPM)	(SN)	(PPM)	YB	(PPM)	(LU)	(PPM)	AS	(PPM)	(SB)	(PPM)
V00010	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.6	3.6	0.1	1.5	0.1	0.26	0.02	6.6	1.2	0.63	0.14
V00011	0.0	0.0	0.0	0.0	0.0	0.0	21.2	0.7	3.9	0.1	2.4	0.2	0.33	0.02	7.1	1.3	0.64	0.14
V00012	0.0	0.0	0.0	0.0	0.0	0.0	24.8	0.8	4.7	0.1	2.4	0.2	0.34	0.02	8.1	1.4	0.92	0.20
V00013	0.0	0.0	0.0	0.0	0.0	0.0	25.8	0.8	4.4	0.1	2.4	0.2	0.33	0.02	9.6	1.7	0.75	0.16
V00014	0.0	0.0	0.0	0.0	0.0	0.0	24.0	0.8	4.3	0.1	2.4	0.2	0.32	0.02	8.8	1.6	0.97	0.21
V00015	0.0	0.0	0.0	0.0	0.0	0.0	27.5	0.9	4.2	0.1	2.4	0.2	0.37	0.02	15.5	2.7	1.10	0.24
V00016	0.0	0.0	0.0	0.0	0.0	0.0	27.5	0.9	4.1	0.1	2.4	0.2	0.33	0.02	13.5	2.4	1.16	0.25
V00101	0.0	0.0	0.0	0.0	0.0	0.0	22.0	0.7	0.0	0.0	2.3	0.1	0.34	0.03	12.7	2.3	0.93	0.20
V00102	0.0	0.0	0.0	0.0	0.0	0.0	22.1	0.7	0.0	0.0	2.1	0.1	0.31	0.02	11.0	1.9	0.73	0.16
V00103	0.0	0.0	0.0	0.0	0.0	0.0	26.5	0.9	0.0	0.0	2.4	0.1	0.33	0.02	4.8	0.9	1.43	0.31
V00104	0.0	0.0	0.0	0.0	0.0	0.0	20.4	0.6	0.0	0.0	1.4	0.1	0.25	0.02	6.9	1.2	0.64	0.14
V00105	0.0	0.0	0.0	0.0	0.0	0.0	16.7	0.6	0.0	0.0	2.4	0.2	0.39	0.02	14.4	2.6	1.00	0.22
V00106	0.0	0.0	0.0	0.0	0.0	0.0	33.0	1.1	5.4	0.2	2.5	0.2	0.40	0.02	0.0	0.0	0.69	0.15
V00107	0.0	0.0	0.0	0.0	0.0	0.0	20.4	0.6	0.0	0.0	2.4	0.2	0.31	0.02	5.8	1.0	0.56	0.12
V00108	0.0	0.0	0.0	0.0	0.0	0.0	23.2	0.7	3.6	0.1	2.2	0.1	0.32	0.02	6.8	1.2	0.79	0.17
V00111	0.0	0.0	0.0	0.0	0.0	0.0	16.7	0.7	0.0	0.0	2.4	0.1	0.29	0.02	10.2	1.8	0.69	0.15
V00112	0.0	0.0	0.0	0.0	0.0	0.0	23.8	0.8	0.0	0.0	2.1	0.1	0.29	0.02	8.1	1.4	0.68	0.15
V00113	0.0	0.0	0.0	0.0	0.0	0.0	16.5	0.6	0.0	0.0	1.8	0.1	0.25	0.02	8.9	1.6	0.56	0.12
V00114	0.0	0.0	0.0	0.0	0.0	0.0	21.1	0.7	0.0	0.0	2.6	0.2	0.28	0.02	0.0	0.0	0.87	0.19
V00115	0.0	0.0	0.0	0.0	0.0	0.0	21.4	0.7	0.0	0.0	2.6	0.1	0.27	0.02	7.2	1.3	0.77	0.17
V00151	0.0	0.0	0.0	0.0	0.0	0.0	25.4	0.8	4.3	0.1	2.6	0.2	0.39	0.02	5.8	1.0	0.74	0.16
V00152	0.0	0.0	0.0	0.0	0.0	0.0	26.4	0.8	4.8	0.2	2.7	0.2	0.35	0.02	7.4	1.3	0.92	0.20
V00153	0.0	0.0	0.0	0.0	0.0	0.0	25.4	0.8	4.4	0.1	2.7	0.2	0.35	0.02	5.6	1.0	0.71	0.15
V00154	0.0	0.0	0.0	0.0	0.0	0.0	19.6	0.6	4.0	0.1	2.4	0.2	0.33	0.02	9.4	1.7	0.74	0.16
V00155	0.0	0.0	0.0	0.0	0.0	0.0	22.4	0.7	5.0	0.2	4.0	0.3	0.50	0.03	60.7	10.7	1.92	0.42
V00156	0.0	0.0	0.0	0.0	0.0	0.0	18.5	0.6	4.3	0.1	3.1	0.2	0.53	0.03	9.1	1.6	1.87	0.40
V00157	0.0	0.0	0.0	0.0	0.0	0.0	21.5	0.7	5.1	0.2	3.1	0.2	0.48	0.03	7.8	1.4	1.08	0.23
V00158	0.0	0.0	0.0	0.0	0.0	0.0	26.2	0.8	5.7	0.2	3.8	0.3	0.55	0.03	17.6	3.1	1.62	0.35
V00159	0.0	0.0	0.0	0.0	0.0	0.0	23.6	0.8	5.1	0.2	3.2	0.2	0.50	0.03	11.0	1.9	1.37	0.30
V00160	0.0	0.0	0.0	0.0	0.0	0.0	32.0	1.1	5.3	0.2	3.0	0.2	0.39	0.02	8.7	1.5	1.53	0.33
V00201	0.0	0.0	0.0	0.0	0.0	0.0	22.3	0.7	4.1	0.1	2.5	0.2	0.30	0.02	11.8	2.1	0.76	0.15
V00202	0.0	0.0	0.0	0.0	0.0	0.0	19.3	0.6	3.5	0.1	2.0	0.1	0.30	0.02	8.8	1.6	0.84	0.18
V00203	0.0	0.0	0.0	0.0	0.0	0.0	22.3	0.7	4.7	0.1	2.9	0.2	0.40	0.02	7.8	1.4	0.73	0.16
V00204	0.0	0.0	0.0	0.0	0.0	0.0	22.3	0.7	4.1	0.1	2.9	0.1	0.36	0.02	13.0	2.3	1.13	0.24
V00205	0.0	0.0	0.0	0.0	0.0	0.0	20.6	0.7	4.2	0.1	2.4	0.2	0.34	0.02	9.3	1.6	0.83	0.18
V00206	0.0	0.0	0.0	0.0	0.0	0.0	15.2	0.6	3.4	0.1	1.7	0.1	0.23	0.01	5.5	1.0	0.80	0.17
V00301	0.0	0.0	0.0	0.0	0.0	0.0	38.6	1.2	0.0	0.0	3.0	0.2	0.42	0.03	25.2	4.5	0.93	0.20
V00302	0.0	0.0	0.0	0.0	0.0	0.0	23.5	0.8	4.6	0.1	2.5	0.2	0.35	0.02	6.4	1.1	0.73	0.16
V00303	0.0	0.0	0.0	0.0	0.0	0.0	24.4	0.8	4.6	0.2	2.5	0.2	0.37	0.02	5.6	1.0	0.73	0.16
V00304	0.0	0.0	0.0	0.0	0.0	0.0	33.9	1.1	5.3	0.2	2.8	0.2	0.37	0.02	4.8	0.9	0.67	0.14
V00401	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.6	3.5	0.1	1.9	0.1	0.30	0.02	4.2	0.7	0.82	0.18
V00402	0.0	0.0	0.0	0.0	0.0	0.0	18.6	0.6	3.5	0.1	2.1	0.1	0.26	0.02	6.3	1.1	0.78	0.17
V00403	0.0	0.0	0.0	0.0	0.0	0.0	17.4	0.6	3.1	0.1	1.6	0.1	0.21	0.01	7.2	1.3	0.65	0.14
V00404	0.0	0.0	0.0	0.0	0.0	0.0	20.5	0.7	3.6	0.1	1.5	0.1	0.27	0.02	7.1	1.3	0.95	0.18
V00405	0.0	0.0	0.0	0.0	0.0	0.0	38.0	1.2	5.7	0.3	5.1	0.3	0.71	0.04	0.0	0.0	2.26	0.49
V00406	0.0	0.0	0.0	0.0	0.0	0.0	21.1	0.7	4.1	0.1	2.6	0.2	0.37	0.02	12.5	2.2	1.85	0.40
V00407	0.0	0.0	0.0	0.0	0.0	0.0	26.5	0.9	4.4	0.1	2.7	0.2	0.39	0.02	8.1	1.4	0.96	0.21
V00408	0.0	0.0	0.0	0.0	0.0	0.0	25.2	0.8	4.1	0.1	2.4	0.2	0.39	0.02	8.0	1.4	0.72	0.16
V00409	0.0	0.0	0.0	0.0	0.0	0.0	19.7	0.6	3.5	0.1	2.1	0.1	0.28	0.02	6.9	1.2	0.76	0.16
V00410	0.0	0.0	0.0	0.0	0.0	0.0	24.4	0.8	4.3	0.1	2.6	0.2	0.36	0.02	11.5	2.0	1.46	0.31
V00411	0.0	0.0	0.0	0.0	0.0	0.0	17.7	0.6	4.3	0.1	1.6	0.1	0.56	0.03	5.2	0.9	1.82	0.35
V00412	0.0	0.0	0.0	0.0	0.0	0.0	26.5	0.9	7.2	0.2	2.2	0.3	0.79	0.05	20.2	3.6	2.82	0.61
V00413	0.0	0.0	0.0	0.0	0.0	0.0	22.9	0.7	4.2	0.1	2.2	0.2	0.31	0.02	13.6	2.4	0.84	0.18
V00414	0.0	0.0	0.0	0.0	0.0	0.0	21.0	0.7	3.6	0.1	1.6	0.1	0.30	0.02	0.0	0.0	0.64	0.14
V00415	0.0	0.0	0.0	0.0	0.0	0.0	24.3	0.8	4.3	0.1	2.2	0.2	0.34	0.02	6.8	1.2	1.70	0.33

SAMPLE	RB (PPM)	CS (PPM)	(EA) (PPM)	SC (PPM)	CE (PPM)	EU (PPM)	TH (PPM)							
VDU010	88.	16.	7.6	0.6	181.	45.	13.1	C.3	36.3	2.0	0.88	0.04	7.2	0.4
VDU011	73.	13.	6.0	0.4	212.	57.	12.8	C.3	41.2	2.2	0.93	0.05	6.0	0.4
VDU012	98.	18.	6.8	0.5	239.	65.	15.7	C.4	45.3	2.6	1.10	0.06	8.5	0.5
VDU013	78.	14.	7.5	0.5	206.	55.	15.7	C.4	42.6	2.6	1.01	0.05	8.0	0.5
VDU014	67.	12.	5.5	0.4	256.	69.	15.8	C.4	42.1	2.4	1.02	0.05	8.0	0.5
VDU015	169.	31.	16.6	1.2	206.	56.	22.5	C.5	51.2	2.8	1.06	0.05	9.2	0.6
VDU016	150.	27.	12.0	0.5	266.	72.	22.7	C.5	52.0	2.8	0.97	0.05	10.7	0.7
VDU101	56.	10.	6.0	0.4	737.	199.	21.2	C.5	43.6	2.4	0.98	0.05	6.1	0.4
VDU102	25.	5.	4.3	0.2	1252.	365.	15.7	C.5	45.0	2.4	1.00	0.05	7.3	0.4
VDU103	20.	4.	5.9	0.4	787.	213.	20.7	C.5	51.1	3.1	0.52	0.03	9.6	0.6
VDU104	14.	3.	4.2	0.2	1655.	447.	15.0	C.4	35.0	2.1	0.92	0.05	5.6	0.4
VDU105	48.	5.	3.8	0.3	1066.	293.	22.6	C.5	36.1	2.1	1.03	0.05	5.7	0.4
VDU106	56.	10.	5.7	0.4	2109.	565.	15.3	C.4	46.0	3.6	0.89	0.05	11.8	0.7
VDU107	56.	10.	4.6	0.3	733.	192.	15.6	C.5	40.1	2.2	1.06	0.05	6.7	0.4
VDU108	77.	14.	4.1	0.3	1502.	406.	18.6	C.4	44.7	2.4	0.59	0.05	7.3	0.4
VDU111	22.	4.	6.4	0.5	466.	126.	16.4	C.4	35.1	2.1	0.11	0.01	6.0	0.4
VDU112	118.	21.	5.5	0.4	1113.	301.	18.1	C.4	45.5	2.5	1.02	0.05	7.3	0.4
VDU113	89.	16.	6.2	0.4	470.	127.	14.4	C.3	34.6	1.9	0.84	0.04	5.3	0.3
VDU114	87.	16.	7.7	0.6	506.	137.	16.3	C.4	35.8	2.1	0.92	0.05	6.5	0.4
VDU115	78.	14.	5.4	0.4	1003.	271.	17.0	C.4	40.2	2.2	1.01	0.05	6.7	0.4
VDU116	23.	4.	8.3	0.6	171.	46.	18.1	C.4	38.2	2.1	0.99	0.05	7.4	0.5
VDU151	23.	4.	9.2	0.7	556.	231.	15.6	C.4	40.8	2.5	1.10	0.06	8.0	0.5
VDU152	49.	9.	7.3	0.5	633.	171.	23.8	C.6	53.6	2.9	1.17	0.06	9.1	0.6
VDU153	27.	5.	7.3	0.5	566.	153.	18.9	C.5	40.1	2.7	1.08	0.06	8.9	0.5
VDU154	45.	8.	3.6	0.3	2216.	556.	20.4	C.5	37.1	2.0	1.00	0.05	6.2	0.4
VDU155	98.	18.	4.6	0.3	286.	77.	21.5	C.5	41.5	2.6	1.24	0.06	7.8	0.5
VDU156	65.	12.	2.3	0.3	1112.	300.	15.7	C.5	42.2	2.3	1.06	0.05	5.9	0.4
VDU157	115.	21.	3.2	0.3	1065.	288.	22.5	C.5	46.2	2.5	1.20	0.07	6.8	0.4
VDU158	55.	10.	2.9	0.2	1109.	299.	23.6	C.6	51.9	2.8	1.44	0.07	7.5	0.5
VDU159	67.	12.	4.1	0.3	479.	129.	20.2	C.5	47.2	2.5	1.23	0.06	7.0	0.4
VDU160	68.	12.	0.9	0.1	1328.	355.	26.2	C.6	65.0	3.7	1.40	0.07	12.6	0.8
VDU201	27.	5.	5.7	0.4	951.	257.	15.2	C.4	46.1	2.5	1.10	0.06	6.4	0.5
VDU202	97.	18.	7.1	0.5	609.	164.	12.6	C.3	37.2	2.0	0.83	0.04	6.5	0.4
VDU203	81.	15.	3.8	0.3	786.	212.	21.5	C.5	45.5	2.5	1.19	0.06	7.3	0.4
VDU204	39.	7.	5.1	0.4	1238.	334.	17.7	C.4	44.9	2.4	1.05	0.05	7.2	0.4
VDU205	59.	11.	3.5	0.3	864.	233.	24.0	C.6	43.8	2.4	1.17	0.06	6.5	0.4
VDU206	83.	15.	8.8	0.6	748.	202.	12.0	C.2	35.6	2.1	0.79	0.04	6.1	0.4
VDU301	42.	8.	5.9	0.4	1232.	333.	15.6	C.4	46.0	3.5	1.68	0.09	11.1	0.7
VDU302	70.	13.	4.8	0.3	900.	243.	21.1	C.5	47.5	2.6	1.20	0.06	9.1	0.6
VDU303	14.	3.	1.4	0.1	1513.	409.	25.1	C.6	53.3	2.9	1.25	0.06	7.8	0.5
VDU304	72.	13.	2.9	0.3	1450.	362.	22.2	C.5	49.4	3.1	1.25	0.06	10.3	0.6
VDU401	74.	13.	4.7	0.3	299.	81.	15.7	C.5	46.0	2.2	0.56	0.05	6.2	0.4
VDU402	78.	14.	6.0	0.4	560.	151.	17.9	C.4	35.2	1.9	0.87	0.04	5.9	0.4
VDU403	76.	14.	5.6	0.4	509.	127.	12.6	C.3	32.2	1.7	0.82	0.04	5.2	0.3
VDU404	68.	12.	4.3	0.3	730.	197.	13.4	C.3	36.1	1.9	0.92	0.05	6.2	0.4
VDU405	107.	19.	8.0	0.6	365.	104.	23.4	C.6	65.2	3.7	2.39	0.12	8.8	0.6
VDU406	79.	14.	8.6	0.6	450.	122.	14.4	C.3	40.7	2.2	1.07	0.05	6.4	0.4
VDU407	103.	19.	6.6	0.5	445.	120.	19.5	C.5	46.5	2.5	1.31	0.07	7.4	0.5
VDU408	109.	20.	7.8	0.6	281.	76.	17.9	C.4	37.6	2.8	1.02	0.05	10.0	0.6
VDU409	83.	15.	4.5	0.3	582.	157.	16.6	C.4	37.4	2.0	1.00	0.05	6.6	0.4
VDU410	36.	7.	6.0	0.4	485.	131.	15.9	C.4	42.0	2.3	1.14	0.06	7.4	0.5
VDU411	82.	15.	3.9	0.3	332.	50.	20.0	C.5	61.5	3.3	1.23	0.06	7.9	0.5
VDU412	120.	22.	6.4	0.5	373.	101.	23.0	C.6	57.0	3.1	2.01	0.10	9.0	0.6
VDU413	51.	9.	4.2	0.3	940.	254.	15.0	C.4	41.6	2.2	1.03	0.05	7.4	0.5
VDU414	108.	20.	8.1	0.6	684.	152.	15.8	C.4	35.2	2.1	0.81	0.04	7.0	0.4
VDU415	108.	20.	7.2	0.5	706.	191.	15.5	C.5	46.4	2.5	0.58	0.05	8.3	0.5

SAMPLE	FB (PPM)	CS (PPM)	EA (PPM)	SC (PPM)	CE (PPM)	EU (PPM)	TH (PPM)
V0U416	94.	17.	8.7	0.6	743.	201.	15.5
V0U417	55.	10.	11.5	0.8	291.	79.	20.2
V0U418	114.	21.	6.1	0.4	481.	130.	21.6
V0U419	91.	17.	6.2	0.4	344.	93.	15.2
V0U420	91.	17.	10.8	0.6	260.	70.	13.1
V0U421	116.	21.	8.9	0.6	571.	154.	15.3
V0U422	74.	13.	7.4	0.5	489.	132.	16.3
V0U501	72.	13.	5.5	0.4	1804.	487.	26.5
V0U502	139.	25.	8.4	0.6	1245.	337.	24.1
V0U503	174.	32.	10.5	0.8	1014.	274.	24.3
V0U504	182.	33.	9.1	0.6	1132.	306.	23.0
V0U505	165.	30.	9.9	0.7	782.	211.	24.7
V0U506	176.	32.	13.9	1.0	842.	227.	26.7
V0U507	70.	13.	9.2	0.7	739.	200.	26.5
V0U508	137.	25.	7.3	0.5	1026.	277.	24.6
V0U509	157.	28.	9.8	0.7	885.	235.	23.3
V0U510	161.	29.	21.7	1.6	985.	266.	23.7
V0U511	161.	29.	9.8	0.7	757.	204.	22.5
V0U512	132.	24.	8.9	0.6	835.	225.	23.3
V0U513	145.	26.	7.9	0.6	662.	179.	16.7
V0U514	97.	18.	6.4	0.5	1030.	278.	20.7
V0U516	136.	25.	7.5	0.5	1086.	253.	22.5
V0U517	122.	22.	8.1	0.6	732.	198.	22.4
V0U518	143.	26.	6.5	0.5	1208.	326.	15.7
V0U519	86.	16.	5.4	0.4	1090.	254.	21.4
V0U520	135.	24.	5.8	0.4	1154.	312.	21.3
V0U521	206.	37.	12.2	0.5	513.	247.	24.5
V0U522	130.	24.	9.0	0.6	744.	201.	22.3
V0U523	155.	28.	5.4	0.7	755.	205.	22.1
V0U524	139.	25.	10.5	0.6	714.	193.	22.0
V0U525	179.	32.	29.6	2.1	729.	197.	24.5
V0U526	51.	9.	8.9	0.6	2046.	522.	20.7
V0U601	67.	12.	4.6	0.3	839.	227.	19.6
V0U602	68.	12.	3.6	0.3	1110.	300.	21.6
V0U603	128.	23.	9.1	0.7	758.	205.	21.4
V0U604	122.	22.	5.1	0.4	518.	248.	24.2
V0U605	70.	13.	5.1	0.4	678.	237.	13.4
V0U606	156.	28.	7.7	0.6	714.	193.	22.1
V0U607	94.	17.	7.2	0.5	820.	221.	15.6
V0U608	89.	16.	6.3	0.4	662.	179.	20.4
V0U609	154.	28.	8.7	0.6	596.	161.	24.6
V0U610	116.	21.	6.0	0.4	785.	212.	20.8
V0U611	51.	9.	3.9	0.3	1250.	336.	21.0
V0U612	74.	13.	5.2	0.4	446.	120.	16.8
V0U613	108.	20.	6.8	0.5	783.	211.	25.1
V0U614	124.	22.	6.8	0.5	1190.	321.	15.0
V0U615	144.	26.	9.5	0.7	768.	207.	22.4
V0U616	53.	10.	9.1	0.7	368.	99.	21.8
V0U617	179.	32.	8.2	0.6	936.	253.	21.6
V0U618	168.	30.	8.3	0.6	635.	173.	22.2
V0U619	134.	24.	6.9	0.5	675.	162.	22.6
V0U620	89.	16.	5.0	0.4	610.	165.	22.6
V0U621	154.	28.	22.0	1.7	535.	144.	22.4
V0U622	109.	20.	6.0	0.4	409.	110.	17.8
V0U623	96.	17.	4.3	0.2	652.	176.	16.0
V0U 001	210.	123.	5.6	0.5	0.	0.	15.5
V0U 002	262.	161.	11.5	1.0	0.	0.	16.8
V0U 207	262.	168.	9.6	0.6	0.	0.	12.5
V0U 208	136.	139.	3.1	0.6	0.	0.	16.7
V0U 209	0.	0.	0.0	0.0	0.	0.	0.0
V0U 211	0.	0.	0.0	0.0	0.	0.	0.0
V0U 212	268.	162.	8.4	0.6	0.	0.	16.1
V0U 213	247.	158.	6.1	0.6	0.	0.	20.6
V0U 214	183.	155.	5.9	0.7	0.	0.	17.8
MYCN	145.	26.	5.2	0.7	0.	0.	21.1

SAMPLE	HF (PPM)	TA (PPM)	CR (PPM)	FE (1)	CC (PPM)	(NI) (PPM)	SB (PPM)							
V0U010	2.7	0.3	0.44	0.45	163.	6.	3.13	0.07	15.2	0.5	0.	0.	0.00	0.00
V0U011	3.3	0.4	0.41	0.42	139.	5.	3.24	0.07	17.2	0.4	0.	0.	0.00	0.00
V0U012	3.5	0.4	0.72	0.15	220.	8.	3.93	0.05	24.3	0.6	0.	0.	0.00	0.00
V0U013	3.3	0.4	0.41	0.42	215.	6.	3.92	0.05	24.5	0.6	0.	0.	0.00	0.00
V0U014	3.4	0.4	0.54	0.11	200.	7.	3.91	0.05	25.1	0.6	0.	0.	0.00	0.00
V0U015	3.4	0.4	0.66	0.13	267.	10.	6.31	0.14	37.3	0.9	0.	0.	0.00	0.00
V0U016	3.5	0.4	0.64	0.13	268.	10.	6.36	0.14	35.0	1.0	0.	0.	0.00	0.00
V0U101	3.2	0.4	0.21	0.04	261.	10.	5.26	0.12	35.2	1.0	0.	0.	0.00	0.00
V0U102	3.4	0.4	0.42	0.05	556.	21.	5.18	0.11	45.8	1.1	0.	0.	0.00	0.00
V0U103	4.3	0.5	0.44	0.05	277.	10.	5.15	0.11	26.5	0.7	0.	0.	0.00	0.00
V0U104	2.6	0.3	0.24	0.05	424.	16.	3.57	0.05	26.6	0.9	0.	0.	0.00	0.00
V0U105	3.9	0.4	0.61	0.12	370.	14.	5.07	0.11	22.0	0.8	0.	0.	0.00	0.00
V0U106	5.0	0.6	0.73	0.15	185.	7.	4.78	0.11	28.5	0.7	0.	0.	0.00	0.00
V0U107	3.5	0.4	0.28	0.05	385.	14.	4.70	0.10	32.5	0.8	0.	0.	0.00	0.00
V0U108	3.6	0.4	0.74	0.15	532.	20.	5.14	0.11	37.0	0.9	0.	0.	0.00	0.00
V0U111	2.9	0.3	0.36	0.07	260.	10.	4.10	0.05	25.9	0.7	0.	0.	0.00	0.00
V0U112	3.6	0.3	0.39	0.08	364.	14.	4.65	0.10	34.8	0.9	0.	0.	0.00	0.00
V0U113	2.5	0.3	0.41	0.08	278.	10.	3.65	0.05	25.1	0.7	0.	0.	0.00	0.00
V0U114	2.6	0.3	0.43	0.05	306.	11.	4.08	0.05	25.7	0.7	0.	0.	0.00	0.00
V0U115	3.8	0.3	0.74	0.15	254.	9.	4.23	0.05	25.0	0.6	0.	0.	0.00	0.00
V0U116	3.0	0.3	0.25	0.05	380.	14.	4.55	0.10	33.9	0.8	0.	0.	0.00	0.00
V0U151	3.5	0.4	0.64	0.13	217.	8.	3.90	0.05	24.8	0.6	0.	0.	0.00	0.00
V0U152	4.0	0.4	1.23	0.25	527.	20.	6.00	0.13	42.6	1.1	0.	0.	0.00	0.00
V0U153	4.0	0.4	0.59	0.12	232.	9.	4.70	0.10	27.1	0.7	0.	0.	0.00	0.00
V0U154	3.4	0.4	0.51	0.10	131.	5.	4.92	0.11	30.0	0.8	0.	0.	0.00	0.00
V0U155	5.6	0.6	0.58	0.12	102.	4.	4.59	0.10	19.2	0.5	0.	0.	0.00	0.00
V0U156	5.0	0.6	0.75	0.15	238.	9.	4.09	0.09	23.4	0.6	0.	0.	0.00	0.00
V0U157	4.8	0.5	0.56	0.11	210.	8.	4.66	0.10	21.3	0.5	0.	0.	0.00	0.00
V0U158	5.3	0.6	0.70	0.14	209.	8.	4.75	0.10	24.4	0.6	0.	0.	0.00	0.00
V0U159	5.7	0.6	0.77	0.16	164.	6.	4.44	0.10	23.0	0.6	0.	0.	0.00	0.00
V0U160	3.9	0.4	1.12	0.23	292.	11.	6.42	0.14	26.7	0.9	0.	0.	0.00	0.00
V0U201	3.9	0.4	0.44	0.05	242.	9.	3.81	0.05	21.6	0.5	0.	0.	0.00	0.00
V0U202	3.4	0.4	0.59	0.12	177.	7.	3.08	0.07	15.8	0.5	0.	0.	0.00	0.00
V0U203	4.3	0.5	0.61	0.12	474.	18.	4.96	0.11	22.9	0.8	0.	0.	0.00	0.00
V0U204	3.6	0.4	0.47	0.10	350.	13.	4.47	0.10	30.3	0.8	0.	0.	0.00	0.00
V0U205	3.4	0.4	0.46	0.09	425.	16.	5.44	0.12	41.5	1.0	0.	0.	0.00	0.00
V0U206	2.5	0.3	0.46	0.05	169.	6.	3.07	0.07	22.2	0.6	0.	0.	0.00	0.00
V0U301	4.8	0.5	1.41	0.25	330.	12.	4.99	0.11	20.3	0.7	0.	0.	0.00	0.00
V0U302	3.8	0.4	0.77	0.16	501.	19.	5.32	0.12	37.7	0.9	0.	0.	0.00	0.00
V0U303	3.4	0.4	0.72	0.15	535.	20.	6.09	0.13	45.5	1.1	0.	0.	0.00	0.00
V0U304	3.8	0.4	0.79	0.16	462.	17.	5.78	0.13	35.4	1.0	0.	0.	0.00	0.00
V0U401	2.9	0.3	0.56	0.11	1110.	41.	5.04	0.11	46.9	1.2	0.	0.	0.00	0.00
V0U402	2.6	0.3	0.47	0.10	215.	6.	4.14	0.05	25.2	0.7	0.	0.	0.00	0.00
V0U403	2.0	0.2	0.76	0.15	251.	11.	3.38	0.07	25.2	0.7	0.	0.	0.00	0.00
V0U404	2.6	0.3	0.25	0.05	169.	6.	3.38	0.07	25.3	0.6	0.	0.	0.00	0.00
V0U405	5.9	0.8	0.60	0.12	122.	5.	4.38	0.10	19.6	0.5	0.	0.	0.00	0.00
V0U406	3.4	0.4	0.51	0.10	151.	6.	3.48	0.05	15.6	0.5	0.	0.	0.00	0.00
V0U407	3.8	0.4	0.50	0.10	416.	15.	4.74	0.10	33.5	0.8	0.	0.	0.00	0.00
V0U408	5.1	0.6	0.56	0.11	478.	16.	4.79	0.11	36.5	0.9	0.	0.	0.00	0.00
V0U409	2.8	0.3	0.44	0.09	161.	6.	3.85	0.05	24.5	0.6	0.	0.	0.00	0.00
V0U410	3.4	0.4	0.58	0.12	182.	7.	3.57	0.05	24.4	0.6	0.	0.	0.00	0.00
V0U411	5.2	0.6	0.55	0.11	95.	4.	4.07	0.05	16.5	0.4	0.	0.	0.00	0.00
V0U412	6.8	0.8	0.72	0.15	92.	3.	4.36	0.10	16.5	0.4	0.	0.	0.00	0.00
V0U413	2.8	0.3	0.67	0.14	331.	12.	4.45	0.10	22.1	0.8	0.	0.	0.00	0.00
V0U414	2.4	0.3	0.56	0.11	363.	13.	4.18	0.05	31.9	0.8	0.	0.	0.00	0.00
V0U415	2.8	0.3	0.81	0.16	350.	12.	4.91	0.11	37.7	0.9	0.	0.	0.00	0.00

SAMPLE	HF (PPM)		TA (PPM)		CR (PPM)	FE (1)	CC (PPM)		(NI) (PPM)		SB (PPM)	
V0U416	3.2	0.4	0.58	0.12	175.	7.	4.33	0.10	31.8	0.8	0.	0.
V0U417	3.4	0.4	0.56	0.11	293.	11.	5.09	0.11	34.2	0.9	0.	0.
V0U418	3.7	0.4	0.86	0.17	260.	10.	5.42	0.12	33.2	0.8	0.	0.
V0U419	3.7	0.4	0.98	0.20	198.	7.	5.38	0.05	27.5	0.7	0.	0.
V0U420	2.5	0.3	0.37	0.06	171.	6.	5.25	0.07	22.4	0.6	0.	0.
V0U421	6.3	0.7	1.44	0.29	330.	12.	4.31	0.05	31.0	0.9	0.	0.
V0U422	2.4	0.3	0.55	0.11	148.	6.	3.90	0.05	25.6	0.6	0.	0.
V0U501	3.4	0.4	0.40	0.08	257.	11.	6.42	0.14	37.5	0.9	0.	0.
V0U502	3.7	0.4	0.55	0.15	288.	11.	6.15	0.14	33.8	0.8	0.	0.
V0U503	3.6	0.4	1.11	0.23	283.	11.	6.04	0.12	31.5	0.8	0.	0.
V0U504	3.3	0.4	0.56	0.11	271.	10.	6.06	0.12	32.2	0.8	0.	0.
V0U505	3.7	0.4	0.84	0.17	276.	10.	6.28	0.14	34.0	0.8	0.	0.
V0U506	4.4	0.5	1.23	0.25	331.	23.	6.82	0.15	43.1	1.1	0.	0.
V0U507	4.5	0.5	1.06	0.22	281.	10.	6.61	0.15	32.2	0.8	0.	0.
V0U508	4.5	0.5	0.51	0.18	120.	12.	6.19	0.14	32.9	0.8	0.	0.
V0U509	2.8	0.3	0.42	0.09	241.	5.	5.20	0.12	25.8	0.7	0.	0.
V0U510	3.0	0.3	0.79	0.16	285.	11.	5.76	0.12	34.8	0.8	0.	0.
V0U511	3.5	0.4	0.82	0.17	251.	5.	5.57	0.12	30.1	0.8	0.	0.
V0U512	3.4	0.4	0.99	0.20	278.	10.	5.70	0.12	32.6	0.8	0.	0.
V0U513	4.0	0.4	0.85	0.17	301.	11.	4.77	0.10	25.2	0.7	0.	0.
V0U514	3.4	0.4	0.85	0.17	254.	5.	5.45	0.12	32.8	0.8	0.	0.
V0U516	3.8	0.4	1.05	0.21	275.	10.	5.61	0.12	32.5	0.8	0.	0.
V0U517	3.1	0.4	0.43	0.09	257.	10.	5.53	0.12	31.6	0.9	0.	0.
V0U518	4.2	0.5	0.86	0.17	258.	10.	5.31	0.12	23.8	0.7	0.	0.
V0U519	4.7	0.5	1.02	0.21	240.	5.	5.79	0.13	31.0	0.8	0.	0.
V0U520	4.3	0.5	0.66	0.13	272.	10.	5.50	0.12	26.0	0.6	0.	0.
V0U521	4.1	0.4	0.98	0.20	632.	23.	6.20	0.14	37.4	0.9	0.	0.
V0U522	4.6	0.5	0.90	0.18	237.	5.	5.52	0.12	27.0	0.7	0.	0.
V0U523	3.9	0.4	0.76	0.15	243.	5.	5.51	0.12	27.0	0.7	0.	0.
V0U524	3.5	0.4	0.63	0.12	271.	10.	5.60	0.12	25.4	0.6	0.	0.
V0U525	3.5	0.4	1.02	0.21	281.	10.	5.40	0.12	31.4	0.8	0.	0.
V0U526	3.3	0.4	0.76	0.15	295.	11.	5.45	0.12	26.6	0.7	0.	0.
V0U601	5.3	0.6	2.08	0.42	102.	4.	4.02	0.09	26.4	2.2	0.	0.
V0U602	5.1	0.6	1.18	0.24	55.	4.	5.11	0.11	22.6	0.6	0.	0.
V0U603	3.6	0.4	0.84	0.17	233.	5.	5.16	0.11	25.2	0.6	0.	0.
V0U604	4.5	0.5	0.54	0.16	141.	5.	5.41	0.12	34.5	0.9	0.	0.
V0U605	5.5	0.6	1.17	0.24	258.	10.	5.93	0.09	30.2	0.8	0.	0.
V0U606	3.4	0.4	1.07	0.22	243.	5.	5.62	0.12	25.5	0.6	0.	0.
V0U607	5.1	0.6	1.02	0.24	335.	12.	4.21	0.09	22.0	0.8	0.	0.
V0U608	4.4	0.5	0.72	0.15	142.	5.	4.40	0.10	22.8	0.6	0.	0.
V0U609	4.1	0.5	0.54	0.11	254.	5.	5.96	0.13	32.9	0.8	0.	0.
V0U610	3.2	0.4	0.25	0.17	205.	8.	5.27	0.12	26.4	0.7	0.	0.
V0U611	4.2	0.5	0.49	0.10	104.	4.	4.48	0.10	14.0	0.3	0.	0.
V0U612	3.8	0.4	0.61	0.12	94.	4.	4.88	0.09	17.8	0.4	0.	0.
V0U613	3.3	0.4	0.39	0.08	203.	8.	5.95	0.13	32.8	0.8	0.	0.
V0U614	3.9	0.4	0.99	0.20	239.	5.	4.98	0.11	25.0	0.6	0.	0.
V0U615	3.7	0.4	0.58	0.20	248.	5.	5.28	0.12	27.2	0.7	0.	0.
V0U616	3.9	0.4	1.10	0.24	236.	5.	5.28	0.12	22.2	0.7	0.	0.
V0U617	3.6	0.4	1.40	0.28	282.	10.	6.45	0.14	36.4	0.7	0.	0.
V0U618	4.7	0.5	1.04	0.21	271.	10.	5.46	0.12	22.0	0.8	0.	0.
V0U619	4.5	0.5	0.58	0.20	242.	5.	5.42	0.12	22.2	0.7	0.	0.
V0U620	3.6	0.4	0.54	0.19	245.	5.	5.49	0.12	25.4	0.7	0.	0.
V0U621	3.6	0.4	0.24	0.17	306.	11.	5.19	0.11	32.4	0.8	0.	0.
V0U622	3.2	0.4	1.05	0.21	214.	8.	4.42	0.10	32.0	0.8	0.	0.
V0U623	5.3	0.6	0.74	0.15	83.	3.	4.18	0.09	17.3	0.4	0.	0.
V0U 001	3.7	0.4	0.69	0.36	183.	10.	3.93	0.05	23.0	0.5	0.	0.
V0U 002	3.6	0.5	0.54	0.38	158.	10.	4.23	0.05	22.6	0.6	0.	0.
V0U 207	3.4	0.4	0.43	0.22	170.	5.	3.32	0.07	20.8	0.5	0.	0.
V0U 208	3.6	0.6	0.56	0.40	210.	15.	4.45	0.10	26.1	0.6	0.	0.
V0U 209	0.0	0.0	0.00	0.00	0.	0.	0.00	0.00	0.0	0.0	0.	0.
V0U 211	0.0	0.0	0.00	0.00	0.	0.	0.00	0.00	0.0	0.0	0.	0.
V0U 212	3.0	0.4	0.46	0.34	139.	0.	2.65	0.05	15.7	0.4	0.	0.
V0U 213	3.7	0.5	0.86	0.45	318.	15.	5.20	0.11	36.6	0.8	0.	0.
V0U 214	3.3	0.6	0.24	0.41	285.	15.	4.71	0.11	26.3	0.6	0.	0.
MYCN	3.2	0.4	0.82	0.17	221.	8.	5.16	0.11	28.2	0.7	0.	0.

SAMPLE	AL (%)	MG (%)	CA (%)	V (PPM)	TI (%)	(NA) (%)	NA (%)	K (%)	NN (PPM)
ZYG 1	0.00	0.00	0.0	0.0	18.6	1.9	0.	0.	0.
ZYG 2	0.00	0.00	0.0	0.0	2.5	0.3	0.	0.	0.
ZYG 3	7.72	0.06	1.6	0.3	9.4	0.1	135.	4.	0.
ZYG 4	8.12	0.06	2.9	0.3	1.5	0.1	121.	4.	0.
ZYG 6	7.01	0.06	1.6	0.2	10.9	0.3	103.	4.	0.
ZYG 7	0.00	0.00	0.0	0.0	14.6	0.	0.	0.	0.
ZYG 8	0.00	0.00	0.0	0.0	12.1	1.2	0.	0.	0.
ZYG 9	0.00	0.00	0.0	0.0	11.4	1.1	0.	0.	0.
ZYG 10	0.00	0.00	0.0	0.0	12.4	1.2	0.	0.	0.
ZYG 11	0.00	0.00	0.0	0.0	13.5	1.4	0.	0.	0.
ZYG 12	8.46	0.06	2.4	0.4	11.9	0.5	137.	7.	0.
ZYG 13	0.00	0.00	0.0	0.0	0.0	0.0	0.	0.	0.
ZYG 14	0.00	0.00	0.0	0.0	20.4	2.0	0.	0.	0.
ZYG 15	6.31	0.06	1.5	0.2	16.9	0.4	89.	4.	0.
ZYG 16	7.56	0.06	2.2	0.3	10.4	0.3	136.	4.	0.
ZYG 17	9.59	0.10	2.4	0.5	9.1	0.3	174.	4.	0.
ZYG 18	7.14	0.06	2.0	0.3	16.3	0.3	125.	4.	0.
ZYG 19	6.72	0.06	1.9	0.2	16.1	0.3	130.	4.	0.
ZYG 20	8.11	0.06	2.3	0.3	12.1	0.3	135.	4.	0.
ZYG 21	7.36	0.06	1.9	0.3	10.5	0.3	104.	4.	0.
ZYG 22	8.64	0.06	1.9	0.3	9.9	0.3	126.	4.	0.
ZYG 23	8.37	0.06	2.6	0.3	10.9	0.3	166.	4.	0.
ZYG 24	9.11	0.09	2.1	0.3	10.6	0.3	152.	4.	0.
ZYG 25	7.82	0.06	1.9	0.3	11.7	0.3	125.	4.	0.
ZYG 26	7.75	0.06	2.0	0.3	10.0	0.3	124.	4.	0.
ZYG 27	8.79	0.06	2.2	0.3	3.8	0.3	124.	4.	0.
ZYG 28	7.68	0.06	1.4	0.3	12.0	0.3	126.	4.	0.
ZYG 29	7.44	0.06	1.7	0.3	11.3	0.3	114.	4.	0.
ZYG 30	7.36	0.06	1.6	0.3	10.6	0.3	113.	4.	0.

SAMPLE	(U) (PPM)	(SC) (PPM)	W (PPM)	LA (PPM)	(SM) (PPM)	YB (PPM)	(LU) (PPM)	AS (PPM)	(SB) (PPM)			
ZYG 1	0.0	0.0	0.0	0.0	15.	1.	3.1	0.02	17.5	3.5	0.00	0.00
ZYG 2	0.0	0.0	0.0	0.0	18.	1.	0.0	0.03	0.0	0.0	0.00	0.00
ZYG 3	1.6	0.6	15.2	0.4	49.	1.	0.0	0.15	10.7	1.0	0.55	0.20
ZYG 4	2.8	0.8	22.4	0.4	162.	3.	0.0	0.15	10.9	0.9	1.01	0.22
ZYG 5	1.9	0.6	17.8	0.4	41.	1.	0.0	0.12	17.3	1.0	0.00	0.00
ZYG 7	0.0	0.0	0.0	0.0	15.	1.	0.0	0.02	18.4	3.6	0.00	0.00
ZYG 8	0.0	0.0	0.0	0.0	9.	1.	0.0	0.03	26.2	4.0	0.00	0.00
ZYG 9	0.0	0.0	0.0	0.0	16.	1.	0.0	0.03	34.5	4.7	0.00	0.00
ZYG 10	0.0	0.0	0.0	0.0	12.	1.	0.0	0.03	27.3	4.0	0.00	0.00
ZYG 11	0.0	0.0	0.0	0.0	24.	2.	0.0	0.03	25.1	4.1	0.00	0.00
ZYG 12	2.7	1.1	24.1	0.6	71.	2.	0.0	0.20	7.8	0.8	0.00	0.00
ZYG 13	0.0	0.0	0.0	0.0	4.	1.	0.0	0.02	48.3	3.9	0.00	0.00
ZYG 14	0.0	0.0	0.0	0.0	3.	1.	0.0	0.02	44.8	4.0	0.00	0.00
ZYG 15	1.2	0.3	16.1	0.5	28.	1.	0.0	0.23	16.6	0.9	0.00	0.00
ZYG 16	2.0	0.5	23.1	0.5	65.	2.	0.0	0.16	31.4	1.2	0.00	0.00
ZYG 17	2.7	0.4	26.7	0.4	22.	1.	0.0	0.21	4.2	0.7	0.56	0.20
ZYG 18	2.3	0.8	19.1	0.5	20.	1.	0.0	0.18	21.4	1.5	0.90	0.23
ZYG 19	2.7	0.4	19.4	0.4	5.	1.	0.0	0.09	24.7	1.2	0.53	0.14
ZYG 20	2.2	0.7	22.2	0.4	21.	1.	0.0	0.11	10.9	1.2	0.40	0.20
ZYG 21	2.9	0.9	18.5	0.2	105.	2.	0.0	0.14	26.5	1.5	0.82	0.19
ZYG 22	2.9	1.0	21.7	0.5	61.	2.	0.0	0.14	22.8	1.6	0.95	0.21
ZYG 23	2.6	1.0	20.3	0.5	37.	1.	0.0	0.18	17.3	1.1	0.97	0.18
ZYG 24	2.2	0.7	20.1	0.5	14.	1.	0.0	0.14	3.8	0.4	0.30	0.00
ZYG 25	2.5	0.7	20.4	0.4	68.	2.	0.0	0.17	12.2	0.8	0.00	0.00
ZYG 26	3.4	0.9	20.6	0.4	34.	1.	0.0	0.14	12.5	1.0	0.45	0.18
ZYG 27	3.1	0.4	20.8	0.4	345.	4.	0.0	0.20	14.1	0.7	1.42	0.20
ZYG 28	1.6	0.6	19.9	0.4	63.	2.	0.0	0.15	11.7	0.8	0.70	0.18
ZYG 29	2.7	0.6	19.9	0.2	32.	1.	0.0	0.10	8.5	0.9	0.60	0.19
ZYG 30	2.7	0.7	20.4	0.4	30.	1.	0.0	0.10	6.3	0.7	0.00	0.00

SAMPLE	RB (PPM)	CS (PPM)	EA (PPM)	SC (PPM)	CE (PPM)	EU (PPM)	TH (PPM)
ZYG 1	361.	215.	6.9	0.6	0.	0.	17.4
ZYG 2	253.	165.	5.2	0.6	0.	0.	16.7
ZYG 3	108.	11.	9.9	1.2	0.	0.	20.0
ZYG 4	112.	12.	5.5	1.0	238.	72.	21.5
ZYG 5	132.	13.	6.9	0.5	572.	97.	17.2
ZYG 6	270.	171.	10.0	0.9	0.	0.	15.1
ZYG 7	266.	193.	12.7	1.1	0.	0.	22.5
ZYG 8	266.	170.	11.5	1.0	0.	0.	20.7
ZYG 9	433.	255.	14.0	1.2	0.	0.	23.0
ZYG 10	413.	245.	12.3	1.1	0.	0.	21.7
ZYG 11	161.	13.	11.0	1.1	34.	92.	24.0
ZYG 12	261.	180.	11.4	0.9	0.	0.	14.5
ZYG 13	126.	106.	16.4	1.2	0.	0.	15.6
ZYG 14	99.	11.	17.3	1.3	0.	0.	13.8
ZYG 15	157.	14.	12.4	1.6	408.	82.	23.6
ZYG 16	200.	16.	23.3	1.4	616.	135.	26.9
ZYG 17	139.	16.	9.8	0.6	0.	0.	16.2
ZYG 18	129.	14.	10.9	1.2	545.	113.	15.5
ZYG 19	101.	13.	15.7	1.2	361.	115.	22.1
ZYG 20	131.	9.	7.9	0.7	781.	86.	18.3
ZYG 21	131.	16.	12.4	1.1	476.	117.	21.6
ZYG 22	156.	12.	9.1	0.6	748.	187.	22.8
ZYG 23	160.	13.	12.0	0.6	384.	78.	23.6
ZYG 24	135.	9.	10.1	0.3	592.	66.	20.2
ZYG 25	166.	15.	13.5	0.6	231.	73.	20.3
ZYG 26	147.	17.	8.1	0.6	338.	89.	20.1
ZYG 27	126.	13.	9.4	1.2	346.	92.	19.4
ZYG 28	123.	7.	10.8	0.3	139.	28.	19.4
ZYG 29	165.	15.	6.4	0.5	207.	84.	15.3
ZYG 30							

SAMPLE	HF (PPM)	(TA) (PPM)	CR (PPM)	FE (1)	CC (PPM)	(NI) (PPM)	SD (PPM)							
ZYG 1	3.4	0.5	0.27	0.41	254.	16.	4.74	0.10	27.6	0.6	0.	0.	0.00	0.00
ZYG 2	7.2	0.6	1.40	0.42	337.	16.	5.30	0.11	40.5	0.8	0.	0.	0.00	0.00
ZYG 3	4.3	0.4	0.48	0.02	281.	11.	4.64	0.05	26.4	1.5	99.	29.	0.31	0.13
ZYG 4	4.8	0.4	0.40	0.11	305.	11.	5.19	0.16	24.3	0.5	134.	39.	0.38	0.12
ZYG 5	4.1	0.4	0.51	0.02	200.	9.	4.25	0.04	21.5	0.4	146.	35.	0.27	0.10
ZYG 7	2.9	0.5	1.56	0.47	221.	12.	4.86	0.11	25.5	0.6	0.	0.	0.00	0.00
ZYG 8	3.9	0.6	0.64	0.43	245.	12.	5.74	0.12	24.5	0.7	0.	0.	0.00	0.00
ZYG 9	4.0	0.5	0.90	0.43	220.	12.	5.11	0.11	26.3	0.6	0.	0.	0.00	0.00
ZYG 10	3.2	0.5	0.76	0.42	234.	13.	5.06	0.11	27.8	0.6	0.	0.	0.00	0.00
ZYG 11	2.1	0.5	0.80	0.42	246.	13.	5.10	0.11	27.6	0.6	0.	0.	0.00	0.00
ZYG 12	3.1	0.3	0.62	0.05	256.	9.	5.75	0.04	22.5	0.4	261.	62.	0.35	0.13
ZYG 13	2.1	0.5	0.61	0.36	170.	15.	3.66	0.05	22.4	0.5	0.	0.	0.00	0.00
ZYG 14	3.1	0.5	0.57	0.40	239.	12.	4.38	0.10	24.4	0.7	0.	0.	0.00	0.00
ZYG 15	3.5	0.4	0.57	0.05	466.	15.	3.85	0.05	22.5	0.4	209.	46.	0.60	0.14
ZYG 16	2.5	0.4	0.71	0.13	240.	12.	5.85	0.05	22.2	0.5	149.	59.	0.76	0.15
ZYG 17	4.0	0.4	0.46	0.05	316.	12.	5.73	0.05	41.0	0.5	280.	61.	0.42	0.12
ZYG 18	4.3	0.5	0.74	0.11	240.	11.	4.81	0.15	25.4	0.4	168.	54.	0.74	0.15
ZYG 19	2.6	0.3	0.51	0.05	216.	10.	4.86	0.05	25.5	0.4	0.	0.	0.60	0.12
ZYG 20	3.7	0.4	0.69	0.10	261.	12.	4.82	0.17	27.3	0.4	0.	0.	0.73	0.15
ZYG 21	3.6	0.6	0.58	0.07	217.	6.	4.40	0.05	22.0	0.2	136.	24.	0.56	0.08
ZYG 22	3.8	0.4	0.69	0.11	232.	12.	4.57	0.06	26.0	1.6	0.	0.	0.25	0.10
ZYG 23	3.0	0.4	0.74	0.05	254.	11.	5.42	0.06	22.8	0.5	236.	58.	0.47	0.16
ZYG 24	3.3	0.4	0.51	0.10	221.	11.	5.46	0.06	27.3	0.5	122.	40.	0.38	0.13
ZYG 25	4.0	0.2	0.62	0.06	217.	6.	4.81	0.03	26.7	0.3	65.	19.	0.37	0.09
ZYG 26	4.4	0.5	0.67	0.11	213.	10.	4.65	0.05	22.8	1.4	92.	29.	0.48	0.14
ZYG 27	5.4	0.5	0.20	0.12	134.	9.	4.95	0.06	13.4	0.5	0.	0.	1.33	0.25
ZYG 28	4.1	0.4	0.51	0.05	194.	10.	4.51	0.05	22.7	0.4	124.	53.	0.40	0.12
ZYG 29	4.2	0.5	0.75	0.14	222.	11.	4.55	0.05	23.7	0.2	138.	28.	0.46	0.09
ZYG 30	4.0	0.4	0.30	0.07	218.	11.	4.47	0.05	22.6	0.4	177.	64.	0.40	0.11

APPENDIX B: Comparative analyses from the Brookhaven
National Laboratory data bank

Descriptions of the samples may be found in the following sources:

SP (Sparta)	Attas <u>et al.</u> 1982
D, M, 25 (Attic)	Fillières 1978
P, HS, ID (black-glazed)	Bieber <u>et al.</u> 1976b.
LC (Ayios Stephanos)	"
MC (Berbati)	"
and the rest	"

The cobalt concentrations have not been corrected for drill-bit contamination.

SAMPLE	CA (%)	NA (%)	K (%)	MN (PPM)	LA (PPM)	SB (PPM)	LU (PPM)	AS (PPM)	RB (PPM)	CS (PPM)	DA (PPM)
SP01	16.4	0.38	1.02	851.	16.7	5.3	0.38	0.0	67.	4.2	528.
SP02	4.5	0.57	1.37	1001.	22.5	5.2	0.49	0.0	148.	7.6	626.
SP03	14.4	0.44	1.57	851.	20.5	6.1	0.43	0.0	80.	4.5	639.
SP04	9.4	0.41	1.51	881.	40.5	6.9	0.59	0.0	86.	4.4	549.
SP05	7.9	0.58	1.98	708.	37.4	8.7	0.42	0.0	135.	5.6	447.
SP06	8.8	0.56	2.46	836.	35.0	5.8	0.40	0.0	148.	6.9	611.
SP07	8.9	0.43	2.06	495.	40.5	7.5	0.48	0.0	144.	7.4	491.
SP11	6.7	0.75	2.04	881.	35.5	6.7	0.56	0.0	119.	4.6	384.
SP12	6.1	0.49	2.06	1090.	37.7	7.8	0.43	0.0	145.	5.8	449.
SP13	5.8	0.77	2.30	911.	37.4	5.8	0.58	0.0	141.	6.1	392.
SP14	4.8	0.53	2.13	874.	42.5	8.8	0.66	0.0	144.	6.3	509.
SP15	6.1	0.32	1.57	831.	44.0	7.4	0.52	0.0	138.	6.0	412.
SP16	3.2	0.53	1.89	504.	48.3	9.5	0.52	0.0	128.	5.0	491.
SP17	5.2	0.51	1.74	1202.	37.2	8.6	0.50	0.0	87.	3.6	537.
SP18	6.1	0.34	1.62	605.	44.8	6.0	0.42	0.0	78.	2.0	519.
SP19	4.4	0.52	1.15	1120.	42.7	9.4	0.57	0.0	135.	5.6	363.
SP31	5.7	0.84	2.32	792.	41.7	4.5	0.48	0.0	167.	7.1	472.
SP32	5.3	0.67	2.06	1173.	41.7	8.5	0.55	0.0	127.	4.9	621.
SP33	5.7	0.47	2.32	2166.	44.0	10.7	0.43	0.0	146.	7.0	656.
SP34	3.9	0.54	2.32	423.	41.2	8.0	0.52	0.0	147.	6.4	539.
SP35	5.4	0.77	2.42	822.	32.2	6.4	0.45	0.0	156.	7.0	469.
SP36	4.7	0.68	2.30	822.	32.2	5.7	0.45	0.0	145.	6.4	437.
SP37	5.1	0.61	2.17	718.	42.5	9.6	0.58	0.0	147.	6.7	566.
SP38	4.4	0.70	2.15	1266.	42.4	7.6	0.42	0.0	153.	7.2	385.
SP39	4.4	0.52	2.15	1266.	42.4	7.6	0.42	0.0	135.	5.9	598.
SP41	6.0	0.77	2.50	911.	34.4	6.3	0.41	0.0	150.	6.9	509.
SP42	3.7	0.52	2.23	1105.	44.2	8.4	0.56	0.0	158.	7.0	562.
SP43	5.2	0.77	2.24	926.	32.2	6.6	0.43	0.0	112.	4.9	402.
SP44	3.7	0.53	2.50	1155.	39.1	7.8	0.39	0.0	158.	6.8	524.
SP45	3.9	0.51	2.35	1038.	44.1	11.1	0.44	0.0	156.	6.9	558.
SP46	4.6	0.78	2.48	777.	32.2	8.7	0.46	0.0	164.	5.9	496.
SP47	4.9	0.57	2.29	1083.	40.5	9.9	0.41	0.0	154.	7.0	579.
SP48	4.6	0.74	2.41	859.	42.5	8.1	0.41	0.0	154.	5.7	603.
SP51	4.3	0.48	1.99	1222.	42.5	8.0	0.33	0.0	144.	5.2	455.
SP52	4.8	0.72	2.36	534.	24.7	5.7	0.39	0.0	150.	5.7	467.
SP53	7.1	0.70	2.53	636.	22.7	8.7	0.37	0.0	170.	6.5	463.
SP54	4.0	0.49	2.35	1222.	32.2	8.2	0.59	0.0	170.	6.5	530.
SP55	5.1	0.79	2.56	836.	32.2	5.4	0.35	0.0	167.	6.4	410.
SP56	4.3	0.69	2.57	814.	26.0	5.9	0.47	0.0	177.	6.0	460.
SP61	4.1	0.55	2.54	904.	41.0	8.2	0.39	0.0	179.	6.9	552.
SP62	4.1	0.56	2.51	857.	32.2	6.3	0.29	0.0	170.	6.6	487.
SP63	5.5	0.71	2.41	874.	32.2	7.4	0.46	0.0	170.	6.6	387.
SP64	4.2	0.77	2.25	546.	32.2	7.9	0.48	0.0	148.	5.0	419.
SP65	5.2	0.60	2.73	769.	32.2	6.5	0.38	0.0	174.	6.2	539.
SP66	5.1	0.70	2.53	534.	37.2	6.4	0.45	0.0	172.	6.6	546.
SP67	5.3	0.64	2.62	867.	32.2	5.9	0.38	0.0	176.	6.1	578.
SP68	5.3	0.69	2.75	866.	32.2	6.0	0.41	0.0	174.	6.2	519.
SP69	4.9	0.65	2.30	563.	32.2	6.3	0.47	0.0	156.	5.6	476.
SP71	4.7	0.49	2.05	759.	32.2	7.2	0.75	0.0	156.	6.4	679.
SP72	6.7	0.34	2.05	1389.	47.1	7.2	0.50	0.0	164.	6.4	454.
SP73	4.2	0.37	2.69	866.	32.2	9.0	0.40	0.0	183.	5.0	500.
SP74	8.8	0.69	2.20	1046.	32.2	6.7	0.43	0.0	141.	6.0	396.
SP75	7.4	0.53	2.22	1210.	37.2	7.4	0.41	0.0	154.	6.9	445.
SP76	3.2	0.54	1.87	655.	37.2	7.4	0.36	0.0	126.	4.3	448.
SP77	2.0	0.50	1.80	1083.	22.2	5.8	0.51	0.0	128.	4.2	443.
SP80	4.1	0.95	2.53	417.	44.0	7.9	0.48	0.0	187.	6.4	604.
SP81	5.8	0.46	2.53	417.	44.0	8.0	0.50	0.0	157.	5.9	595.
SP82	5.0	0.61	2.75	742.	34.4	6.5	0.46	0.0	170.	6.2	426.
SP83	0.0	0.76	2.25	336.	30.0	7.9	0.41	0.0	170.	5.1	758.
SP84	6.3	0.70	2.64	784.	36.4	9.2	0.51	0.0	161.	6.2	537.
SP85	6.8	0.53	2.71	812.	44.4	7.9	0.46	0.0	172.	6.7	738.
SP86	4.9	0.42	2.29	291.	42.1	7.9	0.44	0.0	138.	6.4	541.
SP87	7.7	0.37	2.21	225.	42.7	7.8	0.43	0.0	131.	5.7	559.
SP88	4.6	0.48	2.49	447.	46.0	8.6	0.40	0.0	141.	6.1	540.
SP89	4.8	0.45	2.53	447.	46.0	9.0	0.46	0.0	143.	7.1	515.
SP90	4.7	0.64	2.41	645.	46.0	9.0	0.41	0.0	151.	5.7	527.
SP91	4.2	0.59	2.72	1718.	47.0	9.0	0.25	0.0	151.	6.8	537.
SP92	3.3	0.54	2.58	1352.	46.7	9.0	0.61	0.0	162.	6.3	537.
SP93	6.2	0.41	2.45	799.	44.0	8.8	0.52	0.0	145.	6.7	677.
SP94	6.6	0.44	2.32	582.	44.0	8.1	0.44	0.0	170.	5.7	583.
SP95	7.7	0.41	2.44	428.	43.2	8.9	0.58	0.0	154.	6.4	486.
SP96	5.7	0.39	2.47	1016.	42.1	7.9	0.41	0.0	169.	6.9	566.
SP97	6.2	0.41	2.51	741.	43.1	8.3	0.58	0.0	160.	6.8	528.
SP98	10.4	0.39	2.58	656.	43.0	9.0	0.43	0.0	114.	6.2	426.
SP99	10.9	0.31	1.01	948.	31.6	5.8	0.39	0.0	39.	2.5	342.
SPM1	3.2	0.55	2.45	754.	45.1	10.1	0.46	0.0	139.	6.1	528.
SPM2	2.7	0.42	2.52	1404.	44.4	5.4	0.62	0.0	135.	6.4	605.
SPM3	3.6	0.59	2.04	588.	31.4	6.5	0.35	0.0	110.	4.4	404.
SPM4	3.5	0.46	1.83	1135.	42.2	7.3	0.50	0.0	123.	5.2	503.
SPM5	4.0	0.49	2.21	1636.	42.2	7.3	0.49	0.0	138.	6.1	633.
SPM6	5.1	0.41	2.41	1337.	42.7	6.9	0.46	0.0	142.	5.9	496.
SPM7	0.7	0.27	1.55	645.	46.2	8.3	0.51	0.0	125.	5.4	507.
SPM8	3.4	0.63	2.47	686.	44.0	8.0	0.40	0.0	143.	6.5	556.
SPM9	4.0	0.60	2.56	673.	22.2	6.7	0.34	0.0	130.	6.2	454.

SAMPLE	CA (%)	NA (%)	K (%)	MN (PPM)	LA (PPM)	SN (PPM)	LU (PPM)	AS (PPM)	RD (PPM)	CS (PPM)	BA (PPM)
PA17	0.0	0.73	3.08	710.	3.0	0.0	0.37	0.0	157.	9.7	549.
PA20	0.0	0.54	3.20	866.	3.0	0.0	0.41	0.0	177.	12.8	692.
PA22	0.0	0.53	3.12	856.	3.0	0.0	0.36	0.0	172.	13.0	733.
PA36	0.0	0.58	2.48	844.	3.0	0.0	0.34	0.0	163.	10.5	472.
PB18	0.0	0.54	3.04	738.	3.0	0.0	0.42	0.0	163.	12.5	570.
PR32	0.0	0.52	2.41	881.	3.0	0.0	0.35	0.0	146.	13.7	514.
PC 2	0.0	0.55	2.35	941.	3.0	0.0	0.40	0.0	164.	11.8	514.
PC 4	0.0	0.56	2.62	666.	3.0	0.0	0.43	0.0	168.	11.8	724.
PE 1	0.0	0.57	2.79	814.	3.0	0.0	0.46	0.0	157.	11.6	609.
PE 2	0.0	0.54	3.14	740.	3.0	0.0	0.47	0.0	169.	11.0	507.
PE 3	0.0	0.55	2.87	666.	3.0	0.0	0.49	0.0	153.	10.4	487.
PE 5	0.0	0.59	2.80	705.	3.0	0.0	0.52	0.0	152.	11.7	572.
PE 6	0.0	0.68	2.10	705.	3.0	0.0	0.52	0.0	168.	9.6	687.
PE 7	0.0	0.66	2.55	601.	3.0	0.0	0.52	0.0	177.	10.6	539.
PE22	0.0	0.50	2.81	874.	3.0	0.0	0.31	0.0	179.	13.4	461.
PE27	0.0	0.55	2.96	671.	3.0	0.0	0.35	0.0	156.	9.8	642.
PF 8	0.0	0.60	2.90	759.	3.0	0.0	0.47	0.0	168.	10.1	547.
PG21	0.0	0.58	2.12	629.	3.0	0.0	0.37	0.0	182.	13.1	487.
PG32	0.0	0.53	3.00	822.	3.0	0.0	0.33	0.0	144.	13.3	564.
HS27	0.0	0.00	0.00	0.	3.0	0.0	0.51	0.0	179.	11.8	625.
HS56	0.0	0.55	2.90	836.	3.0	0.0	0.41	0.0	167.	11.0	709.
HS57	0.0	0.52	2.74	874.	3.0	0.0	0.36	0.0	165.	12.0	498.
HS59	0.0	0.59	2.78	689.	3.0	0.0	0.29	0.0	161.	10.2	608.
HS60	0.0	0.50	2.79	911.	3.0	0.0	0.31	0.0	169.	12.8	620.
ID30	6.5	0.59	2.75	844.	3.0	6.4	0.35	0.0	161.	12.5	643.
ID42	4.3	0.53	3.06	713.	3.0	6.4	0.37	0.0	187.	13.9	802.
ID44	2.3	0.66	2.04	666.	3.0	5.7	0.35	0.0	200.	13.7	629.
LR 1	4.4	0.47	2.11	874.	3.0	6.2	0.31	0.0	185.	13.0	523.
LR 3	6.5	0.65	2.96	666.	3.0	6.5	0.38	0.0	164.	12.7	570.
ID16	6.0	0.61	2.86	856.	3.0	6.4	0.35	0.0	161.	12.7	480.
ID29	4.7	0.56	2.71	689.	3.0	6.6	0.44	0.0	176.	12.7	1128.
ID26	5.7	0.60	2.65	754.	3.0	6.1	0.36	0.0	154.	10.9	1605.
ID27	6.4	0.59	2.61	666.	3.0	6.6	0.33	0.0	151.	10.7	2296.
ID28	4.4	0.33	1.69	527.	3.0	3.8	0.22	0.0	106.	8.0	1235.
ID33	5.2	0.62	2.77	851.	3.0	0.0	0.33	0.0	153.	10.8	1062.
ID39	0.0	0.55	2.76	743.	3.0	0.0	0.42	0.0	168.	11.9	897.
ID40	6.3	0.59	2.54	889.	3.0	6.5	0.38	0.0	173.	13.0	856.
ID41	6.1	0.59	2.54	851.	3.0	6.6	0.38	0.0	159.	12.4	1325.
ID43	4.9	0.42	2.00	956.	3.0	6.1	0.35	0.0	172.	14.2	1160.
HS28	0.0	0.00	0.00	0.	3.0	0.0	0.57	0.0	201.	10.2	1078.
HS30	0.0	0.00	0.00	0.	3.0	0.0	0.44	0.0	219.	11.7	930.
D191	4.5	0.46	2.79	716.	3.0	6.6	0.41	0.0	169.	12.6	848.
D192	4.7	0.48	2.58	769.	3.0	6.7	0.37	0.0	139.	10.3	584.
D193	3.6	0.45	2.31	714.	3.0	6.9	0.56	0.0	116.	8.8	500.
D194	6.2	0.52	2.29	754.	3.0	6.8	0.40	0.0	112.	8.1	565.
D195	4.2	0.43	2.06	777.	3.0	7.3	0.43	0.0	77.	4.6	547.
D196	5.1	0.52	3.03	762.	3.0	6.7	0.52	0.0	171.	12.7	630.
D197	4.0	0.58	2.86	844.	3.0	6.3	0.38	0.0	172.	13.5	539.
D198	4.3	0.50	2.08	836.	3.0	6.6	0.38	0.0	174.	13.6	556.
D199	4.0	0.51	2.55	679.	3.0	6.8	0.40	0.0	167.	13.9	633.
D200	6.2	0.40	2.94	742.	3.0	6.2	0.35	0.0	185.	16.1	591.
D201	4.7	0.55	2.90	866.	3.0	6.4	0.40	0.0	147.	11.8	518.
D202	5.7	0.47	2.03	754.	3.0	6.7	0.41	0.0	199.	14.8	575.
D203	4.8	0.47	2.89	777.	3.0	7.1	0.42	0.0	156.	9.0	583.
D204	4.4	0.54	2.92	617.	3.0	6.6	0.40	0.0	165.	13.8	573.
D205	5.1	0.55	2.84	766.	3.0	6.9	0.41	0.0	159.	10.5	523.

SAMPLE	CA (%)	NA (%)	K (%)	PN (PPM)	LI (PPM)	SN (PPM)	LU (PPM)	AS (PPM)	RB (PPM)	CS (PPM)	BA (PPM)
D178	6.6	0.45	3.37	1023.	32.0	6.2	0.42	0.0	165.	14.5	691.
D181	4.8	0.48	3.37	889.	2.0	6.3	0.39	0.0	175.	14.0	686.
D185	5.2	0.62	3.37	978.	1.5	6.2	0.40	0.0	174.	10.3	685.
D188	3.3	0.45	2.92	769.	2.4	6.5	0.41	0.0	173.	12.7	607.
D189	6.2	0.48	2.92	658.	0.0	5.9	0.37	0.0	156.	11.6	532.
D190	6.3	0.51	3.01	747.	2.2	6.4	0.40	0.0	162.	12.8	546.
2502	3.6	0.50	2.25	724.	7.7	7.0	0.44	0.0	191.	13.4	569.
2503	4.0	0.58	0.08	653.	5.6	6.0	0.52	0.0	182.	12.5	560.
2506	4.3	0.66	0.90	1386.	5.0	6.6	0.41	0.0	142.	10.3	751.
2504	3.8	0.65	0.01	856.	0.0	6.1	0.40	0.0	171.	10.8	509.
2585	3.7	0.89	0.92	657.	6.0	6.1	0.38	0.0	184.	12.1	471.
25A5	3.4	0.65	0.02	658.	34.6	6.5	0.43	0.0	191.	12.0	577.
D258	5.1	0.51	0.82	659.	27.0	5.6	0.34	0.0	139.	9.5	464.
D259	3.5	0.52	0.95	792.	22.7	6.8	0.50	0.0	205.	11.8	530.
D260	4.1	0.62	0.87	814.	25.7	6.1	0.49	0.0	180.	12.0	508.
D263	6.5	0.53	0.47	759.	25.2	5.5	0.45	0.0	151.	16.0	462.
D264	6.4	0.62	0.54	926.	25.0	5.5	0.50	0.0	140.	14.2	623.
D265	5.9	0.63	0.67	856.	7.7	6.0	0.49	0.0	149.	15.7	502.
D266	4.6	0.56	0.80	889.	3.6	6.5	0.39	0.0	161.	9.7	488.
D267	3.7	0.40	0.15	511.	1.8	6.3	0.45	0.0	180.	13.9	551.
D268	5.7	0.57	0.80	754.	5.0	5.9	0.38	0.0	162.	11.4	479.
D269	4.8	0.61	3.10	754.	5.0	6.1	0.46	0.0	174.	10.5	571.
D270	5.0	0.63	0.27	759.	5.0	5.9	0.38	0.0	147.	10.3	494.
D271	5.5	0.61	0.33	684.	5.0	6.0	0.43	0.0	155.	16.1	450.
D261	2.6	0.43	0.51	327.	3.1	5.8	0.44	0.0	174.	9.2	337.
D262	6.1	0.61	2.33	1060.	2.8	5.6	0.42	0.0	154.	7.4	349.
D272	2.7	0.93	3.48	563.	4.0	6.4	0.40	0.0	177.	8.7	679.
D273	3.8	0.48	0.84	671.	6.0	5.6	0.41	0.0	151.	12.0	442.
D274	4.3	0.54	0.47	1210.	3.1	5.4	0.38	0.0	134.	15.1	456.
D275	5.1	0.84	1.72	468.	2.5	4.5	0.36	0.0	91.	4.3	412.
D276	4.8	0.58	1.80	624.	2.7	4.7	0.31	0.0	97.	6.4	349.
M177	7.8	0.45	1.85	1217.	4.8	4.6	0.34	0.0	111.	6.5	417.
M178	11.7	0.49	2.00	1277.	5.6	5.2	0.34	0.0	120.	7.1	425.
M179	9.9	0.29	1.62	1255.	2.2	4.2	0.32	0.0	107.	5.9	447.
M180	6.6	0.37	1.98	1210.	5.6	4.6	0.33	0.0	139.	9.0	449.
M181	9.4	0.64	1.58	1314.	4.4	5.0	0.47	0.0	111.	6.5	397.

SAMPLE	SC (PPM)	CE (PPM)	EU (PPM)	TH (PPM)	FF (PPM)	TA (PPM)	CR (PPM)	FE (X)	CO (PPM)	SB (PPM)
PA17	23.2	78.3	1.17	11.1	4.1	C.79	520.	5.57	33.4	2.15
PA20	24.0	74.3	1.28	11.4	4.1	C.82	628.	5.57	38.1	2.19
PA22	23.5	77.0	1.29	11.6	4.4	C.81	617.	5.89	37.8	2.45
PA36	22.7	77.5	1.34	11.8	4.0	C.88	567.	5.66	38.8	2.19
PB18	22.9	71.4	1.23	11.7	4.0	C.86	624.	5.77	38.9	1.94
PB32	22.3	70.1	1.28	11.0	3.9	C.83	550.	5.62	39.1	2.20
PC 2	22.6	76.3	1.11	11.2	2.6	C.78	607.	5.88	38.0	2.55
PC 4	21.5	75.6	1.25	11.7	4.4	C.84	580.	5.73	38.6	2.61
PE 1	23.8	85.6	1.03	11.9	4.0	C.83	600.	5.96	39.9	3.28
PE 2	25.1	88.1	1.27	12.0	3.8	C.76	560.	6.13	35.9	4.07
PE 3	24.0	78.3	1.30	11.2	4.3	C.09	513.	5.78	33.0	2.67
PE 5	23.3	83.1	1.07	12.1	5.0	C.71	621.	5.78	36.6	3.14
PE 6	24.5	78.6	1.20	12.0	4.0	C.75	518.	5.89	35.7	3.09
PE 7	25.8	79.8	1.17	11.9	3.7	C.70	576.	6.34	37.8	3.69
PE22	23.2	70.3	1.24	11.5	3.7	C.82	654.	5.73	38.9	2.43
PE27	22.2	76.5	1.22	11.6	4.0	C.86	523.	5.47	37.1	2.95
PF 8	22.8	77.8	1.28	11.7	2.6	C.70	520.	5.88	34.0	2.93
PG21	24.8	87.2	1.66	12.7	4.3	C.85	565.	6.14	41.4	2.89
PG32	24.9	75.3	1.77	11.9	4.3	C.90	632.	6.16	37.2	2.62
HS27	22.2	70.9	1.14	12.1	3.8	C.89	661.	5.93	39.2	2.33
HS56	24.1	0.0	1.29	11.0	3.5	C.43	552.	6.00	45.4	1.83
HS57	22.7	57.9	1.24	11.4	2.5	C.90	559.	5.66	39.8	1.82
HS59	22.3	112.8	1.34	11.9	4.2	C.00	488.	5.45	50.0	1.78
HS60	23.5	48.9	1.39	11.6	3.8	C.89	588.	5.84	39.5	1.69
ID30	23.8	81.8	1.36	11.9	4.0	C.87	590.	5.94	39.4	0.00
ID42	25.5	87.2	1.42	12.7	4.0	C.83	565.	6.21	39.6	0.00
ID44	24.0	75.4	1.13	12.1	4.2	C.92	592.	5.98	35.3	0.00
LR 1	25.3	78.4	1.48	12.1	4.2	C.87	628.	6.34	41.8	0.00
LR 3	23.8	80.5	1.43	11.8	4.0	C.79	549.	5.92	38.9	0.00
ID16	23.0	84.0	1.28	11.7	4.4	C.74	567.	5.68	37.3	0.00
ID29	23.5	81.9	1.28	12.0	4.5	C.74	537.	5.73	38.1	0.00
ID26	22.8	79.8	1.26	11.2	4.7	C.95	544.	5.54	35.9	0.00
ID27	21.8	88.1	1.28	11.6	4.8	C.83	520.	5.43	35.8	0.00
ID28	14.2	50.9	0.71	7.5	2.7	C.88	354.	3.51	24.5	0.00
ID33	22.8	76.6	1.42	12.0	4.0	C.88	519.	5.49	36.4	0.00
ID39	24.8	84.0	1.36	12.9	3.5	C.86	807.	6.16	40.6	0.00
ID40	24.9	84.8	1.28	11.9	4.0	C.94	651.	6.20	42.2	0.00
ID41	23.2	84.0	1.33	12.1	4.0	C.73	595.	5.76	38.0	0.00
ID43	24.0	84.8	1.25	12.4	4.0	C.75	623.	6.09	40.7	0.00
HS28	22.2	74.9	1.23	12.5	4.0	C.36	605.	5.43	36.9	0.82
HS30	22.5	78.5	1.29	13.2	4.0	C.30	661.	5.98	38.4	3.12
D191	25.1	82.3	1.44	12.7	4.2	C.94	558.	6.24	37.9	2.20
D192	25.8	82.3	1.40	12.4	4.1	C.01	572.	6.39	36.7	0.95
D193	25.4	86.4	1.47	13.3	4.6	C.16	624.	6.58	39.6	2.03
D194	24.0	65.6	1.43	12.9	5.1	C.56	590.	6.10	38.5	2.05
D195	25.8	90.5	1.50	13.4	5.1	C.54	659.	6.67	42.3	2.21
D196	25.6	80.2	1.40	11.8	4.2	C.54	542.	6.21	37.8	2.00
D197	23.3	85.6	1.28	11.9	4.4	C.00	600.	5.73	37.8	1.73
D198	24.6	87.2	1.43	12.1	4.5	C.00	593.	6.02	39.9	1.38
D199	24.1	88.9	1.43	12.7	4.5	C.81	600.	6.03	40.3	1.97
D200	24.8	77.4	1.36	12.1	3.8	C.78	651.	6.25	41.3	2.34
D201	23.8	82.3	1.25	12.0	4.0	C.90	579.	5.83	36.6	2.48
D202	26.0	83.1	1.44	12.5	4.4	C.81	686.	6.46	41.6	1.89
D203	25.9	87.2	1.60	13.2	4.3	C.73	572.	6.40	40.3	1.88
D204	23.8	84.0	1.40	12.0	4.2	C.82	527.	5.82	39.0	1.92
D205	25.0	94.7	1.48	12.6	4.7	C.90	652.	6.31	41.6	2.04

SAMPLE	SC (PPM)	CE (PPM)	EU (PPM)	TH (PPM)	HF (PPM)	TA (PPM)	CR (PPM)	FE (Z)	CO (PPM)	SB (PPM)
D178	25.5	76.0	1.35	12.3	3.6	1.02	640.	6.36	40.0	1.27
D181	24.8	77.2	1.34	12.5	4.2	0.90	645.	6.28	46.2	2.04
D185	23.3	75.3	1.34	11.6	3.5	0.50	566.	5.78	36.1	2.17
D188	24.5	78.4	1.36	12.1	3.7	0.92	621.	6.18	39.4	2.05
D189	22.8	75.4	1.25	11.9	4.0	0.85	603.	5.80	35.5	1.92
D190	24.5	80.2	1.42	12.5	4.1	1.06	637.	6.14	37.6	2.66
2502	25.1	88.9	1.46	12.7	4.1	1.01	557.	6.14	60.3	2.46
2503	25.8	71.6	1.28	12.7	4.2	1.03	540.	6.21	38.3	2.45
2506	23.0	79.3	1.35	11.8	4.1	0.92	526.	5.58	34.6	1.94
2504	26.0	76.1	1.32	12.1	4.0	1.14	506.	6.16	58.3	1.25
2585	22.3	77.9	1.22	11.4	4.2	0.89	493.	5.52	38.0	2.22
25A5	23.3	72.0	1.36	11.7	4.6	1.03	511.	5.65	41.2	2.33
D258	20.4	70.3	1.11	10.1	4.0	0.68	481.	5.05	30.6	2.47
D259	24.0	82.3	1.48	12.3	4.4	0.87	538.	5.82	39.1	2.60
D260	24.4	78.0	1.35	11.7	4.5	1.06	566.	5.76	38.5	2.13
D263	23.8	64.1	1.05	9.3	4.1	0.85	689.	5.41	38.2	1.53
D264	23.0	64.7	1.17	9.4	4.5	0.56	604.	5.64	33.7	2.68
D265	24.9	69.0	1.28	10.5	4.4	0.76	664.	5.90	39.6	2.11
D266	23.5	84.0	1.33	11.2	4.0	0.86	521.	5.70	41.7	2.20
D267	25.5	85.6	1.34	12.6	3.7	0.93	665.	6.42	39.3	1.97
D268	21.3	75.8	1.29	10.6	4.0	0.79	584.	5.54	35.3	2.15
D269	22.2	75.8	1.31	11.0	4.4	0.55	561.	5.53	35.9	2.20
D270	20.9	75.8	1.25	10.3	4.2	0.69	537.	5.37	34.6	2.26
D271	24.3	68.2	1.29	9.8	4.5	0.78	652.	5.42	37.0	1.72
D261	17.0	81.2	1.08	16.5	6.6	1.13	130.	4.32	21.8	1.63
D262	19.5	77.2	1.22	13.0	3.5	1.05	194.	5.21	23.4	1.57
D272	22.8	82.3	1.34	14.0	4.2	0.93	175.	5.54	25.5	3.03
D273	21.3	70.5	1.17	10.1	4.1	0.74	614.	4.86	45.5	1.71
D274	20.7	78.0	1.15	13.2	5.5	1.05	261.	5.32	38.7	2.98
D275	12.4	64.7	0.91	11.8	5.1	0.54	87.	3.51	22.8	1.24
D276	14.5	64.4	0.57	11.4	5.1	0.55	190.	4.24	33.5	1.53
M177	17.8	61.6	0.96	9.6	4.3	0.79	300.	4.54	28.9	6.39
M178	20.6	66.0	1.08	10.2	4.6	0.71	511.	5.40	36.2	3.59
M179	17.8	60.5	0.88	6.5	3.5	0.80	490.	4.57	34.2	2.33
M180	21.2	75.2	0.94	10.6	4.5	0.87	523.	5.79	34.1	2.55
M181	21.8	70.4	1.14	10.3	6.2	0.78	598.	5.72	40.3	7.19

SAMPLE	CA (X)	NA (X)	K (X)	MN (PPM)	LA (PPM)	SV (PPM)	LU (PPM)	AS (PPM)	RB (PPM)	CS (PPM)	BA (PPM)
LC01	0.0	0.70	3.58	658.	35.6	0.0	0.41	0.0	172.	7.9	434.
LC02	0.0	0.40	2.64	609.	33.4	0.0	0.43	0.0	183.	10.9	346.
LC 3	0.0	0.62	3.08	562.	40.6	0.0	0.42	0.0	163.	8.9	344.
LC 4	0.0	0.55	2.72	714.	44.0	0.0	0.38	0.0	143.	7.2	523.
LC 5	0.0	0.68	2.88	678.	41.6	0.0	0.39	0.0	164.	8.7	425.
LC 6	0.0	0.67	2.76	647.	35.4	0.0	0.43	0.0	158.	7.1	354.
LC 7	0.0	0.55	2.55	465.	37.6	0.0	0.37	0.0	178.	7.3	355.
LC 8	0.0	0.58	2.44	406.	34.6	0.0	0.33	0.0	164.	6.7	411.
LC 9	0.0	0.66	2.77	511.	35.6	0.0	0.41	0.0	179.	6.2	440.
LC10	0.0	0.64	2.64	576.	34.6	0.0	0.34	0.0	150.	6.3	465.
LC11	0.0	0.72	2.71	634.	35.6	0.0	0.36	0.0	159.	6.8	371.
LC12	0.0	0.69	2.69	725.	35.6	0.0	0.36	0.0	163.	6.4	329.
LC13	0.0	0.63	2.84	565.	36.6	0.0	0.38	0.0	158.	8.4	402.
LC14	0.0	0.69	2.24	486.	31.1	0.0	0.38	0.0	126.	6.6	365.
LC15	0.0	1.19	2.84	578.	26.1	0.0	0.30	0.0	52.	8.6	864.
LC16	0.0	0.63	2.75	659.	35.6	0.0	0.44	0.0	153.	8.1	359.
LC17	0.0	0.61	2.72	1255.	37.3	0.0	0.36	0.0	157.	7.6	418.
LC18	0.0	0.67	3.02	524.	35.6	0.0	0.46	0.0	147.	8.1	412.
LC19	0.0	0.74	2.71	729.	35.6	0.0	0.34	0.0	159.	7.9	351.
LC20	0.0	0.40	2.51	836.	30.6	0.0	0.27	0.0	158.	8.2	321.
MC 1	0.0	0.71	1.98	822.	30.6	0.0	0.29	0.0	106.	5.3	463.
MC 2	0.0	0.38	2.96	896.	32.1	0.0	0.32	0.0	188.	7.9	334.
MC 3	0.0	1.02	1.42	859.	30.6	0.0	0.31	0.0	132.	7.4	415.
MC 4	0.0	0.42	2.09	552.	31.1	0.0	0.32	0.0	156.	7.8	392.
MC 5	0.0	1.21	2.16	934.	30.6	0.0	0.32	0.0	118.	4.1	514.
MC 6	0.0	0.51	2.19	1232.	31.1	0.0	0.29	0.0	131.	6.0	426.
MC 7	0.0	0.68	2.70	904.	30.6	0.0	0.31	0.0	135.	6.2	378.
MC 8	0.0	0.61	2.19	566.	28.1	0.0	0.28	0.0	119.	6.0	490.
MC 9	0.0	0.70	2.16	904.	31.1	0.0	0.32	0.0	145.	7.2	370.
MC10	0.0	0.27	3.68	881.	35.6	0.0	0.38	0.0	201.	8.8	347.
MC12	0.0	0.49	3.02	556.	33.1	0.0	0.33	0.0	179.	7.9	356.
MC13	0.0	0.44	2.54	556.	35.6	0.0	0.34	0.0	152.	6.7	362.
MC14	0.0	0.55	1.86	941.	31.1	0.0	0.34	0.0	142.	8.9	420.
MC15	0.0	1.24	1.37	934.	32.1	0.0	0.34	0.0	161.	8.0	393.
MC17	0.0	1.13	1.44	971.	31.1	0.0	0.36	0.0	151.	7.8	305.
MC18	0.0	0.56	2.27	556.	33.6	0.0	0.32	0.0	184.	8.1	383.
MC19	0.0	1.29	1.26	889.	32.1	0.0	0.34	0.0	161.	8.4	313.
MC20	0.0	0.48	3.33	1023.	35.6	0.0	0.36	0.0	193.	8.7	305.
MC22	0.0	0.41	2.55	578.	30.6	0.0	0.32	0.0	158.	8.1	264.
MC23	0.0	0.57	2.41	859.	35.6	0.0	0.33	0.0	128.	6.1	367.
MC30	0.0	0.50	2.59	856.	27.5	0.0	0.34	0.0	138.	8.6	356.
MC31	0.0	0.46	2.71	919.	32.1	0.0	0.39	0.0	157.	8.9	351.
AE 1	0.0	1.22	1.13	524.	23.6	0.0	0.30	0.0	52.	5.0	243.
AE 2	0.0	0.77	1.46	330.	16.4	0.0	0.23	0.0	58.	3.8	173.
AN 1	0.0	1.43	2.53	740.	31.1	0.0	0.26	0.0	88.	7.3	305.
AN 2	0.0	1.25	2.50	722.	32.4	0.0	0.27	0.0	80.	4.2	349.
AN 3	0.0	0.41	1.31	349.	14.6	0.0	0.14	0.0	38.	4.0	138.
DL 1	0.0	0.75	2.77	1389.	40.1	0.0	0.42	0.0	161.	13.6	412.
EU 2	0.0	1.43	1.48	1314.	23.1	0.0	0.38	0.0	71.	4.6	275.
EU 3	0.0	0.29	2.38	1060.	31.1	0.0	0.33	0.0	123.	9.0	370.
EU 4	0.0	0.55	2.29	556.	25.5	0.0	0.33	0.0	129.	19.2	393.
KN22	0.0	0.57	1.86	754.	22.7	0.0	0.26	0.0	107.	5.0	971.
KN30	0.0	1.24	0.67	646.	26.7	0.0	0.36	0.0	41.	8.8	646.
KN34	0.0	0.66	2.22	765.	26.5	0.0	0.35	0.0	127.	6.8	393.
RO 1	0.0	0.73	1.58	799.	21.3	0.0	0.35	0.0	102.	3.7	244.
RO 2	0.0	0.63	1.45	859.	23.4	0.0	0.28	0.0	103.	5.1	234.

SAMPLE	SC (PPM)	CE (PPM)	EU (PPM)	TH (PPM)	FF (PPM)	TA (PPM)	CR (PPM)	FE (X)	CO (PPM)	SB (PPM)
LC01	21.3	80.3	1.28	12.9	4.6	1.06	287.	5.55	23.7	0.00
LC02	22.7	74.6	1.34	11.9	3.6	0.82	323.	4.79	39.8	0.00
LC 3	22.7	84.0	1.40	13.4	3.1	1.67	305.	5.50	29.9	0.00
LC 4	20.5	85.6	1.43	13.7	3.3	1.10	222.	4.52	25.6	0.00
LC 5	20.9	81.8	1.30	12.3	4.6	0.55	293.	5.07	26.6	0.00
LC 6	23.0	78.6	1.34	12.8	4.6	1.68	306.	5.43	32.2	0.00
LC 7	22.0	78.8	1.28	13.5	4.6	1.03	284.	5.30	26.7	0.00
LC 8	20.0	74.4	1.37	11.9	4.6	0.64	279.	4.99	24.6	0.00
LC 9	22.0	84.0	1.38	14.0	4.1	1.11	289.	5.27	30.9	0.00
LC10	19.9	78.7	1.27	11.9	4.7	1.00	263.	4.86	24.0	0.00
LC11	21.0	79.0	1.38	12.5	4.6	0.70	290.	5.41	0.0	0.00
LC12	20.2	79.1	1.26	12.5	4.6	0.81	269.	5.11	26.0	0.00
LC13	19.9	76.1	1.36	13.4	4.6	1.12	232.	4.38	27.9	1.05
LC14	17.8	67.1	1.15	11.0	4.7	0.64	179.	4.60	21.0	0.99
LC15	18.6	57.9	1.09	9.9	3.2	0.74	219.	4.94	25.9	1.40
LC16	20.2	80.6	1.45	13.3	4.7	1.03	234.	4.77	24.3	0.67
LC17	21.5	82.1	1.43	12.9	4.7	1.03	279.	5.40	31.5	1.24
LC18	21.6	80.6	1.38	13.2	4.4	1.18	273.	5.18	29.1	1.28
LC19	19.4	78.4	1.32	12.1	4.7	1.01	256.	4.91	25.0	0.87
LC20	20.1	62.2	1.21	10.2	3.5	0.73	229.	5.05	28.0	0.00
MC 1	16.8	56.0	1.02	9.4	3.7	0.52	212.	4.27	23.8	0.00
MC 2	23.6	68.0	1.22	11.4	3.6	0.65	299.	5.60	32.3	0.00
MC 3	19.2	63.8	1.06	10.5	4.1	0.83	257.	4.77	27.9	0.00
MC 4	21.5	65.9	1.11	11.1	4.5	0.90	229.	5.32	26.8	0.00
MC 5	19.2	69.3	1.55	11.0	4.0	0.74	193.	4.95	23.2	0.00
MC 6	17.8	60.7	1.33	10.0	3.6	0.63	258.	4.52	32.6	0.00
MC 7	18.8	62.1	1.18	10.2	3.6	0.72	230.	4.84	27.3	0.00
MC 8	19.2	55.7	1.13	10.2	3.7	0.62	289.	5.04	27.1	0.00
MC 9	20.5	66.4	1.22	11.4	3.7	0.66	255.	5.17	27.3	0.00
MC10	25.3	73.3	1.28	12.5	3.7	0.70	283.	5.92	35.5	0.00
MC12	23.3	71.4	1.22	11.9	3.6	0.81	266.	5.57	31.2	0.00
MC13	19.9	62.6	1.05	10.2	4.4	0.64	233.	4.84	27.4	0.00
MC14	22.5	66.3	1.18	11.3	4.4	0.76	281.	5.76	32.2	0.00
MC15	22.1	68.1	1.18	11.2	4.7	0.72	274.	5.52	29.6	0.00
MC17	21.1	71.6	1.14	11.2	4.7	0.79	250.	5.32	29.4	0.00
MC18	22.7	71.2	1.34	12.1	4.4	0.64	240.	5.27	29.0	0.00
MC19	22.9	70.7	1.23	12.1	4.4	0.67	251.	5.60	31.3	0.00
MC20	24.5	72.2	1.11	12.3	4.4	0.71	266.	5.76	34.0	0.00
MC22	21.3	66.9	1.18	10.7	4.3	0.66	276.	5.22	28.7	0.00
MC23	17.8	56.0	1.04	8.6	4.4	0.64	255.	4.39	26.6	0.00
MC30	19.5	64.2	1.17	10.9	4.4	0.61	235.	5.04	28.4	0.67
MC31	22.3	70.6	1.42	11.5	4.4	0.65	248.	5.27	30.6	0.98
AE 1	16.6	52.0	1.25	7.4	4.1	0.59	510.	4.42	26.2	0.00
AE 2	11.7	33.9	0.82	5.2	2.5	0.37	340.	3.01	15.4	0.00
AN 1	15.8	46.9	0.74	5.3	2.5	0.64	283.	3.69	21.7	0.00
AN 2	17.6	65.9	0.99	11.4	2.6	0.62	252.	4.54	23.2	0.00
AN 3	7.5	31.5	0.49	4.3	1.6	0.48	254.	1.57	10.4	0.00
DO 1	23.3	86.4	1.41	16.8	2.2	1.72	336.	6.03	38.9	0.00
EU 1	30.6	57.4	1.52	7.0	4.5	0.77	255.	6.26	36.8	0.00
EU 3	16.2	64.8	1.28	13.8	3.5	0.68	291.	4.48	23.6	0.00
EU 4	23.0	65.0	1.57	9.5	3.5	0.76	325.	5.28	31.6	0.00
KN22	17.8	53.6	0.83	8.3	2.4	0.70	363.	4.84	31.6	0.00
KN30	21.9	57.2	1.15	9.0	2.4	0.88	463.	5.37	32.1	0.00
KN34	22.2	63.5	1.13	9.6	2.4	0.61	555.	6.12	42.1	0.00
RO 1	18.5	51.4	0.95	7.4	2.4	0.65	677.	5.40	43.7	0.00
RO 2	20.2	56.2	0.94	8.3	2.1	1.02	758.	5.91	53.0	0.00