

THE ROLE AND DEVELOPMENT OF METALLURGY IN THE LATE NEOLITHIC
AND EARLY BRONZE AGE OF GREECE

Thesis

Submitted by

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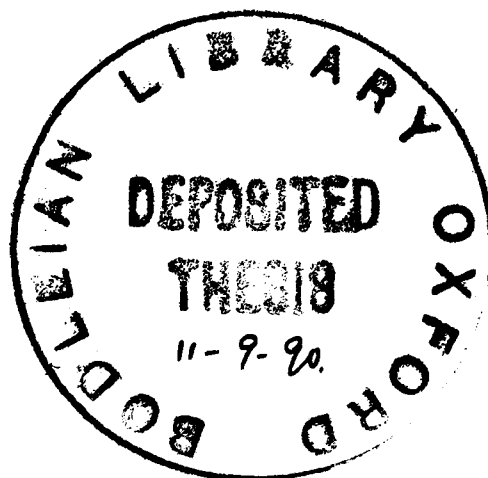
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DECLARATION

**I hereby declare that the work presented
in this thesis is my own, unless otherwise
stated in the text, and that the thesis has
been composed by myself**

Veronica McGeehan Liritzis

I DEDICATE THIS THESIS TO MY LOVED ONES
as a small token of my gratitude to them

TO MY MOTHER AND MY FATHER
for their sacrifices, unselfishness and
support and for their steadfast guidance
and help

TO YIANNIS
for his encouragement, patience and sound
advice and for graciously accepting a
part-time wife for so long

TO KATHLEEN, MAUREEN, MANUS and JENNIFER
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ABSTRACT

The main object of this thesis is to reassess critically the nature and development of the earliest metallurgy of the Greek mainland in the Late Neolithic and Early Bronze Age periods (c. 4800 - c. 1900), both in its technological and socio-economic context.

The aims of the research are thus to: 1) show whether or not the LN finds represent the beginnings of autonomous mainland metallurgy or whether they simply represent artefacts imported from contemporary neighbouring cultures involved in metalworking. Diffusionists regard the development of EBA metallurgy as some revolutionary break. Accumulating evidence should put the Greek/^{mainland}industries more into line with those from the Aegean; 2) show whether the LN industry was ancestral in some way to that of the EBA or if the development of the EBA industry was due to external influence; 3) make some chronological assessment of the initial progress of technological ability as well as the structure and organisation of metallic mineral acquisition. This will further provide data on the degrees of communication between communities and metalworking sites; and, 4) examine the socio-economic context which permitted the development of metallurgy.

To achieve these aims it will be necessary to demonstrate the potential availability of copper, tin and other minerals and to show clearly through analytical techniques the range of technical skills known and mastered (especially smelting and alloying). Evidence on the relationship between metalwork, settlement, sources and the role of foreign influence will also be required.

The first step was to compile a fully up-to-date catalogue of metal finds and evidence for metalworking. This was done from published

material, museum collections in Greece and Britain, tracing artefacts referred to in publications but never fully described, and obtaining information on artefacts from recent excavations and finds (until end 1986). This work had the effect of doubling the number of artefacts to come under study and justified taking a fresh look at the state of the industry, the range of types and techniques, and, through them, the evidence for foreign or internal relations. This was a necessary preliminary to the analytical study and the study of the contexts of the metals.

No single typological study had been devoted specifically to the LN and EBA material and so one was made, devising at the same time a standard typology and comparing previous classification systems. The typological affinities of the artefacts from every sub-phase of the LN-EBA period were then studied and discussed. This study brought out the range of local types, the continuity of some types from the LN to the EBA and the evidence of foreign influence.

The next task was to demonstrate that this large collection of metals could have been produced from local sources. The geological evidence for metallic minerals in Greece was reviewed and a visit was made to one of the richest mineral areas in Greece to assess the types of deposits with which we were dealing. It was demonstrated that the copper, arsenic, gold, silver and lead supplies of the mainland were more than adequate to meet the needs of the local industries in the LN and EBA. Tin was not locally available and so an extensive review of all possible sources was carried out and two potential supply areas were designated - Yugoslavia and north west Anatolia.

The analytical programme presented the chemical and lead-isotope results of over seventy mainland artefacts, attempting to interpret these results for both the technological and chronological information which they could give, formed the main part of the programme. The actual analyses were carried out, in the main, by Dr N H Gale (Oxford).

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To assist the interpretation of the results a review was made of the metallurgical processes used in the manufacture of copper, arsenical copper, tin bronze, lead, silver and gold.

The historical background of the metal technology of the Old World was reviewed, in particular the beginnings of melting, smelting and the origins and development of alloying, in order to provide a reference with which to compare the status of the Greek mainland metallurgical industries.

A brief review of the ^{analytical} techniques used then led to a full interpretation of the results themselves. The results of the lead-isotope programme demonstrated that several sources were used by both the LN and EBA metallurgists - three sources were used in the LN and EBA periods - so there was some continuity of tradition. A new source was identified in the lead-isotope diagrams, though it was not geographically located. This source was used only by mainland communities and, on present evidence, it is highly likely that it is a local source. The chemical results for the mainland artefacts demonstrated that all the main techniques current in the Aegean were known and practiced on the mainland. These include smelting, alloying with arsenic tin and even lead, casting in single and double moulds, cupelling silver from lead and smelting lead as well as working gold. The Greek LN metal industry was not simply an offshoot of the Balkan industries and the EBA industry was in no way backward compared with the other industries of the Aegean.

Over 200 chemical results mainly from the EBA Aegean were computed in order to obtain some new information regarding the status of the mainland industry and also to attempt a new approach to provenancing. All the computing work was carried out by Dr M Pollard (Oxford). First of all, the character of the mainland industry was assessed and then it was compared,

using various computer techniques, with the industries of the Troad, the Cyclades and Crete. The result was that the mainland industry was basically quite distinct from the other three industries, though it did share several common techniques (or possibly sources) with other areas in the Aegean. Provenancing metals by chemical analyses has had little success in the past and so an attempt was made to utilise the vast bulk of chemical results available for the Aegean by devising a new approach to provenancing, employing the results themselves, lead isotope results (where available), computer cluster dendrograms and typological information. While the approach does not claim to be a general panacea for provenancing problems it did, when applied, offer a few insights into the problem and will become more effective when more lead-isotope data becomes available. One of the advantages of the approach is that it provides a much needed check on the lead-isotope technique.

A study of the temporal, spatial and socio-economic context of metals and the evidence for metalworking during the LN and EBA periods was quite revealing.

The dating of artefacts showed that there were two main periods of increased metallurgical activity - the LN and the EBA II. Metalworking started in northern and southern Greece at roughly the same time, though there is more evidence for metals in northern Greece during the LN and in central and south west Greece during the EBA II and III. The relative distribution of different types of metals demonstrated that copper was always the main metal used, though lead and silver were restricted to southern Greece and gold was found mainly in northern Greece. The distribution of different types showed that weapons were most often found in central Greece, tools in northern Greece and tools and jewellery in southern Greece.

Both artefacts and the evidence for metalworking tended always to be

located on land routes or close to the sea. Most of the finds come from ^{settlement} sites, with grave finds being important only in central Greece. Sites with the most metals or with evidence of metalworking tended to be "special feature" sites, that is, sites with architectural evidence for social or political authority, fortifications etc. There is no direct relationship between metalworking sites, or important sites, and sources - that is they are not located close to sources, though there is every reason to believe that ^{quite} apart from their prime function as centres concerned with the needs of local agricultural communities, they also had some monopoly over metal supplies. The relationship between general settlement and sources revealed some interesting information. While there was no domination of any source, settlements in good agricultural land had the added advantage of being close to good sources which also bordered the areas of good land, so the relationship between settlement and potential sources was close. As settlement expanded in the later EBA (evidence for southern Greece), the possibility that local sources would have been discovered would increase.

Important settlements, centres of high population and sites with evidence for metals and metalworking all had a rather discrete distribution in central and south west Greece (except for Levkas). Foreign influence can be traced in the general assemblage of most of the sites in this area. An attempt was made to explain this phenomena, accepting at the same time that one of the main determinants of settlement growth in the area was the availability of good agricultural land and an extension of the subsistence base to include olives and the vine. The most viable sea routes between the communities of the mainland and the rest of the Aegean were plotted using new data on winds and seacurrents. The aim was to see if there was any relationship between the sea routes and the distribution of cultural phenomena which suggested social, political or economic advancement (such as the distribution of "special feature" sites). A direct correlation between sea routes and such phenomena

was revealed and so the role of trade, exchange and external contact played an important part in stimulating socio-economic change on the mainland and this in turn contributed greatly to the development of metallurgy, though the mainland contributed as much to the "international spirit" of the Aegean at this time as it gained from it. To further demonstrate that local craft specialisation was in a healthy state, an attempt was made to show that the development of the sailing ship could have been local also. The possible ship from Pelikati suggests this.

The evidence for population growth and settlement change in the LN and particularly the EBA was not taken for granted, but an attempt was made to account for the settlement distribution patterns of the periods. The emphasis of the research in this section was to see where sites would have been lost. In the process, the contribution of tectonic instability to site loss was brought out and stressed and three areas were looked at in some depth (Corinthia, West Central Euboea and Ionian Sea). The result was that the picture given by the present surveys more or less represents a true picture of settlement distribution. There are areas where settlements have become lost, but this does not change the overall picture and thus the south west Peloponnese and central Greece (Euboea, Copais and Levkas) do stand out as the major EH centres.

The overall achievement of this thesis has been to demonstrate that the mainland of Greece (especially the south) was an autonomous centre within the Aegean.

INTRODUCTION

The main object of this thesis is to reassess critically the nature and development of the earliest metallurgy of the Greek mainland in the Late Neolithic and Early Bronze Age periods both in its technological and socio-economic context.

The Late Neolithic metallurgy of the mainland has been largely overlooked or undervalued, because of inadequate publication of the finds, as well as a lack of much concrete evidence for metalworking or distinctly local types. The Early Bronze Age mainland metal industry has been termed, "backward" or "undistinguished" (Branigan 1968, 227; Muhly, 1973^a, 188, 367 note 89), because it was accepted that there was relatively little of it and it was believed to be typologically narrow in comparison with the corpora from both Crete and the Troad, and, to a lesser extent, the Cyclades.

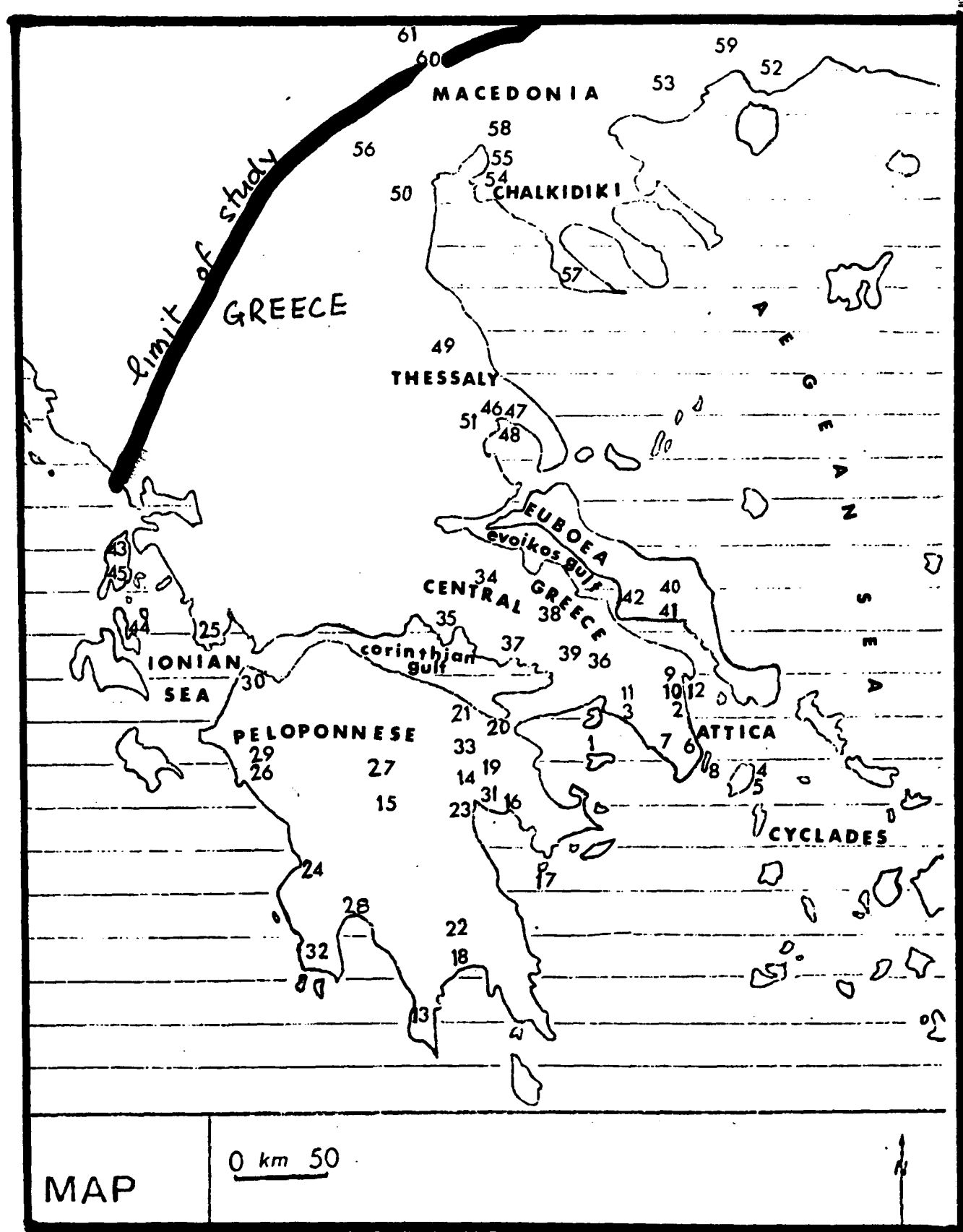
Without rehearsing the entire discussion on the origins of Aegean metallurgy, it is necessary here to introduce the opposing interpretations of the mainland metal data which have led to theories which range from Diffusionism to Semi -Autonomism.

The strongest statement of the Diffusionist position, following the theories of Frankfort (1927, 83-135) and Childe (1950, 65) is that of Schachermeyr (1955, 182-196; 1954) whose concept of **metallschock** implies a sudden impact of Anatolian metalwork in the Aegean. This idea of a direct cultural transfer across the Aegean has been criticised by French (1968, 136, 139-40) and forcibly rejected by Renfrew (1972, 337-338, 454). The theory of **regional metallurgy** by Renfrew argues that each region of the Aegean was already metallurgically competent in Neolithic times and that metallurgy grew up in each region somewhat independently although strongly

GENERAL MAP

- | | | |
|---------------------------|--------------------------|--------------------------|
| 1. Aegina | 21. Korakou | 41. Lefkandi |
| 2. Raphina | 22. Sparta | 42. Manika |
| 3. Aghios Kosmas | 23. Lerna | 43. Steno, Nidri, Levkas |
| 4. Aghia Irini, Kea | 24. Malthi | 44. Pelikati, Ithaka |
| 5. Kephala, Kea | 25. Mesolonghi | 45. Syvres, Levkas |
| 6. Kitsos/Laurion | 26. Lepraion | 46. Dimini |
| 7. Koropi | 27. General Peloponnese | 47. Petromagoula |
| 8. Makronissos | 28. Nichoria | 48. Pevkakia |
| 9. Marathon | 29. Strephi | 49. Rachmani |
| 10. Tsepi | 30. Teichos Dymaion | 50. Servia |
| 11. Rouf | 31. Tiryns | 51. Sesklo |
| 12. Askitario | 32. Voidokilia | 52. Dikili Tash |
| 13. Alepotrypa | 33. Nichoria | 53. Dimitra |
| 14. Argos | 34. Aghia Marina, Phokis | 54. Gona |
| 15. Asea | 35. Delphi | 55. Kritsana |
| 16. Asine | 36. Eutresis | 56. Mandalo |
| 17. Aghia Marina, Spetses | 37. Levadheia | 57. Petralona |
| 18. Aghios Stephanos | 38. Lithares | 58. Seratse |
| 19. Berbati | 39. Thebes | 59. Sitagroi |
| 20. Corinth | 40. General Euboea | 60. Vardina |
| | | 61. Vardarophtsa |

FIGURE 1. GENERAL MAP OF MAINLAND GREECE (WITH INDEX)



influenced by other regions of the Aegean. He claims that regional preferences in type indicates strong individuality stimulated rather than suppressed by the exchange of ideas between regions.

Branigan (1974, 110-113) in his review of Aegean metalwork in the EBA and MBA, does not accept Renfrew's views and claims that the mainland and the Cycladic industries are "secondary" developments of the "primary" Aegean industries on Crete and in the Troad. Warren (1972) believes that although the status of the EBA I Troadic metallurgy is clear, the same cannot be said for Crete. At none of the sites, he argues, do the metal finds have to be earlier than EM II (except three small finds) and thus there is no reason to believe that the Cretan industry is significantly earlier than the Cycladic. French (1968, 111) said it was not clear whether the relatively greater numbers of metal objects from the Cyclades represents a local industry or one which is shared in common with Greece.

None of these hypotheses has yet been tested in any rigorous sense and a reevaluation is needed. This will require more data, however, especially of a technological nature.

The objectives of this thesis are thus to:

- 1) show whether or not the LN finds represent the beginnings of autonomous mainland metallurgy or do they simply represent artefacts imported from contemporary neighbouring cultures involved in metalworking. Diffusionists regard the development of EBA metallurgy as some revolutionary break. Accumulating evidence should put the Greek industries more into line with those from the Aegean.
- 2) show whether the LN industry was ancestral in some way to that of the EBA or if the development of the EBA industry^{was} due to external influence.
- 3) make some chronological assessments of the initial progress of technological ability as well as the structure and organisation of metallic mineral acquisition. This will further provide data on the degrees of communication

between communities and metalworking sites ; 4) study the context of metallurgy

To achieve these aims, it will be necessary to demonstrate the potential availability of copper, tin and other minerals and to show clearly through analytical techniques the range of technical skills known and mastered (especially smelting and alloying). Evidence for the development and socio-economic context of early Greek metalwork - the relationship between metalwork, sites, sources and the role of foreign influence - will be required also.

Having defined the objects of the thesis and the nature of the problems with which this thesis will deal, it is necessary to give a brief explanation of the methods of the enquiry and then a brief history of archaeological studies in Greece in this period.

Chapter One collects together an up-dated and comprehensive catalogue of Greek mainland finds from the LN and the EBA. Chapter Two presents the typological study of all the material, assessing repertoire, local and foreign types, and carrying out an inter-Aegean typological comparison which will attempt to trace influences on, and the origins of, types. Chapter Three assesses the availability and nature of copper, silver, lead and gold sources in Greece, along with tin sources accessible to Greece. Other minerals which occur as alloy elements are also studied. In order to test the Diffusionist-Semi-Autonomist hypotheses, it is necessary to make a valid assessment of mineral wealth. Chapter Four will, through a programme of chemical and lead-isotope analyses, attempt to make a chronological assessment of technological ability and to provenance artefacts to source. Chapter Five, with the aid of the computer, will attempt to detect similarities and differences between the general chemical composition of the mainland, Cycladic, Cretan and Troadic industries and to suggest a new method of provenancing which may be potentially very useful. Chapter Six studies the

socio-economic and technological context of metals and metalworking in LN and EBA Greece, through a look at the relationship between the evidence for social, economic or technological complexity and evidence for metalworking. Chapter Seven assesses the most viable sea routes and modes of sea transport in the Aegean and the evidence that southern Greece was involved actively in trade and contact with the wider Aegean. It also assesses the importance of such contact. Chapter Eight reviews the evidence for settlement in the LN and the three phases of the Early Bronze Age and attempts to redress the imbalance in settlement distribution which may have resulted from either differential surveys or from geomorphological changes.

A brief review is now given of the history of archaeological research in mainland Greece. This is given as much to provide a necessary background to the research as to justify the chronological system employed throughout the thesis.

The search into the prehistoric past of the Greek mainland began with Schliemann's excavations at Mycenae which were published in 1880. At that time, all prehistoric finds were simply classed as pre-Classical. It was not until the first two decades of this century that more attention was given to the mainland, as much archaeological research had been going on in Crete (Evans, 1921-1925). The new mainland excavations, such as those at Orchomenos (Bulle, 1907), Korakou (Blegen, 1921), Levkas (Dörpfeld, 1927), Sesklo and Dimini (Tsountas, 1908) and Wace and Thompson's work in Thessaly (1912) gave a clearer picture of Greek cultures. In the 1930's and 1940's, further important work in Macedonia (Heurtley, 1939), and in southern Greece (Asine, Frödin and Persson, 1938; Eutresis, Goldman, 1931; Orchomenos, Kunze, 1931; 1934) to mention the most important researches, brought out further the character and richness of both the Neolithic and Early Bronze Age periods. These works were complemented by excavations at Thermi in Lesbos (Lamb, 1936) which attempted to synchronise the material

from that site with the data from the east and west Aegean. Little work was done thereafter until the 1950's, because of the Second World War and Civil Wars in Greece, but from the 1950's significant progresses in establishing the fundamental features of the EBA periods in southern Greece and the character of the Neolithic in northern Greece was made, (for example at Lerna in the Argolid (Caskey, 1953 - 1957), in Thessaly (Milojčić, 1956, 1959, 1967) and at Raphina and Astitario in Attica. (Theocharis, 1953, 1954,^{a,b} 1955). This work was complemented by work in the Troad which provided new comparative material (Troy, Blegen 1950; Poliochni, Brea, 1964). By the beginning of the 1960's and with a further review in 1971, Caskey was able to summarise the basic characteristics of the EH culture and assess it in an Aegean context. The work of Renfrew (1969) at Sitagroi, Theocharis (1973) in Thessaly, French (1972) in central Greece and Phelps (1975) in southern Greece provided similarly sound data on the Neolithic of these areas.

Recent work since the 1970s, mainly, has involved more a reevaluation of previous excavations and the pottery sequence, rather than any major new excavation, (eg. Tiryns, Aegina). This has been as much due to the prohibitive costs of excavation as to the need to reassess the material and archaeologists were also given the opportunity to benefit from the growth of archaeometric analytical and dating techniques which have developed since the last war. The main benefit of the response has been a refining of the relative pottery sequence and a growing body of absolute dates (mainly radiocarbon, but also thermoluminescence and archaeomagnetic) which provided new data otherwise unavailable to archaeologists.

Before the development of radiocarbon dating (hereafter C-14) in the 1950's, the Early Bronze Age in Greece and the Aegean was dated relative to the Dynastic records in Egypt. The Late Neolithic could not be "dated" as the records did not extend back beyond about 2,400 BC.

Petrie (1899) first used cross-dating to date the Bronze Age in Crete and Greece on the basis of Egyptian exports to the Aegean and imports from the Aegean to Egypt. In particular, third millenium synchronisms rest on two stone vases from Egypt found in EM II Knossos (Warren, 1965). Evans (1964) and Hood (1961) do not accept these and Cadogan (1978) believes this evidence alone to be too meagre.

Evans divided up Minoan civilisation into tripartite, almost equally long, divisions (Evans, 1921) and Childe (1925) divided up the Danubian civilisations on similar lines and provided "synchronisms" between Europe and the Aegean. Wace and Blegen (1916-1918) devised a tripartite development of mainland cultures which corresponds to those for Crete. Blegen (1921) refined this further, giving eight mainland phases (three for the EH, two for the MH and three ^{for} the LN) which equate with the nine phases in Crete. Up until this time, Europe beyond the Aegean could not be dated relative to Egypt in the absence of tangible evidence for contact between them.

The beginning of C-14 dating, and in particular the perfection of the calibration technique (Renfrew, 1968), produced alarming changes in chronological relationships and provided the first means of dating the Neolithic. The accepted dates for Egypt, the Aegean and the Near East remained unchanged; everywhere else was set earlier. This upset most of the arguments for Diffusion, the most important of which could be said to be the view that Balkan metallurgy began through stimulation from the Near East (Renfrew, 1969).

The radiocarbon dates available for the Greek mainland in the LN/EBA belong mostly to the MN/LN period. Sixty-seven are presently available and ten must be discarded as they are very doubtful.

Figure 2 gives the C-14 dates for Greece. All dates are calculated on the 5568 half-life and are quoted in years BP (based on the 1950 starting point). These dates require us to rethink the synchronisms

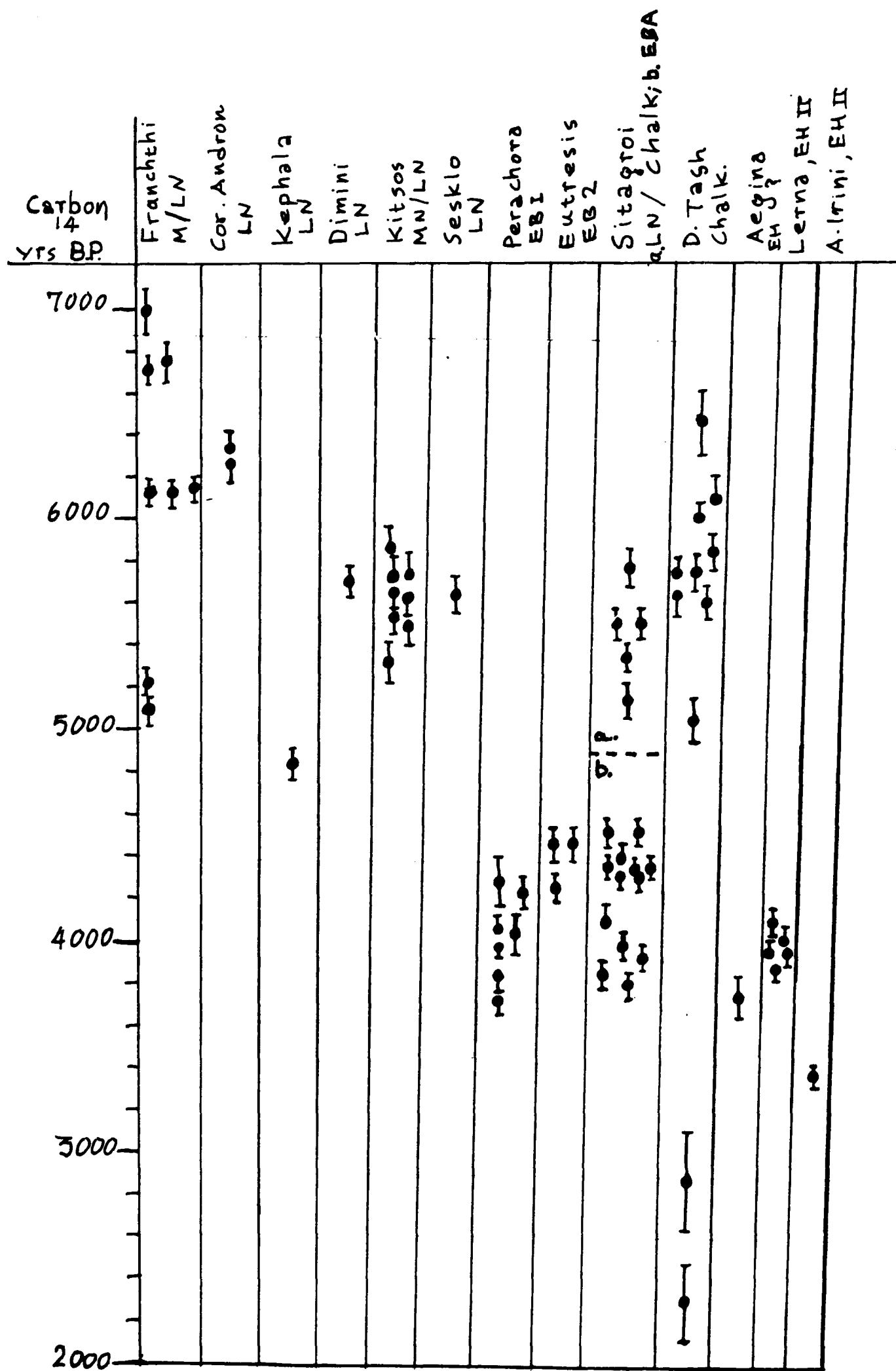
Conventional C-14 ages (half-life = 5568 years), along with their statistical errors, are shown on the figure opposite. There are several calibration tables which agree to within 100 years, and all of these are based on tree ring sequences for their respective geographical locations and refer to a 68% confidence level. As a guide to the dates in the tables, the following calibration factors should be added: for dates c. 3000 BP, add c. 250 ± 50 years (or 80-160 years from the Egyptian historical correction); for c. 4000 years BP, add c. 520 ± 50 years (or 420-570 years from the Egyptian historical correction); for c. 5000 years BP, add c. 720 ± 20 years; for c. 6000 years BP, add 900 ± 30 years; for c. 7000 years BP, add c. 900 ± 100 years. For the latter, the correction factor ranges from 500 - 1200 years for 95% confidence level which depends on the statistical error of the conventional data. The calibration system MASCA was employed in this thesis. For the dates under consideration the result is not significantly different from the latest calibration of Stuiver and Kraft (1986) which is discussed in detail in Pearson (1987).

Where calibrated dates are discussed, they are explicitly referred to and the MASCA correction tables are used. Otherwise all references are to uncalibrated radiocarbon dates. The BC/bc convention is not used.

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FIGURE 2 C-14 Dates in Third Millenium
Mainland Greece (see opposite)



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between Aegean EBA cultures, especially since the new sets of dates for Troy I and II have become available. Blegen (1950) believed Troy I to begin around 3000 BC and Mellaart (1966) placed the beginning of Troy I at around 3500 BC. The recent TL and C-14 dates for the destruction levels at Beşiktepe suggest an age of close to 3000 BC for early Troy I (Wagner et al, 1986). Coleman (1985) has recently discussed the difficulties in the relative (and absolute) chronology in the EBA Aegean and has suggested that Troy I overlaps parts of the EH I and II periods. For Sitagroi, one of the northern Greek sites for which good C-14 dates have been obtained for the LN and EBA sequence, Coleman suggests and Sherratt (1986) confirms a break between Sitagroi III (LN) and Sitagroi IV (LN/EB). Sitagroi III would, in this scheme, begin at the same time as the LN II in the Peloponnese/central Greece, dating to perhaps 4500 - c. 3800 BC and Sitagroi IV would end somewhere towards the end of the EH I (dating perhaps to about 3100 - 2700 BC). On the same scheme Troy I lasts from 3300 - 2800 BC. Sitagroi V is roughly contemporary with EH II/EBA II/Troy II in the Troad, that is somewhere between 3000-2500 BC in Coleman's absolute chronology. Fig. 3.

One should note that the term Copper Age or Chalcolithic has not traditionally been used as a division of the prehistoric sequence in Greece. However, copper metallurgy existed in the Aegean before the Bronze Age and the period which in Greece is commonly termed "Late Neolithic" is chronologically equivalent to the growth of an indigenous metallurgy in the Balkans (Renfrew, 1969). The term LN extends from c. 4800 to c. 3100 BC (dates derived from calibrated radiocarbon dates and thermoluminescence dates, Liritzis and Galloway, 1980). Here it includes the term Final Neolithic and Chalcolithic. The radiocarbon dates, and to a greater extent pottery typologies, confirm that the LN can be regarded as roughly contemporary in technological and cultural development in north

FIGURE 3 Chronological Table for Greece, the Aegean
and the Balkans (based on C-14 synchronisms)

CALEND RICAL*	b.c	WEST ANATOLIA	CRETE	CYCLADES	S. MAINLAND GREECE**	THESSALY	MACEDONIA	YUGOSLAVIA	BULGARIA	HUNGARY
5400										
5300										
5200										
5100										
5000										
4900	4000									
4800							SITAGRO I II	VINČA PLOČNIK		
4700							DIKILI TASH (LN)			
4600	3800									
4500				SALIAGOS						
4400	3600									
4300						EARLY DIMINI	EARLY SITAGRO I III		MARICA	
4200	3400									
4100								FINAL VINČA		
4000	3300								EARLY GUMELNITSA	TISZA- POLGÁR
3900	3200									
3800	3100					LATER DIMINI	LATER SITAGRO I III			
3700	3000									
3600	2850				KEPHALA FINAL NEOLITHIC	(RACHMANI)	SITAGRO I HIATUS		LATE GUMELNITSA	BODROG- KERESZTÖR
3500										
3400	2700									
3300			LN	LN	EUTRESIS EH I			EARLY BADEN		EARLY BADEN
3200	2500	KUM TEPE					SITAGRO I IV			
3100		KARATAŞ				E.TH. I			EARLY EZERO	
3000	2300	TROY I	EMI	EC I						
2900										
2800							SITAGRO I Ia			
2700								LATE BADEN		LATE BADEN
2600	2100	TROY II	EM II	EC II	EH II	E.TH. II				
2500							SITAGRO I V			NYÍRSEG
2400										
2300	1900				EC I or EC II					
2200					EH III	E.TH. III				
2100	1700	TROY III-V	EM III	EC III					POST- EZERO (CIGANKA MOGILA)	
2000	1600									
1900										
1800										

*calibrated on 5568 half life ; MASCA calibration.

** see detailed Fig. 2.

and south Greece (the Rachmani and Larissa cultures and the Corinthian, Agora-Kephala and Grotta cultures, respectively).

An ongoing chronological controversy first arose after the publication of the Lerna excavations by Caskey in the 1950s (Caskey, 1952; 1953; 1954; 1956 and 1958). The stratigraphic observations there permitted Caskey to define accurately the particular characteristics of the EH II and EH III periods and, based on these observations, to reconsider the chronology of various other sites (such as Zygouries, Asine, Aghios Kosmas) the excavators of which had attributed them to the EH III period (Caskey, 1960, 1964). These new views were accepted by other researchers, (French, 1968, 1972; Hanschmann, 1976; Rutter, 1979).

The initial excavations at Lefkandi (Popham and Sackett, 1968) and at Aghia Irini on Kea (Caskey, 1972) indicated that the chronological sequence may be more complex. These two sites represented a slightly different phase. They were neither fully EH II nor EH III, as their ceramics were different from the two known phases and had obvious prototypes in north west Asia Minor. This material came to be known as Lefkandi I and it was realised that similar material had been discovered from previous excavations at various sites in the Aegean, such as Syros (Kastri) and Pylos (Kythnos), Renfrew, (1972, 533-534; 538); Rutter, (1979); Macgillivray, (1980); Barber and Macgillivray, (1980, 150-151); at Manika Renfrew, (1972, 103-105) and at Raphina Rutter, (1979, 16-17). Ceramics with characteristic Lefkandi I have recently been located in Thebes (Dimakopoulou and Konsola, 1975, 85; Konsola, 1981, 145-146) and in Aegina (Walter and Felten, 1981, 104; Rutter 1983, 108).

There is as yet no agreement amongst archaeologists regarding the exact placement of this phase in the chronological chart of the EH period. French (Popham and Sackett, 1968, 8), places it after the EH II and considers it probably as an early stage of the EH III. Renfrew (1972, 103-105;

533-534) considers it as contemporary with the beginning of the EH III and Howell (1973, 85) places it with the EH III and names it Early Cycladic III. Similar views are held by Barber and Macgillivray (1980, 143) and Macgillivray (1980, 5) who, particularly for the Cyclades, propose the term Early Cycladic III A. Conversely, Hanschmann (1976, 174) and Rutter (1979, 15, 22 Table 3) place the Lefkandi I phase in an advanced stage of the EH II. Rutter in particular, suggests the term by Barber and Macgillivray be changed to Early Cycladic IIB, wanting thus to stress the continuation of this phase in the Cyclades with the EH II period on the mainland of Greece (Rutter, 1983b, 74-75; Barber, 1983; Macgillivray, 1983).

The chronological problems of the EH period took on yet new dimensions after the recent German excavations at Tiryns. Wiesshaar (1981, 221-222, 237; 1982, 351-354) recognised a transitional phase ("Übergangsphase") in the EH ceramics which was a mixture of EH II characteristics (sauceboats, ring-footed bowls, ouzo cups, etc.) and EH III characteristics (proto-Minyan, ouzo cups, etc.). According to Weisshaar, this phase dates to the beginning of EH III and is missing from Lerna, whereas it was present at Asine and Berbati (1982, 462-463; see also Rutter 1983c, 354-355). The proven survival of two typical EH II shapes (sauceboats and ring-footed bowls) in EH III levels in the Peloponnese, immediately poses the problem of the re-examination of the chronological phasing of those sites whose attribution to the EH II was based on the Lerna stratigraphy.

It will be obvious from the above that the controversy regarding the relative chronology has not yet been fully resolved. However, whether the transitional phase dates to the EH II or the early EH III, it is in fact the same chronological period and it appears with similar characteristics in various regions. It would be wisest to name the period "transitional". This

phase appears in the ceramics of Boeotia, Euboea and Attica where some designs characteristic of Lefkandi I are found with some ceramics which survived from the preceding EHII. There is a lack of Lefkandi I designs in the Peloponnese where the pottery is restricted to the characteristic EH II and EH III shapes.

Rutter (1983)^c has also noted that the lack of EH III material from Messenia and Laconia is most likely the result of EH II survival into the EH III with a lack of development of pottery styles and shapes in these regions at the end of the third millenium, rather than to a decline in population after the end of the EH II.

Further, in the EH II and EH III pottery attribution is more difficult as archaeologists rely heavily on the pottery's decorative pattern or colour for typological distinction. The acuteness of the problem is felt more in western Greece, which was a wetter climate and soils which are deleterious to the preservation of surface texture and paint. This is reflected in the recorded settlement pattern.

As the relative chronological sequence in central and southern Greece is so complicated, the regional studies which will examine settlement patterns per EH sub-phase will have to take into account the problem of variant cultures and transitional cultures which afflict many areas after the end of the EH II.

NOTE ON ILLUSTRATIONS

Because many of the objects used in this thesis were accessible to the author only indirectly, through publication or by special permission (since the objects themselves are under the control of the excavator or regional museum), it has not been possible to reproduce illustrations of them in a uniform manner. Drawings therefore convey the degree of information which it is possible to show in the circumstances—under the conditions laid down by the Greek Archaeological Service. Objects which have been personally examined and drawn are thus marked (*). Sources for other information are given in the synoptic tables.

CHAPTER ONE

CATALOGUE OF METAL FINDS

1.1 INTRODUCTION

This section presents a fully up-to-date catalogue of copper, bronze, lead, silver and gold artefacts from the Greek mainland which date to the Late Neolithic and Early Bronze Age periods. It has been compiled from: published material; museum collections in Greece and Britain; artefacts referred to in publications, but never fully described until now, and unpublished artefacts from recent excavations and finds (i.e. 1976 until 1986).

1.2 PREVIOUS WORK

There have been sporadic references to metal artefacts or evidence for metalworking in Greece since excavations of archaeological sites first began at the end of the last century. French (1968), in his study of Aegean metalwork in the third millennium BC produced the first catalogue of EBA artefacts. He discussed 128 finds of all kinds of metals from some 26 sites in Greece. Branigan (1974) compiled the first major account of the complete range of Aegean metalwork in the EBA and MBA. He listed over 231 artefacts from 31 sites on the Greek mainland. Tripathi (1976), in his examination of southern mainland Greek copper and bronze metallurgy from the Early Helladic til Early Mycenaean times, discussed 188 artefacts from 30 sites which belonged specifically to the EH period. Table 1.2.1 lists the sites and number of finds incorporated in these three main typologies. Figures 1.2.2 to 1.2.4 show the respective geographical distribution of the material.

1.3 THE UP-DATED CATALOGUE

Table 1.3.1 is the complete catalogue of all the artefacts which resulted from the up-date. The difference between the present and previous typologies in terms of both numbers and geographical distribution is apparent from both Table 1.3.2 and Figure 1.3.1.

1.4 CONCLUSION

The number of artefacts brought into this study is twice as many as in any previous work. The increase in artefact numbers is proportionately greater in the north, Thessaly and south-west regions of Greece. The increase in data justifies taking a fresh look at the range of metal types in Greece and, through them, the evidence for external and internal relations, the range of technological skills demonstrated and the variety of metals used. This is a necessary preliminary to analytical work and a study of the context of metals in the earliest metalworking communities of the Greek mainland.

CHAPTER TWO

TYPOLOGY

2.1 INTRODUCTION

No single typological study has been devoted specifically to the metalwork from the Greek mainland in the Late Neolithic and Early Bronze Age periods. Both French (1968) and Branigan (1974) reviewed Aegean metalwork. French (1968) gave emphasis to Anatolian metalwork and Branigan (1974) to Cretan metalwork. Tripathi (1976) looked at the relationship between the EH repertoire and those of the succeeding Middle Helladic and early Shaft Grave periods. Several other typological studies of a grand or small scale pertaining to various parts of the Aegean, or including the Aegean in their general scope, have incorporated or referred to some Greek material. These studies are listed in Table 2.1.1.

The absence of a standard reference typology presents difficulties for archaeologists attempting to classify their metal finds. This is enhanced by conflicting and often confusing terminologies. Inconsistencies between terminologies and taxonomic systems of the main works arise as a result of the different principles of classification. Visually it is usually easy to categorise large, distinctive artefacts or sets of quite common types. Controversy regarding the significance of tangs, slots and butt shapes is common and it is here that Deshayes' (1960) emphasis on hafting as a determinant of both function and shape can help clear up confusion. It is with the smaller tools and artefacts that one often encounters greater problems in taxonomy. Here there is much need of standardisation.

The new typology which follows is essentially functional and visual, subdivided on the basis of the major differences of form and hafting method. Previous typological systems are compared and a standard reference system is produced. An attempt is made to avoid numerous subdivisions and misleading terminology.

2.2. WEAPONS

Forty-seven weapons or fragments of weapons as well as one mould are known from LN/EBA Greece. There are thirty-two complete, or almost complete, examples. Seven pieces have not been included in any of the previous typological studies.

The weapons are not distributed evenly throughout mainland Greece as the majority come from Levkas (20). Only five examples are possibly Late Neolithic. All others fall towards the second half of the third millenium BC.

The weapons are listed in Table 2.2.1., drawings for which are given in type sets after the discussion of each individual type (Figures 2.2.1.1. to 2.2.1.8). The same procedure is followed for each metal type. The distribution of types is shown in Figures 2.2.1.9 and 2.2.1.10.

The artefacts discussed here were used for fighting and hunting. They have been variously classified as daggers, spearheads, dirks, halberds, swords and knives. Typological differentiation can only be done on the very broadest lines, as no two pieces are identical. The features which distinguish one sub-type from another are: the butt shape (tanged or riveted); the general form of the blade; the section (central long axis of the blade as shown in the midrib section), and the length.

The shorter, two-edged blades have been called "daggers" or "spearheads". The difference between them is one of hafting. Those with thin tangs, slot holes and broader blades are more likely to have been used as spearheads; narrower blades with either a broad tang or a row of rivets are more likely to be daggers. Catling noted that, "... the same type can occur in so many sizes that it is difficult to classify the weapons separately ... without introducing some arbitrary definitions based on dimensions" (Catling, 1964,56). As we will see, the introduction of dimensions in our definitions of types is quite appropriate for Greece.

The catalogue of Aegean daggers in Branigan (1974) shows that these weapons never usually exceed 30cms. in length. Renfrew (1969) actually suggested a length of 40cms., but the evidence for the Aegean shows that the dagger/spearhead blades did not usually exceed 30cms. in length.

Short swords, common in the third millennium BC, range from 30 to 40cms. in length. Long swords, not common until later in the Bronze Age, range from 40cms. to over 100 cms.

Knives are single-edged blades with an, "approximately wedge-shaped section" (Catling, 1964,102). Knives are considered separately in 2.3. Halberds, which are rare, are shaped like spearheads, but hafted transversely to the haft. It is often difficult to prove that they were actually hafted in this way and so no separate sub-type is made for them.

The weapons of the Greek mainland divide into eight main groups. Further sub-division is not worthwhile, since there are so many minor differences that a different sub-type would have to be devised for each variant. Known parallels are shown in Figures 2.2.1.11 and 2.2.1.12.

2.2.1. TYPE W.1

Tangless blade; straight-to-slightly convex butt;
rivets, but not slot holes; under 30 cms. in length
(Figures 2.2.1.1., 2.2.1.9)

Site	Length	Date	Marked Midrib?	Fig.	Cat. no.
Zygouries	16.8	EH II	slightly	✓	207
Athens	20.5	EH II?	yes	✓	12b
Lerna	12.0+	EH II	?	✓	85
Levkas	10.8+	EH II	yes	✓	345
Berbati	17.2	EH II/III	no	✓	77
Ay. Marina	9.2	EH III	no	✓	209
Lerna	13.7	EH III	no	✓	84
Athens	19.5+	EH?	yes	✓	12a
Levkas	13.0+	EH?	no	✓	324a

DISCUSSION

There are seven well-dated and two poorly dated examples of this type. The type dates to the middle/later EBA. Tripathi (1976,31) suggested that the Aghia Marina blade was LN, but this is not so (see 6.2).

The type is found mainly in southern Greece. Its presence in Levkas is by no means clear. Both Branigan (1974, cat. no. 130) and Tripathi (1976, cat. no. 14) quote Dörpfeld (1927,pl. 62.8) as the source of their blades, but their respective illustrations demonstrate that they were referring to two quite different blades. Neither blade belongs to this type, even though they both claim so.

Part of the butt is missing from the Levkas example (cat. no. 345) but what remains suggests a slightly more rounded butt than qualifies for this type. However, the artefact fits better into this category than any other.

Similarly, the Levkas example (cat. no. 324a) which has no rivets or midrib and represents a rather unique form, happens to be closer to our type W.1 than to any other type. Three blades from Levkas with prominent elliptical/lobed midribs are very similar to type W.1, but they form a separate sub-type on the basis of their distinctive midrib. (type W.6).

The examples of type W.1 from Athens (cat. nos. 11 and 12), Berbati (cat. no. 77) and Aghia Marina (cat. no. 209) are particularly homogeneous. Branigan (1974) groups nos. 12, 23a and 209 with his "long daggers, type II" and 12a as "long dagger, type IIb". Renfrew (1967) had suggested that the EC II examples preceeded the Cretan examples of the type, which do not appear until the EM III, but Branigan demonstrated that some Cretan examples are at least as early, if not earlier, than the Cycladic examples. The Mainland weapons of this type become more common at the same time as the Cycladic and Cretan blades of this type.

Renfrew (1967) classed the two blades from Aghia Marina as short daggers, type IIc (round butted). Only one of the blades is round butted: it belongs to our type W.5. The other dagger from Aghia Marina belongs clearly to Renfrew's type IV, or our type W.1.

The blades from Zygouries (cat. no. 207), Athens (cat. no. 11) and possibly Lerna (cat. no. 85) probably represent the same type. Tripathi (1976) classes them as type IVb blades, exact equivalents of Renfrew's type IVb blades (round butted). They all have straight to

slightly convex butts, however. Renfrew himself actually classed the Zygouries blade as type IVa (straight butted).

Regarding the Lerna blade in particular, Banks (1967,21) views it as an intermediary between the short, broad EM form and the later, more slender forms. She selects parallels from Mochlos (Seager, 1912,78, fig. 4, xxi, 22) as this blade is also an intermediary type and from Mesara (Xanthoudides, 1924, pls. xxxix, b, no. 1434), because the tongue-shaped blades are similarly straight. Tripathi (1976,36) said the blade had no specific hafting device, but Banks (1967, 22) suggested that the two rounded notches at the butt supplemented the rivet holes. It was the manner of hafting which led Branigan (1974, cat no. 425) to suggest that it was a spearhead, type I. Two other type I spearheads of similar form are known from Thermi in the EB II (Lamb, 1936, pl. xxv, 32.2) and Chalandriani in the EC II (Bossert, 1967, fig. 2.6). Branigan compares it with his type I spearhead from EM Crete (Branigan, 1968, 28). Dickinson (1970, 51 note 58) regarded the blade too small to be a spear.

If this blade had to fit into any of the above categories, it would be closest to our type I. It appears to be a local mainland adaptation of a south Aegean type. A MH example is also known from Levkas (Dörpfeld, 1902, vol. I, 309 310; vol. II, pl. 70.3). As the earliest example of this type is known from EM I/II Crete and the type is unknown in the EBA III, the Athens example (cat. no. 12) must be either EH II or MH. The evidence for an EM I context for some Cretan examples is slight and it is reasonable to regard the EBA II as the period when this type evolves in the south Aegean.

As a group, all the type W.1 blades can be considered of south Aegean origin. They did not develop from Anatolian parallels.

It is worth noting that arsenical-copper riveted blades are known

from several locations north of the Black Sea in the first half of the third milenium BC (Antony, 1986, 30). The Kurgan culture sites of Usatovo and Sukleya have given us examples. It

seems that, "with this evidence, there are indications that riveted, thrusting daggers were in use much earlier in Europe than they were in the Aegean" (Antony, 1986, 30-31). It is curious that such blades are absent from the Troadic sites which guard the Bosphorus, the quickest route into the Aegean from the Black Sea. The evidence for the connections between the Kurgan and Aegean cultures of the third millenium BC is discussed in 4.3.

The butt shape is the main difference between W1 and W5. The round butt of W5 is very rare and diagnostic and thus deserves its own sub-type.

2.2.2. TYPE W. 2.

Tanged blade; no slots; with or without a single rivet;

sloping shoulders; less than 30 cms. in length

(Figures 2.2.1.2, 2.2.1 9)

Site	Length	Date	Marked Midrib?	Fig. .	Cat. no.
Levkas	12.9	EH II	no	✓	318
Manika	12.9	EH II/III	no	✓	272
Manika	11.5	EH II/III	no	✓	280
Manika	5.6	EH II/III	no	✓	281

DISCUSSION

This type has been established as Anatolian and it makes its appearance in both Cyprus and the Greek mainland towards the end of the third mllenium BC (Catling, 1964, 59-60, fig. 3, nos. 3 and 4).

The type is first known from Thermi II, in the EBA I, and later at Troy and Poliochni in the EBA II (Branigan, 1974). Stronach

classes similar blades with no rivets in his dagger/spearhead type I group (Stronach, 1957). Although the mainland examples do not have rivets, their basic form is much more like Stronach's type II, in particular an example from Yazilikaya (Stronach, 1957, 91, fig. 1, nos. 1 and 2).

The Troadic and Central Anatolian examples are very similar, but the type developed in Central Anatolia, where a broad, raised flange down the middle of the blade becomes an established technique by the EBA III period. This variant does not reach Greece until after the EBA.

If one ignores the rivet, then the mainland examples are close to parallels in the early Troadic industry. They may even represent imports. The only parallels for such forms with rivets are from north Anatolia and the Caucasus. Stronach suggested that the more squat, rivetless dagger from Karaz in east Anatolia seemed to be an unlikely variant of the same type (Stronach, 1957, 94). It seems more logical to regard the mainland examples as imports from north west Anatolia.

This type of blade is absent from the Cyclades and Crete. Renfrew's type IIa blade, with no slots, does resemble the basic form of Stronach's type II blades. Renfrew considers that the type is probably of Cycladic origin. These Cycladic blades could represent an adaptation of the Anatolian blades, however. Mainland examples have closer affinities with the Anatolian blades than the Cycladic.

Renfrew believed that the Manika dagger (cat. no. 272) had a definite Anatolian look, but said that it did not seem to fall into any of his Cycladic types (Renfrew, 1967). The two daggers from Manika (cat. nos. 280 and 281) and the example from Levkas (cat. no. 318) confirm that this was a distinct type which does not belong to any other group.

Tripathi (1976) noted the similarity between the profile of the Poliochni razor and this general type, (Brea, 1964, 593, fig. 322 h, pl. lxxxviii 13). Another possible parallel is the newly excavated razor from Petromagoula.

The presence or absence of rivets was the main reason for sub-dividing W2 and W4. The blades would have been hafted differently.

2.2.3. TYPE W. 3.

Tanged blade; slots with or without rivets;

length not greater than 30 cms.

(Figures 2.2.1.3; 2.2.19)

Site	Length	Date	Marked Midrib?	Fig.	Cat. no.
Levkas	18.0	EH II	no	✓	316
Levkas	10.6	EH II	yes*	✓	317
Corfu or Ithaka	24.5	EH?	yes	✓	315a

(* not marked in Tripathi, 1976, fig. 2)

DISCUSSION

There are only three examples of this type, two of which are well-dated.

The main difference between these three pieces is the midrib section and the length of the tang. Tripathi's drawing of our blade no 317 from Levkas was incomplete as it omitted the midrib.

All the blades are equivalent to Renfrew's type IIa slotted dagger/spearhead, (Renfrew 1967). They fall into his categories types VI, VII and IX, all basically similar.

The type is apparently of Cycladic origin, but as noted above in 2.2.2. the main difference between this type and Stronach's type II dagger/spearhead is the presence of slot holes. Slot holes were

thought peculiar to the Cyclades, but Stronach (1957, 111-112) has noted that, "while metal-smiths in the hinterland of western Anatolia were able to introduce slots on a local form of blade with a long, bent tang ... those in the offshore islands and the nearby Cyclades ... developed a different type of spearhead with slotted blade which was based upon the shape of the short tanged dagger." Anatolian influence upon this predominately Cycladic type cannot be excluded.

The slot holes enabled a thong to be passed around the midrib and so hold the blade in place. Perhaps the slots were skeuomorphically preserved in the metal form.

The Corfu or Ithaka example belongs to a similar type which Branigan places in the EBA II (Branigan, 1974, spearheads, type IX). While it is not accepted here that this is the most suitable classification, it is most likely that this artefact dates to the Early Helladic. The Corfu/Ithaka blade is closer to Branigan's type VIII, however.

2.2.4. TYPE W.4

Tanged blade; thin tang; no rivets or slots;
long, slender blade; point not sharp; not
greater than 30 cms. in length
(Figures 2.2.4.1; 2.2.19)

Site	Length	Date	Marked Midrib?	Fig.	Cat. no.
Levkas	13.9	EH II	no	✓	320
Levkas	15.2	EH II	no	✓	319

Site	Length	Date	Marked Midrib?	Fig.	Cat. no.
Levkas	17.8	EH II	yes	✓	322
Levkas	-	EH II	?	NA	323

DISCUSSION

There are four examples of this type, all from Levkas in the EH II. One has a marked midrib and suggests a more developed form than the others. Their closest parallels are Branigan's spearhead type VIII. However, none of these blades have slots and their tangs are not obviously rat-tailed. Branigan's type group is not particularly homogeneous, however.

Other examples of this general group, more akin to Branigan's type than to our present group are known from Anatolia and Amorgos.

Tripathi's drawing of the preserved blade (cat. no. 320) does not bring out sufficiently the midrib section, especially at the butt, where it forms a "V". Although quite similar to Stronach's dagger/sword type I, as Tripathi suggested, this blade has generally much closer affinities with Stronach's type I spearheads (Stronach, 1957, fig. 4.1). These, however, have bent tangs. The earliest examples date back to the middle of the third millennium BC, occurring simultaneously in western Anatolia and Cyprus (Stronach, 1957, 104). The Levkas examples are contemporary with the more primitive models from Troy II.

Branigan (1974, 19) noted the possibility that these Levkas blades each had two slots. While this is not at all apparent, we should mention that Stronach (1957, 106) believed the earliest examples to be very similar in appearance to contemporary spearheads with a slotted blade.

The type seems to have been a north west Anatolian development which spread south via inland routes in western Anatolia, reaching Cyprus by the end of the EBA. The finds from Levkas and Amorgos are evidence, not

available to Stronach at the time, that this type was known, or had reached, the Aegean in the middle of the Early Bronze Age.

2.2.5. TYPE W.5

Tangless blade; circular butt; length less than 30 cms.

(Figures 2.2.5.1; 2.2.19)

Site	Length	Date	Marked Midrib?	Fig.	Cat. no.
Ay. Marina	9.3	EH II/III	no	✓	210
Levkas	13.0+	EH II	no	✓	341

DISCUSSION

Only two examples of this type are known from the mainland. This is a rare type in the Aegean. Renfrew (1967) classes them as short daggers, type IIc, a form which he believes is very common in western Europe. He quotes two examples from Aghia Marina in this category, but as noted, one example (cat. no. 209) belongs to W.1. He regards the Aghia Marina daggers as possible prototypes for his type V daggers. There may be a connection between these and the straight-butted dagger from Aghia Marina, but there is no obvious typological relationship between the above example and Renfrew's type V blades.

Aegean examples of blades of this type come from Lebena in the EM I-EM II (Branigan, 1974, no. 143), Chalandriani (Bossert, 1967) and Amorgos (Renfrew, 1967, 5, 65).

The closest western parallels come from the Italian Rinaldone and Remedello cultures. Renfrew and Whitehouse (1974) classified these blades in their knife/dagger type B2 as, "concave sides, round heels, and

two, three or five rivets."

An unpublished example in the Ashmolean Museum Oxford, from a mid-third millennium BC Balkan context is almost identical to the Aghia Marina example (Cluj, Romania, Accession no. 1918,37; Ashmolean Museum, UK) It has three pin-holes instead of rivet holes and was hafted by means of fine wire.

The earliest example of our type W.5 comes from the mainland of Greece. It should be considered a local type, unless evidence is forthcoming which proves earlier examples elsewhere. The exact connection between the Italian, Balkan, Cycladic and mainland examples is difficult to establish.

2.2. 6. TYPE W.6

Tangless blade; prominent elliptical midrib.

convex sides; broad, straight butt; rivets;

not over 30 cms. in length

(Figures 2.2.6.1; 2.2.19)

Site	Length	Date	Marked Midrib?	Fig.	Cat. no.
Levkas	19.5	EH II	ellip.	✓	342
Levkas	14.3	EH II	ellip.	✓	343
Levkas	15.0	EH II	ellip.	✓	344

DISCUSSION

There are three examples of this type, all from Levkas. They are similar to type W.1 blades, except for their pronounced midrib. This technique of strengthening the blade by a reinforced midrib was an important technological step which led to the production of more elongated blades.

The final product was the sword (type W.7).

The simpler form (type W.1) is apparently absent from Levkas. On current evidence, the development from type W.1 to type W.6 blades took place in the Aegean. Reinforcing blades by building-up a broad central flange or midrib can be observed first in the ^{Anatolian} blades with raised flanges, grouped in Stronach's type I. Raised flanges are not known in mainland Greece and are rare in the Aegean in the third millennium BC. The rhomboidal midrib was the first method used in Anatolia. The elliptical and lobed midrib develops from the rhomboidal and is first seen in the Aegean in the mid-third millennium BC. Type W.6 thus represents the adaptation of a local south Aegean blade (type W.1) under the influence of west Anatolian industries.

Contemporary with the Levkas examples are two blades from Platanos in Crete (Branigan, 1968, 73, III, nos. 3 and 4) and one example from Naxos (Renfrew, 1967). Two further examples, from possibly earlier contexts, are known from Salame in Crete (Branigan, 1968, 73, III, 1 and 2). However, as the EM I date of the type W.1 is doubtful, it seems unlikely that these Cretan examples really start so early.

The three Levkas blades represent the evolution of the type W.1 blades and are intermediaries between type W.1 and type W.7.

2.2.7. TYPE W.7

Tangless blade; prominent lobed midrib;
narrow blade; possibly riveted; over
30 cms. in length
(Figures 2.2.7.1; 2.2.19)

Site	Length	Date	Marked Midrib?	Fig.	Cat. no.
Levkas	34.0	EH II	lobed	✓	347
Levkas	37.0	EH II	lobed	✓	346
Levkas	2.6+	EH II	lobed	✓	349

DISCUSSION

There are only three examples of this type, all from Levkas. The lobed section and narrow blade of the fragment from Levkas (cat. no. 349) make it clearly a member of this group.

These blades, which must have developed from type W.6, represent a technological step forward - the blade is lengthened even further than type W.6 and is supported by a strong, but more slender, midrib.

Renfrew (1967) discusses blades with the prominent midribs in his type VII. These blades fall into this group. They are precursors of the later long swords, defined by Karo as type A and discussed by Sandars (1961).

The development of this type from W.1 to W.7 seems to have taken place in the Aegean. Other examples of blades similar to our type W.7 are known from Crete and Amorgos. It is in Levkas that we observe the best examples of the intermediary blade, W.6. The development from dagger to sword took place in the middle of the third millennium BC. Greek swords appear at the same time as Cretan and Cycladic swords.

2.2. 8. VARIOUS BLADES AND FRAGMENTS OF BLADES

(Figures 2.2.8.1; 2.2.1 9)

Site	Length	Date	Marked Midrib?	Fig.	Cat. no.
1. Corinth	-	LN	no	✓	78
2. Petromagoula	-	EBA II	no	✓	424a

Site	Length	Date	Marked Midrib?	Fig.	Cat. no.
3. Levkas	6.5+	EH II	partial?	✓	324
4. Lerna	18.5	EH II	no	✓	86
5. Levkas	-	EH II	no	✓	350
6. Levkas	4.7+	EH II	yes	✓	351
7. Lithares	18.2	EH II/III	no	✓	235
8. Askitaro	NA	EH II/III	?	NA	7
9. Askitaro	NA	EH II/III	?	NA	6
10. Pelikata	NA	EH II/III	?	NA	368
11. Saratse	NA	EBA	?	NA	446
12. Levkas	NA	EH	no	NA	348
13. Athens	15.2+	EH?	yes	✓	11

DISCUSSION

Very little can be said about artefacts numbered 8 to 12 in the above list as only very small parts of them remain. All that can be said is that they were blades, not knives, and thus fall into this category. Artefact no. 1 from Corinth is the earliest blade of its size. Little information is available on the blades from Kephala on Kea (cat. no. 21). The Petralona blade resembled the Corinth blade and is one of the few blades found in the northern half of Greece at this time.

We will now give an account of the remaining blades, as yet unclassified.

3. Levkas (cat. no. 324/Fig. 12)

This is a unique type. As it is broken and damaged, it is difficult to assess its purpose. Tripathi (1976, 34) suggested that it was a votive offering or an unfinished cast of a small tanged tool. It was undoubtedly a blade and not a tool, though the most likely explanation for its

presence in the grave does seem to be as a funerary offering. As a blade it would have been of little practical use. It is interesting that several of the blades from the Levkas graves were not intended for practical use (see 4.7).

4. Lerna (cat. no. 86/Fig. 21)

This blade is very like type W.1, but it narrows sharply from a broad butt to a narrow blade. If it had a midrib, it would qualify for type W.6. The blade itself is gently curved to one side, off the longitudinal axis.

Banks (1967, 30) called the blade a knife. Its transverse section seems to be triangular, indicative of single-edged knives. She regards the Eutresis knife as a parallel, (Goldman, 1931, 218, fig. no. 286,7). The Eutresis and Lerna blades are quite distinct, however.

Branigan (1974, no. 474) classes this blade as a halberd, type I. It represents the only one of its type in the Aegean before the MM II examples from Palaioikastro. The Cretan examples are also curved on one side, though the rivet holes are larger.

Renfrew (1967) noted that it was difficult to accept that an assymetrical blade is evidence that the blade was mounted transversely to the shaft.

Whether a knife, a dagger or a halberd, the type is the earliest of its kind in the Aegean and is therefore unique.

5. Levkas (cat. no. 350/ Fig. 22)

Very little can be said about these odd pieces. Two of the four pieces are non-joining. They are fragments of two blades, mis-shapen as a result of excessive heat. It is reasonable to assume that they were once on a funeral pyre as the practice of cremation is suggested at Nidri. These blades were a votive offering. Unfortunately they are in a poor

state of preservation and are at present corroding away in the museum at Levkas.

7. Levkas (cat. no. 351/ Fig. 24)

This is a section of narrow blade with a triangular midrib. It is the only piece of this type known and suggests an early sword. Little more can be said about it.

8. Lithares (cat. no. 235/ Fig. 31)

Branigan classes this as a long dagger, type IIb, but it is quite unlike any others in this group, as they all have rounded butts with three rivets in triangular arc formation. The Lithares blade is an elongated triangular dagger without a midrib. It has an unusual concave butt. Branigan (1968, 13) suggested that the concave butt could have acted as, "a sort of two pronged tang". The type of haft is uncertain. The method of hafting may have imitated procedures of hafting stone arrowheads. Treuil (1983, 50) illustrates some arrowheads in stone with similar deep concave butts. He suggests that the type did not appear until the EB II-MB I and even then it was little used. Branigan (1974) gives no examples of this type of butt on any arrowhead or blade, but it must have been with a similar hafting method in mind that the Lithares blade was formed. Further examples of stone arrowheads with deep concave butts are given in Frödin and Persson (1938, 234, fig. 175:4), Goldman (1931, 206, fig. 276:4) and Blegen (1928, 199, pl. xx;23).

The closest parallels in metal within the Aegean are the triangular daggers, but not Renfrew's type IV blades, as suggested by Tripathi (1976, 37). However, the triangular daggers are not exclusively Cretan as Branigan (1968; 1974) has suggested. The triangular type of dagger is known from LN contexts in Dikili Tash (Treuil, 1983) and Cucuteni-Tripolje

cultures. In the EBA, it is known from Poliochni, (blue phase, Brea, 1964) and Dikili Tash. It can no longer be considered exclusively Cretan (Treuil, 1983, 147). The Lithares dagger need not be a Cretan import.

A similar dagger to that from Lithares is known from an MBA context in Jericho (Kenyon, 1957, 367, 146:1), but the type is rare and the blades are usually convexly curved. There seems to be no meaningful connection between the Lithares and the Levantine examples.

It is safest to regard the Lithares dagger as a local development or ^{as} a local adaptation of a Cretan prototype. The butt and the hafting methods no doubt copied contemporary procedures in stone-work.

13. Athens (cat. no. 11 / Fig. 34)

There are no typological parallels for this type, but its form suggests that it falls within the EBA II (Branigan, 1974, 19).

2.2.9 CONCLUSION

(Figure 2.2.9.1.)

It is quite obvious that the island of Levkas had some kind of monopoly in weapons. Most of the finds come from there, helped no doubt by the fact that they came from graves and had therefore more chance of surviving.

Type W.1 blades evolve in the south Aegean in the middle of the EBA. Their origin is not necessarily Anatolian, Cretan or Balkan, though influences on the development of this blade could have come from all, or any of, these directions. Greek blades of this type develop at the same time as other blades of this type from the Cyclades and possibly Crete.

Type W.2 blades are of known Anatolian type. They are known outside of north-west Anatolia in the first half of the third millennium BC, but

only reach the mainland, Manika, at the end of the third millenium BC. This site had marked connections with north west Anatolia at this time.

Type W.3 is apparently of Cycladic origin. Its distribution in Greece is restricted to the Ionian area.

Type W.4 blades have no direct parallels, but are closer to an Anatolian type which was not thought to be known in the Aegean until the MBA. Its presence in the EH II is now confirmed.

Type W.5 blades represent a type which became common in the Balkans, Italy and the Cyclades at the same time as in Greece. It is thus difficult to be sure from what direction the influence came. Certainly the Greek and Cycladic finds could have provided the stimulus.

Type W.6 blades were long, supported by a midrib. They appear to have developed from Type W.1 blades and co-existed with them. It is difficult to say if this development took place in Greece or the Aegean.

Type W.7 blades are swords in the true sense of the word. Their distribution is restricted to Levkas, though such fine pieces are unlikely to survive outside the ~~protected~~ environment of the grave. The type developed from Type W.6. This indicates that the Aegean, including Greece, kept up pace with contemporary Anatolian developments.

Types unique to the mainland seem to be type W.6 and blades numbers 4, 8, and 13 in section 2.2.1.8. Foreign types seem to be types W.2, W.4 and possibly W.7.

Unfortunately the comparative data for these blades is out-dated. The work of Stronach (1957) and Renfrew (1967) are thirty and twenty years old, respectively. Should a new catalogue of Anatolian and Cycladic blades be produced greater resolution could be achieved in this section of the typological study.

The importance of the analytical programme in tracing typological

and technological influences cannot be over-estimated. Several of the weapons discussed here are included in the analytical programme presented in chapter 4.

2.3. KNIVES

(Table 2.3.).

2.3.1 TYPE K.1

Straight to slightly curved back(concave);
straight to slightly curved cutting edge;
wedge-shaped section; straight or slightly
rounded butt; rounded tip; flanges with
or without a rivet.(Figures 2.3.1.1.a; 2.3.1.2; 2.3.2.1)

Site	Length	Date	Rivet	Fig.	Cat. no.
Malthi	5.6+	EH?	no	✓	159
Lerna	5.2+	EH III	yes	✓	88
Levkas	5.2+	EH II	yes	✓	352
Lerna	11.52+	EH III	yes	✓	87

DISCUSSION

There are four blades which belong to this type. None are identical, yet they are similar in form. They are contemporary with other single-edged knives in the Aegean and it seems to be in the Aegean that this type evolves. It becomes the most common metal object in the succeeding periods.

The type has two sub-types: the first has flanges which were produced by hammering up the edges of the haft section and fitting a handle in between. The remains of the wooden or bone handle is still to be found under the flanges of the Malthi find (Tripathi, 1976, 399).

Only three blades have flanges, one has a rivet hole in addition.

As many published knives do not show clearly whether or not flanges were used it is difficult to assess the extent of this hafting technique. On present evidence, which is itself limited, the flange technique seems to have originated on the mainland. Something similar to the flange technique/^{is observed} in early Minoan arrowheads (Mochlos; Branigan, 1968,88) and/^aspearhead (Aghia Photia). No knives from EM Crete have flanged haft-ends, however.

This mode of hafting must have been ineffective, because it quickly fell into disuse. The pressure exerted on the haft/blade juncture would have loosened the handle.

The round butt/round tip and almost parallel blade, without shoulders, has no good parallels outside the mainland. The Malthi example is most probably EH as all other examples are. The Lerna blade is very similar to the Malthi knife except that it has a rivet instead of flanges. A further, incomplete, knife from Lerna (cat. no.88) has both flanges and a rivet and clearly falls into this type. A remaining incomplete blade from Levkas (cat. no. 352) has a rounded tip and at one time had roughly parallel sides and so falls better into this type than any other.

The only parallel in Deshayes (1960, no. 2526) is Medieval from Amnisos in Crete and thus quite clearly is unrelated to these third millennium BC Greek mainland finds.

Other knife blades of this general group, represented by Branigan's (1974) knives types I, II, III and V are not known on the Greek mainland in the EBA.

This type of knife starts in the second half of the EBA and does not survive into the MBA. Sandars (1955, 183) suggested that, "unspecialised blades" were first standardised as knives in Crete. In view of the lack of evidence from Crete, this hypothesis is no longer tenable.

2.3.2. TYPE K.2

Straight to convex back; convex cutting edge;
wedge-shaped section; shouldered butt; upcurved
blade tip. (Figures 2.3.1.1.b; 2.3.2.1; 2.3.1.2)

Site	Length	Date	Rivet	Fig.	Cat. no.
Eutresis	16.5	EH III	yes	✓	221
Ay. Marina	11.0	EH III	no	✓	210
Levkas	18.0	EH II	no	✓	351
Levkas	14.2	EH II	?	✓	321

DISCUSSION

This group is not homogeneous, but constitutes a group of convex blades with up-turned tip and are thus quite distinct from type K.1 knives. The mode of hafting is different in each case. There is one example of a flanged haft and this must surely represent a local mainland adaptation.

This type of knife has been labelled "Anatolian" as the vast majority of knives with this shape do come from Anatolia, particularly the Troad. Sandars (1955, 183) has effectively demonstrated that the ultimate origin of this type of knife was Asian. The mainland evidence shows that the local Greek industry was influenced at the end of the third millenium BC. The question is whether or not the mainland examples represent imports or locally made copies. The flanges on the Aghia Marina blade suggests a local adaptation. The up-turned blade tip is original. The shouldered blade from Levkas is very similar to the Aghia Marina example. It no doubt had a rivet or rivets and thus represents a form mid-way between the Aghia Marina and the Eutresis blade, which is more pronouncedly convex.

This type of knife actually divides well into two sub-groups. The first are those with a separate haft and the second sub-group are those

with a haft of metal.

It is easier to assign the Eutresis knife to other known types as it is both well-preserved and distinctive. Deshayes (1960, no. 2395, 124) classes the Eutresis knife as type C2b. A direct parallel is known in Troy II and Deshayes (1960, 306) believes that Goldman (1936, 230) is correct in assuming that the Eutresis knife is an import. Branigan (1974, 167) classes it with others from Troy of his type VI.

The Levkas knife (cat. no. 321) has a metal haft with a knob-butt. This knife is incompletely drawn in Tripathi (1976, pl. 3, no.7). Two examples are known from Levkas though these knives, according to Branigan (1974, 168) belong to a general type common in Troy (type VIIla).

The "Anatolian" knives all date to a period when there is marked evidence of Anatolian influence on the mainland.(see Ch.7).

2.3.3. CONCLUSION

Knives become known in mainland Greece at the same time as the Cyclades. The main influence on the development of knives could have come from Crete (for type K.1) or from Anatolia (type K.2). It is quite possible that some of the mainland knives represent copies of foreign prototypes. Analyses of one knife from Levkas by the lead-isotope method was made to see if local copper was used to make a foreign type (see 4.5).

2.4. AXES

Of the sixty-two axes studied, forty-seven were of the flat axe variety and fifteen had shaft-holes, Table 2.4.1. Nine examples are known from Late Neolithic contexts. The tools are divided into three main groups, within which there is variation in form and size. Some groups are more homogeneous than others.

Each of the three groups are represented in the LN, and stone parallels are known for the earliest types within each group.

Ten of the axes are from undatable contexts, but are arguably EBA in the light of their typological similarities to the well-dated Greek examples.

The axes are quite evenly distributed throughout Greece (Figure 2.4.1.). Figure 2.4.2 shows the chronological distribution of axes throughout the LN/EBA.

Before giving the elements of typological classification for axes, a clear distinction must be made between axes and chisels. Much of the interpretation of the relative use of these tool groups rests upon this.

Deshayes (1960, I, 26) claimed that it was difficult to establish a boundary between chisels with diverging sides (and therefore broader cutting edges) and axes. Implements of the forms designated "chisels" in this thesis (2.5) are listed by Deshayes as "axes", "chisels" and "lugged axes" (Deshayes, 1960, 51-84, 85-100, 113-131). Tripathi (1976, 46) suggested that the difference was simply one of size and Banks (1967, 23) selected the name "chisel" for some of her tools, "because of the comparatively small size of the objects ...". Some of the EBA chisels catalogued in Branigan (1974) are over 30 cms. in length. Moreover, the function of an axe (chopping tool) is different from the function

of a chisel (shaping tool). Although most workers divide axes and chisels into two separate "functional" groups, they do not stress sufficiently how function determines and limits form. It is an established physical law that: pressure: $\frac{\text{force exercised}}{\text{area of striking point of implement}}$ and this means that for a set force, the larger the chopping edge which strikes an object, the lower the pressure exercised. Conversely, the narrower the chopping edge, the higher the pressure exercised. Thus, the basic functional difference between the two types is reflected in the size and shape of the tools' chopping/cutting edge.

Catling (1964, 63) noted that axes with proportionately wider and straighter cutting edges were, "technically the most efficient of the prehistoric axe series." The axe thus has a broader cutting edge (straight, convex or flared) and the chisel has a narrow and straight-to-slightly convex cutting edge. Branigan (1974, 24) divided his flat axes into three basic types according to the shape of the sides (convex, parallel or concave), and this is directly related to the width of the cutting edge. The main sub-divisions of the axes given here are similar to his types II and III.

Catling (1964, 63) classified the Early Cypriot axes according to variations in the butt form, because "it was the only distinctive feature unaffected by the forging." Tripathi (1976, 46) chose the same criteria to sub-divide chisels. The butt shape is only important for what it tells us about the mode of hafting. As an axe was necessarily hafted, the butt is of little functional significance. This is not the case with chisels where the form of the butt is very important in the classification.

The length/maximum width (L/MaxW) ratio can be usefully employed to help us distinguish between axes and chisels. From a survey of Aegean

axes and chisels it is possible to give a standard ratio for each of the two tool types. Axes have a L/MaxW ratio of up to 4.4; chisels start at that point. As a result of this "standardisation", many of the axes and chisels in other previous classifications have been rearranged.

2.4.1. TYPE A.1

Straight almost parallel sides; straight/
rounded butt; straight/slightly convex cutting
edge; plano-convex; rectangular/square section
(Figures 2.4.1.1.; 2.4.2)

Site	Length	Date	L/MaxW	Fig.	Cat. no.
Sesklo	14.2	LN	3.3	✓	402
Eutresis	5.9	EH I/II	3.0	✓	223
Dimini	9.1	EBA	3.4	✓	378
Eutresis	13.3	EH II	3.1	✓	219
Levkas	4.8	EH?	2.9	✓	354a

DISCUSSION

Five axes belong to this type. Their distribution is restricted to southern Thessaly and west/central Greece, except for a sole example from Levkas. The tools range in date from the LN til the mid-third millenium BC.

These axes appear to copy Thraco-Thessalian stone axes which are also known in the west Balkans (Bulgaria and Romania, Heurtley, 1939, 164). Metal parallels for this type are known from both the east and west Balkans. Two Albanian tools, classified by Branigan as chisels are considered here as axes (Branigan, 1974, nos. 760 and 761). These

LN/EBA Libonik axes provide very close parallels for our type A.1. West Balkan axes from contemporary Kodja-Dermen, Deve Bargan and Seid are of a similar type (Deshayes, 1960, type A4a, 12). The LN Greek axes and their Balkan parallels are not therefore pre-dated by the earliest eastern Aegean examples of the type, from Tepe Gawra V (Bliss, 1898, 213, pl. CLXXXII, 3). The evidence for links between Greek communities and their northern or eastern neighbours, suggesting strong links with the Balkans in the LN/early EBA periods, is confirmed.

Early Cycladic II axes from Naxos and Poliochni (Copenhagen National Museum cat. no. 3193; Brea, 1964, pl. CLXXII,a) indicate when the type had reached the Aegean islands. No stone parallels for it are known in the Cyclades. Cherry (1981) has shown that Naxos was not even occupied until the third millennium BC.

This form of Greek axe either developed locally from stone prototypes or copied Balkan (especially Albanian) prototypes in metal.

The Sesklo and Dimini axes have been analysed by the lead-isotope and chemical methods (see 4.5 and 4.6).

2.4.2. TYPE A.2

Concave sides, narrowing to a straight or mildly rounded butt; convex cutting edge; flat profile; rectangular section

(Figures 2.4.2.1; 2.4.1; 2.4.2)

Sub-types:

A.2a: as A.2 but with pronounced convexity of cutting edge

A.2b: as A.2 but with markedly rounded butt

A.2c: as A.2 but sides narrow to a high waist, after which sides converge on narrow butt

A.2d: as A.2 but with lugs

TYPE A.2

Site	Length	Date	L/MaxW	Fig.	Cat. no.
Euboea	5.8	EH I	2.0	✓	216a
Pefkakia	11.9	LN	2.1	✓	395
Alepotrypa	7.8	LN/EH early	2.1	✓	52
Marathon	16.4	LN	2.0	✓	26
Laconia	20.0	EH early	4.4	✓	83
Petralona ¹ (18 examples)		EBA late	-	✓	442- 431, 432-440

DISCUSSION

There are twenty-three axes in this category, dating from the LN to the late EBA. All the axes from Petralona and two examples from Alepotrypa and Laconia, respectively, have not been published before.

There are no known Greek parallels in stone. Deshayes (1960, vol. II, 58) believes that none are known from the Aegean or Anatolia either. However, a direct stone parallel for the Alepotrypa axe is known from the tombs of Collechia, Parma, Italy (Bull. Pal. Ital., 1900, 225, fig. 117). In metal, similar types are known from the Aegean and, though more rare, from peninsular Italy. Most of the Cycladic examples have holes for hafting and a uniformly straight butt. Two examples from EC II Chalandriani and EC Naxos do not have holes and perhaps should not be considered typically Cycladic (Bossert, 1967, fig. 2,4). In general, Cycladic examples are not known before the second half of the third millennium BC.

Italian axes from the eneolithic Remedello and Rinaldone cultures are contemporary but have a more splayed cutting edge, with "hammered up edges", (Renfrew and Whitehouse, 1974, figs. 2 and 3)

Outside the Aegean the closest parallels are presented in

Deshayes' B3a axe/adze type. The earliest examples of these are known from early third millennium BC Pločnik, Serbia (Grbić, 1929) and Karnobat, Bulgaria (Deshayes, 1960). Eastern examples are known from the mid-fourth millennium BC in Cilicia (Mersin XVI), Garstang, (1953) and from the mid-third millennium BC in Mesopotamia (Al 'Ubaid), Hall and Woolley (1927), and the later third millennium BC in Anatolia (Alaca Hüyük), Koşay, 1951, Bunarbashi-Goli, Soli and the Troad, especially Thermi (Lamb, 1936).

The earliest Greek axes of this type are contemporary with both east-west Balkan parallels and an example from Mersin. Cycladic and Troadic examples do not appear before the mid-third millennium BC. The Alepotrypa example has an exact parallel in metal in an axe from the Caverna di San Canziano del Timavo, near Trieste but in Yugoslavia. (Phelps *et al*, 1979; BPI 1889, 9 pl. II, 40 (41)). Other metal artefacts from Alepotrypa as well as pottery in the south Peloponnese strongly suggest close parallels in the north west Adriatic. In view of the strong connection north, a west Balkan origin for this type would be the most probable if the axes were either introduced from, or influenced by, the metal industries of the west Balkans. Independent invention cannot be ruled out.

TYPE A.2a

Site	Length	Date	L/Max.W	Fig.	Cat. no.
"Peloponnese"	4.6	EH I/II	0.5	✓	163
Gona	6.0	EBA I/II?	1.9	✓	419

DISCUSSION

Phelps *et al* (1979, 178) discussed the dating of the Peloponnese axe and decided upon a date early in the EBA. They also suggested that the

Gona axe might belong to the same phase, though others have often believed it is MBA in date (Branigan, 1974, no. 607).

No parallels in either stone or metal exist in the Aegean LN or EBA. Both examples have "hammered up" edges and this practice is known from the Italian and Yugoslavian Chalcolithic cultures (Renfrew and Whitehouse, 1974). Phelps *et al* (1979, 178) rejected the Italian and Yugoslavian axes as suitable parallels for the Peloponnesian axes, but these^{are}/the closest. The Gona axe resembles the Italian Remedello and Rinaldone axes very closely indeed. Two further parallels, in the east, are known from Iran, Hissar Ic, at the end of the fourth millenium BC and from Cyprus, Alambra, from the second half of the third millenium BC (Schmidt, 1937, 57, pl. xvi, H4,176; Cesnola Cyprus Collection, 1903, III, pl. lxx, 5). The later third millenium BC examples^{come}/from the Cyclades (Naxos and Amorgos), Cilicia and Troy (National Museum of Athens, nos. 6198,5 and 1887; Zeit. Assy. Vord. Arch. 1940, 194, p. V.S. 3445 and 3449); Blegen *et al* 1950, 329, fig. 358, no. 35.551). An axe from Thermi (Lamb, 1936, pl. xxv, 29.9) can be placed typologically between the Peloponnesian and Gona types.

The closest parallel is undoubtedly between the Gona axe and contemporary Italian examples. Parallels for the Peloponnesian axe are more difficult to find, though it is closer to the Gona axe than to any other yet known.

The main difference between A2a and A2b rests in the cutting edge and butt. The rounded butt is unique and quite distinctive and deserves a separate sub-type.

TYPE A. 2b

Site	Length	Date	L/MaxW	Fig.	Cat. no.
Sesklo	16.8	LN	3.5	✓	403
Eutresis	7.8	EH II	3.25	✓	217
Thebes	15.3	EH III	3.2	✓	243
Petralona		EH II/III	-	✓	441

Site	Length	Date	L/MaxW	Fig.	Cat. no
(Lerna	9.2	EH III/MH I	2.45	✓)	-

DISCUSSION

There are five examples of this type which span the LN/EH III period. They are well distributed throughout Greece. Until now, the Eutresis axe had been considered the sole example of this type (Deshayes 1960, vol. 1 58, 80). The new data from Petralona, which has not been published before, from Lerna and from Thebes have altered that picture, as indeed has the LN axe from Sesklo, which has a more rounded/pointed than straight butt, as incorrectly depicted elsewhere (eg. Branigan, 1974, pl. 13, no. 617).

The examples from Eutresis, Thebes, Petralona and Lerna have often been considered as chisels, but are axes under the present scheme of classification. The Eutresis, Thebes and Lerna axes are very homogeneous, except that the latter is half the size of the others.

Banks (1967, 24, no. 13, pl. 2 no. 13) remarked that the butt of this particular Lerna example was "missing", yet her drawing and description of the axe allows it to be determined. She discusses the EH and MH parallels for the type and all the parallels are axes. She notes the obvious connection between the Eutresis and Lerna tools as well as the actual chisel of similar shape from Levkas (cat. no. 365). The Cycladic parallels, all mid-third millennium BC, which Banks sees as parallels for the Lerna tool are not truly comparable. The distinctive feature ^{of} this type is the very rounded butt and all ^{the} Cycladic parallels suggested possess the characteristic Cycladic straight butt.

The closest Aegean parallel comes from Troy IIg (Schliemann, 1880, 959). The similarity between this example and the Eutresis axe has often been overlooked. The only parallel outside the Aegean is the late third millennium BC example from Palestine, at Tepe el Hesi, (Deshayes 1960, Vol. I), but this parallel is later than Greek examples. There is thus no support for Bank's conclusion that the type originated in the Cycladic islands in the middle of the EBA. The earliest examples in the Aegean appear to be mainland. Anatolian and Cycladic examples are more rare and are so slightly later. Balkan examples are not known.

Deshayes' classification of the Eutresis axe with one from Amorgos is inappropriate as the latter is stylistically very different, especially the butt (Deshayes, 1960, vol. I). What is interesting about the Amorgos axe is the lead used to fill in its hafting hole. The Eutresis axe has one of the highest percentages of lead (6.10%) of any Greek artefact of this period (see 4.6). There may be no connection between them, but the coincidence is intriguing.

TYPE A.2c

Site	Length	Date	L/MaxW	Fig.	Cat. no.
T. Dymaion	17.2	EH III?	4.3	✓	169
T. Dymaion	15.6	EH III?	3.9	✓	170
Thebes	20.3	EH III	3.98	✓	244
Levkas	20.0	EH?	4.0	✓	332b
Levkas	17.5	EH?	3.3	✓	332c
(Acarnania	15.2	?	NA	✓	

DISCUSSION

There are seven examples of this type, three of which cannot be dated from their contexts. The two examples from Teichos Dymaion have not been discussed before and four of the artefacts have previously been classed as chisels.

Parallels are known in the Troad, Aegean, Crete and Levias in both the axe and chisel form (Schmidt, 1902, 6047-8; 6180-1; Bossert, 1967, fig. 2,3; Warren, 1972, 222, fig. 97; Dörpfeld, 1927, pl. 63a, 5). The larger forms, the axe, are more rare. The type was known in the Aegean **before** the first of its type appears on Greek soil. The earliest example comes from Thermi IV (Lamb, 1936, pl. xxv, 29.10), followed by two possible EM I examples from Pyrgos, Crete (Branigan, 1968, 90, I, 2,1). The majority came from Troy though they are well-represented in the Cyclades (Chalandriani and Poliochni), Bossert, (1967); Brea, (1964.)

Connections outside the Aegean are harder to trace. Deshayes' type C3b chisels are too far removed chronologically and the nearest parallel for the Theban axes come from LBA Greek contexts (Deshayes, 1960, II, 38). The only other parallels are from early MBA Palestine, (Megiddo and Gaza), Loud (1948, II, pl. 184, 10 and 14); Petrie, (1931-34, I, 8, pl. xvi, 17).

This type was most likely introduced to Greece from the north west Aegean, where the earliest examples are found.

It should be noted that a further axe from Thebes was found in the hoard possibly of this type. It was not preserved (Konsola, 1981, 138, note 120).

TYPE A.2d

Site	Length	Date	L/MaxW	Fig. .	Cat. no.
T. Dymaion	12.8	EH III?	3.65	✓	168
Lerna	8.6	EH II	3.58	✓	89

DISCUSSION

Branigan classed the Teichos Dymaion axe with his chisels, (Branigan, 1974, no. 923), though Mastrokostas (1962, 132) and French (1968, 357) believed it to be a lugged axe of Maxwell-Hyslop's type A (Maxwell-Hyslop, 1960). Banks (1967) classed the Lerna axe as a chisel even though the only parallels she quotes for it are lugged axes (Deshayes' type B1). Mastrokostas, French and Branigan date the Teichos Dymaion axe to the EH, most probably a late phase, but Tripathi (1976, 244) thought it belonged more to the LBA. Now that two other axes, found together with this axe, have been studied (see A.2c) and dated to the EH III? and we have a similar axe from Lerna which also dates to the second half of the third millenium BC, we can accept a late third millenium BC date for the Teichos Dymaion axe. Mastrokostas (1962) also cites a third millenium BC parallel from Turang Tepe in Anatolia.

This type of axe does not become common in the Aegean until the LBA, though in Anatolia they are common from the first half of the second millenium BC.

If we look away from the axe variety and seek parallels within Greece and the Aegean for smaller tools with similar shape, we do come up with good parallels. The nearest Aegean parallels are represented in Deshayes'awls type B4b, which are known in Greece (see 2.2.5). They start in Mesopotamia in the third millenium BC and so could perhaps have provided the prototype for the lugged axe which becomes common in Hittite Anatolia.

There is no need to view the rare Greek examples as imports from the east. They may well represent the development of a form already known in awls. The awls need not have been Near Eastern. Perhaps bone equivalents of Deshayes' type B4b copper awls were known in Greece.

2.4.3. TYPE A.3

These are shaft hole tools. They fall into four distinct categories: (Figures 2.4.3.1; 2.4.2)

TYPE A 3a

shaft-hole; single axes; convex or straight cutting edge; straight or slightly convex top-side and concave under-side. Three sub-types: 3.1 without sleeve

3.2 with half sleeve

3.3 with full sleeve

SUB TYPE A 3.1

Site	Length	Date	L/MaxW	Fig.	Cat. no.
Delphi	11.4	EH late	3.47	yes	216
(Sparta	12.8	?	1.82	yes)	
(N. Peloponnese	15.0	?	2.14	yes)	

DISCUSSION

There are three examples of this type, only one of which comes from a relatively sure context. The Delphi axe has never been properly published before. The axe is arguably EH (Evans, 1894, 280; 1985, 11, (28) fig 7; 1909, 59; Montelius, 1924, 644, a-c). Evans also remarked that the scratchings on the upper side of the blade were symbols. Upon personal examination of the artefact, it appears that the markings were produced during casting and represent differential corrosion of a secondary

reworked surface. We should note, however, that the axe from the north Peloponnese has what appears to be a symbol on its flank.

Examples of this type are known in the Aegean. Deshayes' shaft-hole axe type G2 provides the best parallels (Deshayes, 1960). There is one example from the second half of the third millennium BC at Thermia on Kythnos (British Museum, 1920, 162, fig. 174,b) and one example from the end of the third millennium BC from Palaikastro on Crete (Bosanquet and Dawkins, 1923, 117, fig. 100). Deshayes (1960, 192) argues for an undoubted Iranian "parentage" for all Aegean examples and dates them all to the mid-to-late third millennium BC. The Delphi and "Spata" axes are more elongated than the Iranian prototypes quoted by Deshayes and bear some resemblance to axes from Kythnos (Renfrew, 1967) and Naxos (Deshayes, 1960, no. 1544). They are similar to stone axes of LN date and also to Deshayes' type Hb shaft hole axes. These come from late third millennium BC contexts in Crete (Montelius, 1924, I pl. 4,9) and Amorgos (Ashmolean museum 1927/2968 and Renfrew, 1967), and are generically similar to the north Peloponnesian axe.

Balkan parallels for this type are only similar. The schaftlochaxt Typ Baniabic (Table 1, Vulpe, 1970) is perhaps the most similar though these have a slightly more pronounced and rounded cutting edge. The distribution of the Baniabic type stretches from above the Danube into Hungary. It is possible that the artefact entered the Greek mainland via the Vardar/Morava passage, but the evidence in support of eastern influence is stronger.

SUB TYPE A 3.2

Site	Length	Date	L/MaxW	Fig.	Cat. no.
Thebes	12.9	EH III	3.98	yes	243

DISCUSSION

The Theban axe has a half-sleeve or support for the heavy blade. It was found in a hoard, the character of which was mixed. The closest parallels in the Near East are seen in the Sumerian axes which appear later and were much more complex than this simple form (Deshayes, 1960). The closest Balkan parallels are seen in the Veselinovo I (Romania) axes, which date to the EBA also. These are distributed along the Danube and in Bulgaria. There are no useful analogies for this type in the Balkans, however, and this type must be taken to represent a local adaptation of a simple shaft hole axe.

SUB TYPE A 3.3

Site	Length	Date	L/MaxW	Fig.	Cat. no.
Petralona	-	EBA III?	-	yes	442
Petralona	-	EBA III?	-	yes	443
Petralona	-	EBA III?	-	yes	444

DISCUSSION

The Petralona axes have never been properly published before¹. They have deep, heavy sleeves or collars. The earliest example of this type in the Aegean comes from Poliochni in the EBA II, (Brea, 1964, 661). A mould from the same site demonstrates that the type was known from the EBA I (Brea, 1964, 661). The Greek examples do not date before the end of the third millenium BC, but they represent the only Aegean examples in the later third

millenium BC. Cretan examples are all Middle Minoan.

Prototypes are known in Anatolia, but there is some confusion over the dating of them. Bittel (1942, 139, note 239) suspected that this type should date to the beginning of the second millenium BC, and this view is in contrast to that of Przeworski (1939, 24, 26, 39, 72, 82, 172, 195, pl. xxi,4) and Maxwell-Hyslop (1949, 112) who had previously suggested a date towards the end of the second millenium BC. Stronach (1957) dated the type to, "at least the end of the EBA", based on parallels between the Kultepe, Poliochni and Mesopotamian examples. This date substantiated Bittel's hypothesis. However, now that the EBA I example (mould) is known from Poliochni, we should perhaps push back the date to the beginning of the EBA. This could mean that the north-west Anatolian examples developed somewhat independently. Stone prototypes are well known in Anatolia (Stronach, 1957), and they are not identical to the Mesopotamian types.

This type of axe, while not paralleled in the Balkans exactly, is similar to the Izvoarele type in Romania (Vulpe, 1970) and to Type 16 in the west Balkans (Chernykh, 1978. Table III.6). The distribution of these types could conceivably have reached the Aegean via the Vardar/Morava route. The Romanian parallels date to the late EBA III/MBA

All the Petralona finds were found in a hoard, along with numerous single axes. Some of these single axes are typically "Helladic" in character. Perhaps the hoard is suggestive of the way in which the sleeved axe reached the Greek mainland - that is, by itinerant metalsmiths. The typological parallels favour an eastern influence more than a Balkan influence.

TYPE A.3b

Shaft-hole tool; convex cutting edge; concave edges which narrow to a rectangular-sectioned hammer butt

Site	Length	Date	L/MaxW	Fig.	Cat. no.
Mesolonghi	11.5	LN	NA	✓	160
"Athens"	10.1	LN	NA	✓	11
Levadheia	12.5	EH	NA	✓	234

DISCUSSION

Shaft-hole axes are known first in Greece from two LN or early EBA examples from Athens and Mesolonghi (Phelps *et al*, 1979). These are the products of the same tradition, but the tradition itself remains something of a mystery. Deshayes (1960) believes that such tools illustrate the interaction between the metal and stone forms and Phelps *et al*, (1979) reinforce this view.

Stronach (1957) suggested that the first Anatolian metal shaft hole axe imitated local forms of stone hammer axes. The closest stone parallels for these two Greek axes do come from the east Aegean, but in the EBA (eg. from Troy (Bittel, 1945, fig. 27); Poliochni (Brea,

1964, pl. 183, 1.2) and Thermi (Lamb, 1936, figs 53 and 54). These however have a round-sectioned hammer end, characteristic of most eastern forms of this type, even in later years. Balkan axe hammers usually have a rectangular-sectioned hammer end. Only two fragments of similar one axe hammers are known from Greece - from Thessaly (Tsountas, 1908, pl. 41.9) and Eutresis (Goldman, 1931, fig. 278, 8). The type is otherwise unknown in Greece at this time.

Phelps *et al* (1979) suggested that Deshayes' axe hammer type A1a provided the closest parallel, particularly the example from Susa. The closest illustrated parallels are from the Balkan Chalcolithic (eg. Corneşti (Vulpe, 1975, pl. 11, no. 79) and possibly Driehaus, group III (Archaeologia Geographica, iii, 1952, fig. 1.4). These have a distribution in north-central Yugoslavia. According to Phelps *et al*, (1979, 179) if we accept the Balkan parallels, as the most probable, they were imported from that direction. If, however, we are convinced by the stone parallels an east Aegean origin would be the most appropriate. As no metal examples of this type actually appear in Anatolia, before the second half of the third millennium BC, influence from a Balkan direction would seem more probable - if we exclude all possibility that they could have been produced locally.

Another hammer is known from Levadheia. French (1968) and Branigan (1974) do not date it, but Deshayes (1960) places it around the second half of the third millennium BC and Phelps *et al* (1979) suggested that it could be EH I.

Stone parallels come from a mid-third millennium BC grave at Yortan in Anatolia (Bittel, 1945, 31) where a stone and metal form of the same type were found side by side. Earlier examples in terra cotta are known from Ur, also (Deshayes, 1960, 265).

The type has no direct parallels inside Greece, though the two previous axes are similar. The Levadheia axe is more "angular". Again, we observe the rectangular-sectioned hammer, a Balkan feature. Copper parallels of this type are known from Bulgaria, Giouzeldki Alan (Skorpil, 1898, 104, fig. 42) and Romania, Vidra (Rosetti, 1934, 45, fig. 42) in the east Balkans to Bosnia and Serbia, in particular Plocnik (Grbić, 1929, 15, fig. 100); Krusevac (BRGK, (1951-1953, 64); Kladovo (BRGK, (1951-1953, 64); Laktasi (WMBH (1896, 180, fig. 36); Vrbas (WMBH 1909, 92, pl. xvii, 1); Travnik (WMBH, 1899, 147, fig. 23, 24), and Gorica (WMBH, 1909, 92, pl. xvii, 2) in the west Balkans. These examples come under types B1a, B1b and B2 axe-hammers in Deshayes (1960, 111).

The shaft-hole axe from Naxos (Deshayes, 1960, no. 1544) bears some resemblance to this general group, but it is difficult to assess the connection between them.

Most of the parallels for the Levadheia axe are early third millennium BC; there is thus every possibility the axe is of this date, as first suggested by Phelps et al (1979). It is typologically closer to the earlier Greek and Balkan axes than to eastern parallels, which become more common towards the end of the third millennium BC.

TYPE A.3c

Axe Adze

Site	Length	Date	Fig.	Cat. no.
Eutresis	9.0	EH II	✓	217
(Acarmania	14.8	?	✓)	
(Athens	-	?	NA)	

DISCUSSION

There is only one well-dated example of this type from Greece.

As this is the earliest of its type in metal found in Greece, Diffusionists have emphasised the connection between the axe and either the Danubian (Schachermeyer, 1955, 197-202) or Cretan (Goldman (1931, 229) varieties. The Eutresis axe-adze has very little in common with the well-known series of Copper Age axe-adzes from the Balkans and the Carpathian Basin as outlined in Sherratt (1976). As both the Balkan and the Cretan parallels post-date the Eutresis example, it shows that they cannot be used in such hypotheses.

There are three more axes of very similar type in the Aegean: one from Thermia on Kythnos (Montelius, 1924/28, pl. iv:1) dated to the second half of the third millenium BC, and two other undated examples from Acarnania and Athens. It is in these two regions exactly that the Mesolonghi and Athens axes were found (see A.3b).

Outside the Aegean, the Maikop axe (OAK, 1897, 2-11) provide the only contemporary parallel; though it is over twice the length of the Eutresis example.

On current evidence, this axe could well represent a Greek adaptation of an earlier axe-hammer type, or an imported tool. There is very little evidence to support the latter possibility, as no stone prototypes are known and metal prototypes are geographically rather remote.

TYPE A.3d

Double axe

Site	Length	Date	Fig.	Cat. no.
Thebes	18.1	EH III	✓	242
Sesklo	15.0	EBA	✓	406a
(Corfu		EH-MH	✓)	
(Levkas		?)		
(Dodona		?)		
(Epirus		?)		
(Peloponia		?)		
(Peloponnese	14.0	?	✓)	

DISCUSSION

Three double axes are known from third millenium BC Greece. The Sesklo axe is made of lead (see 4.6). Six more copper/bronze axes are known from west Greece, but no dates are available for them. Daux (1968, 835-36) is doubtful of the date and provenance of the Corfu example, yet the distinctly Ionian distribution of most of these axes is confirmed by the others, even though they are not well-dated. The Theban and Sesklo examples demonstrate that the type was known in the third millenium BC.

Two schist double-axe moulds from Sesklo (Tsountas, 1908,333) are believed to belong to the EBA. (Childe, 1950, 72; Dickinson, 1970,148). and this rather substantiates the EBA date for the lead axe which Branigan (1974) had dated to the MBA(?). This is made more probable still by the fact that double axes are not known in MBA Greece. The malleable lead may have been used to prepare moulds or to maintain a standard type.

The only other all-lead artefact in the EBA Aegean is known from Samos - a single axe (Milošćić, 1961, pl. 50, 11).

Most Aegean double axes come from EM/MM Crete (Branigan, 1968). Wace and Thompson (1912) noted that the Sesklo moulds would have produced axes very different from the, "typical Cretan types." (1912, 74, note 1).

These axes were either developed separately inside Greece and Crete or were introduced into the areas at the same time, that is, the mid-to-late 3rd millennium BC. Buchholz (1959, 21) argued that these axes were of foreign origin and that they were introduced simultaneously into Greece and Crete. The parallels of several of the other tools found in the hoard with this Theban axe are Anatolian, though the piece was probably made of Aegean lead, for which there is evidence in the western Cyclades (see 4.3). Perhaps the Sesklo axe was an imitation of an imported form. Lead was, of course, reaching Samos in the EBA, but there is little evidence for the exploitation of lead in Anatolia during the EBA.

2.5. OTHER AXES

(Figures 2.4.2)

Site	Length	Date	Fig.	Cat. no
Spata	5.9	LN	✓	164

DISCUSSION

This axe has been fully discussed by Phelps *et al* (1979). The form like the techniques used to finish it, is unique in metal. Its only parallels are with stone celts of the Neolithic/EBA (eg in Thessaly (Tsountas, 1908, fig 232); Thermi (Lamb, 1936, pl. 50, 31.16); Delphi (Montelius,

1928); Asea (Holmberg, 1944) and Kea (Coleman, 1977). Its close translation into metal suggests an early stage in the development of metal tool-making.

The only contemporary copper axes are from Knossos (Evans, 1928, F3F); Melos (Ridgeway, 1901) and Troy (Branigan, 1974, no. 595), but they are not typologically very similar. Its closest contemporary parallel is from Malik (Phelps et al, 1979, 176) in Albania. There is no reason to presume that this artefact is an import. Most likely it represents lithic techniques applied to a LN copper casting. Prototypes in stone are common in Greece, and copperworking was practiced in the region. More light on the provenance of the artefact could perhaps be obtained if lead isotope analyses were carried out.

2.5 CHISELS

This group includes all chisels as defined in 2.4. The tools were used in woodwork, masonry and perhaps metalwork. There are twenty-one tools in this category; these are listed in Table 2.5.1. Six chisels belong to the Late Neolithic and fifteen to the Early Bronze Age. They are quite evenly distributed throughout Greece, Figure 2.5.4.1. Eight chisels in this group have not appeared in previous typologies. Figure 2.5.4.2. shows the distribution of chisels in the Aegean.

The tools are divided into two basic groups:

2.5.1. TYPE CH .1

2.5.1 TYPE CH1

Square/rectangular in section; flat butt;
straight to slightly convex narrow cutting
edge; usually not hafted.

(Figure 2.5.1.1; 2.5.4.1; 2.5.4.2)

Site	Length	Date	L/MaxW	Fig.	Cat . no .
Alepotrypa	14,8	LN	7	✓	54
Alepotrypa	6.1	LN	6	✓	55
Pevkakia	12.0	LN	8.45	✓	395
Lerna	8.9	EH II	4.94	✓	153
Levkas	6.0	EH II/III	6	✓	365
Lithares	9.8+	EH II/III	2.3+	✓	236
Lithares	19.8	EH II/III	5.5	✓	237
Lithares	17.8	EH II/III	4.68	✓	238
Petralona	-	EBA III?	-	✓	432
Thebes	16.1	EH III	12.9	✓	247
Thebes	3.2+	EH III	2.46+	✓	248
Eutresis	14.6	EH II?	5.6	✓	222
(Acarnania	15.2	EH ?	-	✓)	

DISCUSSION

This type is generally well distributed throughout Greece. During the LN we have three examples and the tool does not appear again until the second half of the third millenium BC and then predominately in central and north Greece.

The chisels are not all identical. The general type is quite common and Deshayes warns against viewing far-reaching parallels for it as evidence of diffusion (Deshayes, 1960, Vol. 1).

The Alepotrypa and Pefkakia chisel, though not identical are broadly similar to those in Deshayes' chisels type E1a - especially to an undated example from Byblos (Dunand, 1937-39 and 1954). The earliest examples of the type are from fourth millennium BC Iran and Palestine (Ghirshman, 1938-1939, 54, pl. lxxxiv, S 1698; MJ, xxiv, 1935, pl. III, 22) and are known in the Aegean and Ionian Sea by the third millennium BC. (eg. Lamb, 1936. 168, fig. 49, 30.15). The earliest Aegean example dates to the EBA I from Poliochni (Brea, 1964, pl. pl. lxxxviii, 14) and this is just later than the earlier Balkan examples of the tool known from Chalcolithic levels at Pločnik in Serbia (Garašanin, 1954, 53, pl. I. 17). The Serbian and Greek examples are contemporary. Links between both Thessaly and southern Peloponnese and the north-west Adriatic coast are well-established if an outside origin for the tools is sought. Analyses of material from two of the Greek sites has contributed much to our understanding of their contacts (see 4.5 and 4.6).

The second chisel from Alepotrypa has no exact parallel. Two chisels from Bulgaria, from Gabarevo (GNM, 1926-1931, 111, fig. 30) and Gorsko Kalugerovo (RVL, II, 1948 pl. 102, b), both Deshayes' type E4a chisels and both contemporary with the Alepotrypa example provide the only parallels. Eastern examples of the basic type are known from undated contexts in Iran and Palestine. The B2 group of chisels (Deshayes) also resemble this chisel, but no dates are available for the parallels.

It is interesting that no stone prototypes or parallels are known for any of these chisels. It is highly likely that the type was developed locally and independently.

The EBA examples of this basic type are not found in the Peloponnese

or Attica. They all date to the end of the EBA, except for one chisel from Lerna, which is EH II. This mortise chisel is unique in Greece. There is no Aegean parallel for the tool. Banks (1967, 77-78) has described it as, "a heavy solid rod implement of circular section, made in a one-piece mould. The shaft tapers asymmetrically for one third of its length to form a long, heavy point."

Blegen (1928, 184) believed the Zygouries chisel to be a mortise chisel, but it most definitely falls into type Ch.2. The Theban chisels are more like mortise chisels than the Zygouries examples, but are rectangular in section. Blegen regards the mortise chisel as an imitation metal of bone "awls" which were quite common in the Aegean in the EBA (Blegen, 1950, 28-29, fig. 126).

Outside the Aegean a metal mortise chisel from Byblos, dating to the end of the third millennium BC, provides the only parallel in that medium, (Dunand, 1937-1939, vol. I, 151, pl. lxxix, nos. 2190 and 2191). The Lerna example precedes it and was no doubt a local, independent development having bone prototypes.

By the end of the third millennium BC, this type of chisel becomes more common. Eight examples which date to the later third millennium BC are particularly homogeneous. Six are well-dated and three were derived from undatable contexts. Five of them have previously been classed as axes (three from Lithares (Spyropoulos, 1969, pl. 32b, 30, right, left, centre) one from Levkas (Dörpfeld, 1927, pl. 63a5) and one from Eutresis (Goldman, 1931, fig. 288.1)). The Eutresis example has a more splayed cutting edge but qualifies more for type Ch.1 than type Ch.2. Three undated examples of this type from Acarnania and Levkas are most probably of this type. Deshayes (1960, II, 38) classed the Acarnania chisel with his type C3a chisels, but there is very little

difference between the Eutresis chisel (classed as an axe-adze type D2b by Deshayes) and the Acarnania chisel (classed as chisel type C3a by Deshayes). The Eutresis example was the only Greek artefact of this type given by Deshayes (1960, II, 23). The Greek examples are similar to Branigan's type III chisels and Deshayes' type D2 axe-adze and type C3a chisels. They all date to the EBA II/III and not before. The earliest Aegean examples come from Thermi IV (Lamb, 1936, pl. xxv, 29.10). and perhaps EM I Pyrgos (Branigan, 1968, 90, I.2). Deshayes had given a mid-third millenium BC date for the earliest Aegean examples. He argued that as the earliest Near Eastern example came from Iran (Hissar Ic, Schmidt, 1937, 57, pl. xvi, H 4176) and all Anatolian and Aegean examples dated to the mid-third millenium BC. the type spread from Iran to the Aegean. Certainly, the distribution of this type from Cilicia, Cyprus, Anatolia, the Cyclades and Crete does agree with the proposed diffusion routes. However, none are known from the Levant. There is no further support for Deshayes' hypothesis. The type appears simultaneously in Greece and the Aegean with **possibly** earlier examples from Crete and Thermi. There are as many Greek examples as there as Aegean.

Two remaining chisels from EH III Thebes are quite similar. Branigan (1974, 166) classed them as single axes type III, though at the time he did not have the opportunity of studying them at first hand. They fall somewhere between his type II and type III chisels. Deshayes chisel type F provides the closest parallel (Deshayes, 1960, II, 45). The Theban examples do not have such a pronounced "pyramidical" cutting edge as others in this group. They resemble an undated Mycenaean example most closely (Deshayes 1960, II, no. 872).

The earliest example of these tools outside the Aegean comes from a fourth millenium BC context in Mesopotamia, Tepe Gawra (Speiser, 1935,

I, 108, pl. lxxxii,3). They are known in the Troad from Thermi III and IV (Lamb, 1936) and subsequently in several locations in Anatolia in the second half of the third millenium BC. The Thermi chisel could have provided the prototype for the Theban chisels, but we have no proof of this. The two chisels did come from a hoard which contained other artefacts with possible north-west Aegean connections.

The Petralona chisel has not been published before. It also comes from a hoard. Its section is slightly different from that given in Branigan (1974, no. 716 pl. 14). It has a more pronounced cutting edge, which is narrow and straight. However, its closest parallels are still the two Theban chisels even though it reflects the heaviness of the Pefkakia chisel.

2.5.2 TYPE CH.2

Rectangular in section; round/pointed but thin butt; straight to convex sides; straight to convex narrow cutting edge; usually hafted;
(Figure 2.5.2.1; 2.5.4.1; 2.5.4.2)

Site	Length	Date	L/MaxW	Fig.	Cat. no.
Kephala	-	LN	-	✓	21
Kephala	-	LN	-	✓	21
Kephala	-	LN	-	✓	21
Levkas	10.9	EH II	43	✓	353
Levkas	8.6	EH II/III	4.65	✓	181
Lerna	3.8+	EH II/III	1.6+	✓	90
(Attica	13.5	EH ?	8.43	✓)	
Zygouries	7.9	EH II/III		✓	

DISCUSSION

This type is possibly represented in the Kephala examples in the LN (Coleman, 1977, 108), but is most common in the EBA II/III. The type is not known in northern Greece or Thessaly. Eight tools come into this category, seven of which are well-dated and one of which comes from an uncertain context.

The form is roughly equivalent to Branigan's type V chisels (Branigan, 1974, 170) and Deshayes' type D1a (Deshayes, 1960, II, 39). Their most distinguishable feature is the thin narrow butt or thin broad tang which enabled hafting. Tripathi (1976, nos. 59 and 61) classed two Levkas chisels together because they both had round butts, but the types are quite distinct. The Levkas, Zygouries and Attica examples are very similar indeed. The earliest Greek examples date to the EH II. The earliest Aegean example comes from Thermi IV (Lamb, 1936) followed by Cycladic examples in the ECII and EC III) eg. from Naxos and Chalandriani Tsountas, 1899, pl. x, 44). The chisel from Attica (Branigan, 1974, no. 916; and Deshayes, 1960, II, no. 748), is most probably of EH date also.

Deshayes argues that this type was influenced from the east, because it closely resembles the form of his type B4 awls which are known from Assyria to Anatolia in the course of the third millennium BC and also because Anatolian affinities of certain finds discovered in a Naxos tomb (Deshayes, 1960). However, it is only in the Aegean that this desire to produce larger forms of B4 awls seems to have been present and there does not seem to be enough evidence to support the influence of eastern prototypes on the development of this tool. As only one example comes from Troad and the majority of examples come from Greece and the Cyclades, the origin of this tool must have been regarded as Greek or Cycladic.

2.6 AWLS

There are thirty-nine tools which belong to this group. The earliest examples are firmly established in the LN/Chalcolithic period from four sites. It has previously been suggested that metal awls originated in the EBA (Banks, 1967, 38), but recent evidence shows that they were known from the LN. Fifteen examples are presented here for the first time.

These tools were used in lapidary, woodwork and perhaps metalwork. They had bone prototypes and bone awls were persistently used alongside copper in the EBA. Due to their fairly close uniformity and universal distribution, it is difficult to trace the origin, development and perhaps diffusion of each type.

Classification of awls in the past has been rather arbitrary. Branigan (1974, 26-27) calls circular sectioned awls borers; square sectioned awls as punches. Tripathi (1976, 47) devised two types; those with a rounded butt and those with a square butt. Deshayes' classification was the most thorough. It was guided by the form of the point and its relationship to the shaft, by the presence or absence of a lug, with further sub-division based on the section of the shaft. His system produced numerous sub-types however. (Deshayes, 1960)

The figures show the geographical distribution of awls throughout the period Table 2.6.1 shows the up-to-date list of mainland awls.

Classification of the earliest Greek awls is as follows: the awls fall into two basic groups: square-sectioned and circular-sectioned. Next the presence of lugs or of evidence for the dual purpose of the tool enables us to distinguish sub-groups. A lug or stop was used to stop the fingers or haft slipping down the shaft of the tool. It is often difficult to establish clearly if the butt of the awl was thinned for hafting or

refined to a small spatula. The presence of a distinguishable middle section rib helps us recognise double function awls more easily.

The notation for classification is as follows:

Type I square/rectangular in section; plain

Type Ia" " ; double function

Type Ib" " ; with lug

Type II Circular section; plain

Type IIa " ; double function

Type IIb " ; with lug

2.6.1 TYPE Aw.1

square or rectangular section with thick rectangular butt and sharp point; often square/rectangular section smoothes to a rounded section near the point.

(Figure 2.6.2; 2.6.3)

Site	Length	Date	Fig.	Cat. no.
Kephala	5.0	LN	✓	22
Sitagroi	-	LN/EBA I	✓	448a
Petromagoula	6.5	EBA II	✓	358
Petromagoula	5.0	EBA II	✓	108
Petromagoula	6.24	EBA II	✓	250
Petromagoula	4.0	EBA II	✓	148
Lerna	5.05	EH II	✓	117
Eutresis	6.4	EH II	✓	225
Levkas	6.5	EH II	✓	355
Eutresis	7.8	EH II?	NA	226
Eutresis	6.2	EH II	NA	227
Lerna	2.3+	EH III	✓	98
Lerna	1.8+	EH III	✓	98
Petromagoula	3.8	EB II	✓	120

Site	Length	Date	Fig. no.	Cat. no.
Lerna	8.4	EH III	✓	97
Lerna	2.95+	EH III	✓	129
Lerna	3.2+	EH III	✓	129
Rachmani	-	EBA	NA	398

DISCUSSION

There are seventeen awls of this basic type. They are known throughout the period under study and are well-distributed throughout Greece.

The square/rectangular sectioned awl may have been the first form made commonly from copper because bone awls could so much more easily be worked into circular-sectioned tools. The square section was obviously used to make it easier to hold. The lug or stop was no doubt a development from this (see Aw. 1c). Deshayes (1960, 40) demonstrated that the circular-sectioned awl pre-dates the square/rectangular section, the former being known from the fourth and perhaps fifth millenium BC contexts. and the latter from fourth millenium BC contexts. The earliest examples in the Aegean come from Thermi (Lamb, 1936, 168, fig. 49, nos. 30.45, 31.50 and 30.53) and the Near East from Tepe Gawra in Mesopotamia (Speiser, 1935, II, 89); Sialk and Shah Tepe in Iran (Ghirshman, 1938-1939, I, 54, pl. lxxxiv, s 252) and Arne, (1945, 302-303, fig. 652, a) and Tabara el Akrad in Syria (AS, I, 1951, 144, fig. 12.1).

There is no reason to suggest importation of the earliest pieces, for although the finds from the sites of Sitagroi and Kephala demonstrated contact with neighbouring cultures, both sites had evidence for metalworking in LN contexts (McGeehan-Liritzis, 1983, 153). The EBA awls of this type could easily have been made in Greece and there is no evidence to the contrary.

TYPE Aw.1a

As type Aw.1 but with double function

Site	Length	Date	Fig.	Cat. no.
Sesklo	8.7	LN	✓	405
Petromagoula	8.26	EBA II	✓	90
Petromagoula	5.0	EBA II	✓	114
Petromagoula	6.8	EBA II	✓	121
Sitagroi		LN	✓	

DISCUSSION

There are four tools in this group. Three from Petromagoula, previously unpublished, and one from Sesklo, previously considered "MBA?". It is possible that the Rachmani awl belongs to this group.

The three awls from Petromagoula date to the EBA II. Fig. no 12 is the finest tool. It is now in a very fragile state. Its excessive slimness and very sharp point resembles a needle but the butt is like a very fine spatula. The remaining two examples from Petromagoula are unusual. They are square/rectangular in section and run to a sharp tip. Half way along the shaft the section becomes rounded. The butts are rounded and thinner. It appears that both ends of the tools were used.

The dating of the Sesklo awl to the LN is based on its typological similarity to other LN awls (especially those from Kephalaria on Kea, Coleman, 1977, 108). Deshayes classifies it as an awl type A2, though he does not suggest dual function.

The Rachmani awl was very poorly illustrated in Heurtley (1939, 43, fig. 27 b). Branigan classed it with the Sesklo awls (Branigan 1974; Tsountas 1908, 353, figs 4.4 and 4.5). It belongs to Deshayes' type A2 also. It verifies the continuity of the type.

This is a Thessalian type which lasts from the LN to EBA II.

TYPE Aw.1b

As type Aw.1 but with a lug or stop

Site	Length	Date	Fig.	Cat. no.
Sesklo	6.7	LN	✓	406
Sitagroi	-	LN	✓	448b
Lerna	11.5	EH II	✓	98
Lerna	8.5	EH II	✓	93
Lerna	6.45	EH II	✓	91
Zygouries	10.7	EH II	✓	182
Lerna	5.6	EH II	✓	92
Lerna	9.0	EH III	✓	96
Lerna	7.7	EH III	✓	99

DISCUSSION

There are nine examples of this type. These awls are almost identical. Some have sharper points than others, but basically they form a homogeneous group. They belong to Deshayes' awls type B1.

The earliest Aegean example comes from Thermi II (Lamb, 1936, 168. fig. 49, type 29.3) in the mid-third millennium BC, but the type is not common in the Cyclades or Crete until the second millennium BC. More examples are known from the west Aegean than the east Aegean in the third millennium BC. The two LN examples show that Greek examples pre-date the Troadic awls.

There is no strong evidence that the fourth millennium BC example from Iran, Sialk (Ghirshman, 1938-1939, I, 54 pl. lxxxiv, S 240) "influenced" the Greek or Troadic examples. It is in the later third millennium BC that we find examples appearing in Anatolia (at Alaca

Hüyük, Koşay, 1951, pl. 147, and 171, pl. ccv, fig.2); Cyprus (at Lapithos, Gjerstad **et al** 1934, 92 and 95); Crete (Hatzidakis, 1934, pl. lvi), Cilicia and Tarsus (Goldman, 1956, fig. 425) and Syria (at Tell Ahmar, Thureau-Dangin and Dunand 1936, 107, pl. xxix 4 and pl. xxx 5). It seems that the direction of "influence" was west-east and not east-west as Deshayes suggests.

Forming a "lug" or "stop" is such a practical step that independent development in the metal industries of the third millenium BC in the Aegean and the Near East seems the strongest possibility.

2.6.2. TYPE Aw. 2

Circular-sectioned stem; flat butt and sharp point.

(Figure 2.6.2; 2.6.3.)

Site	Length	Date	Fig.	Cat. no.
Kitsos	7.8	LN	✓	23a
Sitagroi	-	LN	✓	450
Sitagroi	-	LN/EBA I	✓	461
Sitagroi	-	LN/EBA I	✓	463
Mandalo	7.5	EBA I/III	✓	421a
Eutresis	7.8	EH II	✓	227

DISCUSSION

There are six examples of this type. They belong to the LN or the first half of the EBA. Only two of the examples come from southern Greece.

This type pre-dates square-sectioned awls in the Near East but are contemporary with the first Greek square-sectioned awls. Three of

the earliest examples, all from Sitagroi were unfortunately poorly preserved. Only small fragments of the original tools now remain. Analyses of these tools has told us a great deal about their manufacture (see 4.6).

The type is equivalent of Deshayes awls type A1 and Branigan's borers (Branigan 1974, 171). As with Deshayes' type A2, we have no evidence that the earlier Near Eastern awls from Sialk and Nineveh, (Ghirshman, 1938-1939, 16, pl. lii, 56 and AAA xx, 145, pl. lxviii, 5) influenced or encouraged the development of the Greek awls.

The earliest Aegean examples come from EBA I Thermi (Lamb, 1936, 175, 31.26), Emborio on Chios (Hood, 1981.) Kanli Kastelli and Phaistos on Crete (Branigan, 1968, 90, I, 9, 10) and Poliochni (Brea, 1964, pl. lxxxvii 1 and pl. lxxxviii 5, 5-16, 19, 29).

This type of awl was an Aegean type. The Sitagroi and Kitsos examples demonstrate that it was introduced in the LN or it developed in Greece independently. It appears in Greece and the Troad before it appears in the Cyclades.

Type IIb and IIc are not represented in LN/EBA Greece.

Two awls do not fall into any sub-type already given. They are both similar. A LN/EBA I circular-sectioned awl from Sitagroi and an EBA II square-sectioned awl from Petromagoula both have a specially prepared point, separated distinctly from the main stem of the tool by chipping or grinding away the metal to produce a small, sharp point. The haft or sleeve of the point is actually part of the tool. No doubt the point would be constantly resharpened.

Two types published resemble them. The first is Deshayes' awl type D2. (Deshayes, 1960). The second are his "forets", type C, in particular no. 197 from a third millennium BC site in India. This

parallel is not relevant, but type D2 awls, which are broadly similar, are known from Alaca Hüyük in the third millennium BC, though the type has an elaborate sleeve (Koşay, 1944, 101, pl.109, and 110).

The two Greek examples no doubt represent a practical, local development. This type of tool would have been used in fine work, for example piercing, repoussé and engraving.

The earliest Greek awls are representative of a local metal industry.

2.7. PINS

Over 75 pins are known from the mainland in the LN/EBA period. They are well-distributed throughout all Greece and are common in the LN and EBA. In the LN/EBA I, pins are found exclusively in northern Greece. In the second phase of the EBA and after, they are known predominately from south and central Greece. Table 2.7.1, Figures, 2.7.4.1.; 2.7.4.2.

Pins are classified typologically by the section of their stem, when they are without heads, and by the form of the pin head where it is present.

2.7.1. TYPE P 1

Plain shaft; no head; square or circular in section

Figure. 2.7.1.1.

Site	Date	Fig.	Cat. no.
Sitagroi	LN/EB I	✓	44Zb
Sitagroi	LN	✓	44Za
Kritsana	LN/EBA I	✓	420
Sitagroi	EBA I	✓	459
Lerna (16)	EH II	NA	102/4;106/19
Asine	EH II	✓	71
Levkas	EH II	✓	367
Sitagroi	EH II	✓	460
Lithares	EH II-III	NA	241b
Vardarophtsa	EBA	NA	468

Site	Date	Fig.	Cat. no.
Zygouries (6)	EH II	NA	189, 190/1, 192d/e 206
Rouf (6+)	EH II	NA	42- 46
Koropi	EH II	NA	24
Ay. Marina (Spetses)	EH II	NA	74-75
Strephi (3)	EH II	NA	165-167
Lepraion (Olympia)	EH II	NA	162
Lefkandi (1+)	EH II	NA	233a
Askitario	EH II	NA	3
Raphina (2+)	EH II	NA	33
Lerna (7)	EH III	NA	121, 123, 126, 127; 129/131
Vardina	EBA	✓	470
Servia	EBA	✓	446b
Korakou	EH	NA	82
Dikili Tash	EBA	NA	409
Manika	EH II-III	✓	274
Manika(2)	EH II-III	NA	276-277

DISCUSSION

The condition of pins or poorly published data does not permit sharp distinctions of types or sub-types. It is impossible to make any very significant interpretation of distribution of type except in the case of pins with heads.

Few pins are known in the LN. They all come from Sitagroi. The greatest numbers are known from the EH II.

Metal and bone pins were in use at the same time at many sites.

2.7.2 TYPE P 2

Plain shaft; generally heavier than type I pins;
square or circular in section; terminates in a clearly
articulated head, which assumes a variety of forms and
is generally considerably larger in diameter than the
diameter of the shaft. (Figure 2.7.2.1)

Type P.2a roll-up head / double spiral pin

TYPE P.2b hemispherical head; with/without collar(s)

TYPE P.2c conical and pyramidical head

TYPE P. 2d spherical head

TYPE P. 2e vase head

TYPE P. 2f multiple coil head

TYPE P. 2g toggle head

TYPE 2a

Spiral head formed by flattening the shaft
for a short length and then rolling it up
into a tight coil(s) (Figure 2.7.2.1.)

Site	Length	Date	No. of coils	Fig.	Cat.no.
Sitagroi	7.7	III/LN	1, 180 ⁰	✓	448
Sitagroi	2.5+	IV/EBA I	1, 90 ⁰ +	✓	449
Lerna	8.05	EH II	1, 360 ⁰	✓	124
Zygouries	11.2	EH	double	✓	192c

DISCUSSION

Only three example of this type are known from the mainland. The Sitagroi III example is the earliest, as it equates with the LN II in the Peloponnese and central Greece (Coleman, 1985; Sherratt, 1986). The Sitagroi IV example is contemporary with the earliest Troadic roll-up

pins from Troy I and Thermi I. Seventy -three examples are known from the Troad in the EBA I-III periods, with one example from Samos in the EBA (Milojčić, 1961, i, pl. 50, 6). The type is predominately Troadic in distribution, even though the earliest find of this type comes from Macedonia. In the LN Sitagroi had connections with both the Balkans and the Troad.

Banks (1967, 54) suggested that the technique of rolling up the head is perhaps related to Early Cycladic double spiral pin. Only one example of this type of pin is known from a Mainland context, from Zygouries. The earliest examples of this type in the Aegean come from EBA I Poliochni (Brea 1964 pl. clxxvii, 4) all others are EBA II and come from Troy (Schliemann, 1880, 104) Chalandriani (Bossert, 1967), Naxos (unpublished) and Zygouries (Blegen, 1928, xx). Higgins (1980, 50) suggested that the double spiral pins were a Middle Eastern form, known from Alaja (about 2000 BC), Tarsus (around 1900 - 1650 BC) and Tepe Hissar by the end of the Early Bronze Age. The double spiral pin did not provide the prototype for the roll-up pin, which appeared before it and from the EBA I the two types coexisted in the Troad. Further north-west Anatolian examples of the double spiral pins predate the Middle Eastern examples by almost a millenium.

Catling (1964, 238) suggested that as the roll-up pins are fairly well distributed in Cyprus, the east Mediterranean and the Near East in the LBA, a Near Eastern origin can be assumed. However the type is first seen in Sitagroi III and this type of pin no doubt provided the prototype for the double spiral pins.

The roll-headed pin has a particularly limited distribution up to the end of the EBA II. The Lerna example is contemporary with the latest examples from Troy. No MBA examples are known. It is only at the end of the EBA that we see the type outside its "homeland" and one would wonder if there is any connection between its appearance in EH III Lerna and the distribution of Troadic Minyan - in other words the disturbances of the EH II/III period.

TYPE P 2b

hemispherical head, sometimes rather flattened

(Figure 2.7.2.1.)

Site	Length	Date	Diam. of head	Fig	Cat no
Zygouries	7.4	EH II	1.4	✓	205
Zygouries		EH II		NA	192b

DISCUSSION

There are only two examples of this type known from the mainland. The type clearly belongs to north west Anatolia, where the earliest examples date to Troy I (Blegen et al, 1950, 215, 34-502) and Thermi I (Lamb, 1936 fig 48). Two of the pins from Troy are made of gold. Only two examples from Poliochni (Brea 1964, pl. clxxvi, 5,8,13, and lxxxvii,7) one from Samos (Milojcic, 1961) and two from Zygouries are known outside Troy and Thermi. The mainland pins are either imports or chance products of the EH industry. They are most probably imports.

TYPE P 2c

Conical or pyramidal head (Figure 2.7.2.1.)

Site	Length	Date	Head	Fig.	Cat. no.
Zygouries	10.3	EH II	triangular/ pointed	✓	192a
Lerna	5.55	EH II	convexo/ conical	✓	128
Asine	10.0	EH II	rounded profile	✓	70
Lerna	7.6	EH III	pyramidal	✓	128

DISCUSSION

There are three pins of this type known from the mainland. There may have been another from Zygouries. The distribution is strictly limited to the Argolid in the EH II. The heads of the pins vary slightly. A MBA

example, almost identical to the Lerna example is known from Lerna V (Banks, 1967, no. 58, 54) which shows that it continues into the MBA.

Branigan (1974, 36) classes this as pin type VI, the distribution for which is predominately Troadic. The earliest examples are known from EBA I Poliochni (Brea 1964, pl. lxxvii, 2,3,5,6) and Thermi (Lamb, 1936, 176, 31.59), and then in the later EB II levels from Troy (Schliemann, 1880, 928-9), Poliochni (Brea, 1964, pl. clxxv, 6) and Thermi (Lamb, 1936, 176, 32.30). with one EC II example from Chalandriani (Bossert, 1967).

Banks (1967, 54) suggested that the Raphina "arrowhead" could represent this type (our cat. no. 30). Its head certainly is pyramidical, but it is rather heavy and thick for a pin.

The mainland examples of this type appear to be imports from north west Anatolia.

TYPE P2d

Spherical head (Figure 2.7.2.1)

Site	Length	Date	Diam head	Fig	Cat no
Zygouries	8.7	EH II	0.7	✓	186
Lerna	9.0	EH II		✓	105
Manika		EH II-III		✓	273
Asine	-	EH II		✓	72
Manika		EH II-III		✓	275

DISCUSSION

There are six examples of this type known from the mainland. Only one example, which is poorly provenanced and labelled simply "Greece" can be added to this list (Branigan, 1974, no. 1708). As all mainland examples are EH II and the type is not known on the mainland or in the Aegean in the MBA, this example is most probably EH in date.

The earliest examples come from Troy I and Thermi I (Blegen, et al, 1950, 358)

and Lamb.(1936, 174,3056) and it is common in EBA II levels at Troy Poliochni and Thermi (Branigan, 1974, 34, 180). Gold examples are known from Troy (Schliemann, 1880, 65) and silver examples are known from Chalandriani (Tsountas, 1899, pl. 10, 11) Greece (Higgins, 1961,52) and Troy(Schmidt, 1902, 6140).

Higgins (1980, 50) mentions an unpublished silver example from Naxos and suggests that the type could well derive from a type found at Alaja. This example succeeds the earlier north west Anatolian examples, however.

It is again interesting to note how local the distribution of the mainland examples is. All dated examples are from the Argolid.

The silver examples pose an interesting question - was the silver used to produce them obtained from the north Cyclades?(see 4.4)

TYPE P 2e

The vase/jug head of the pin is an extension of the stem. Broad convex constriction separates the top of the shaft from low convex and usually conical head. (Figure 2.7.2.1)

Site	Length	Date	Fig.	Cat. no.
Lerna	3.6+	EH III	✓	123
(Thyreatis(Au)	-	-	NA)	

DISCUSSION

There is only one complete example of this pin from the mainland. A gold miniature jug from the Thyreatis hoard looks as if it once formed the head of a similar pin (Higgins, 1980, 51).

Banks (1967, 50-51) remarked that the "bulge" recalls the toggle. The head of the toggle pin (Banks, 1967, no. 71, our cat no.138) is somewhat hemispherical.

There are several parallels for this type in the Aegean. The heads are

slightly different, but it is clear that they belong to the same basic type.

Branigan (1974, 37) classed this type in his type XIIIa. Almost all the examples belong to the EBA II. No MBA examples are known. The Thyreatis example is most probably mid EBA in date.

Gold, silver and copper/bronze were used to make these pins, though copper/bronze was rare (only one example from Chalandriani, Tsountas (1898) and one from Lerna). An unpublished example from Amorgos mentioned by Higgins (1980, 51) is made of silver. Other silver examples occur exclusively in the Cyclades (Naxos, Chalandriani and Amorgos). The gold example from Thyreatis is unusual in that so little gold is known so far south (see 6.4.). All the Trojan examples are made of gold.

There is no evidence, other than the fact that most EBA pins are of Troadic origin, that these particular pins originated in the Troad. It could be that the Cycladic islanders developed their own type in silver, the Troad in gold. This should be considered an Aegean type which reached the mainland only at the end of the EBA. The fact that the Lerna example was made copper suggests that it was a local copy of an imported type as much jewellery was made of copper in southern Greece, (see 6.5.)

TYPE P 2f

A series of find interlocking coils, built-up like a bunch of bananas on the top of the stem (Figure 2.7.2.1.)

Site	Length	Date	Fig.	Cat. no.
Lerna	6.9	EH II	NA	118

DISCUSSION

There is only one example of this type from the mainland. It was

found in three parts. Banks (1967, 43) confirms that the head was once a nest of loops, comprising a widely expanded and irregular triple coil and a single semi-circular loop.

The closest parallel for this are the three copper/bronze examples from Chalandriani (Tsountas, 1898, pl. 10, 18/21 and 101). It is not a known Troadic or Anatolian type where loops are always bent back around the shaft to form a knotted terminal. That type is popular from Troy (Blegen, 1951, 357) and Cyprus (Catling, 1964, pl. 6 no. 7).

TYPE P 2g

bulge at the top end of the shaft, just below convex conical head; longitudinal eyelet in bulge. (Figure 2.7.2.1.)

Site	L	Date	Fig.	Cat. no.
Lerna	9.1	EH III	✓	138

DISCUSSION

Banks (1967, 57) said that there are no parallels available in the surveyed material. Tripathi (1976, 59) agreed that this was the first example in the Aegean, but Branigan discusses Aegean toggle pins which date from the EBA II-III (Branigan, 1974, 36, 181). The Cypriot examples which Catling (1964, 72-73) described provide the closest contemporary parallels.

The Lerna example is not the earliest in the Aegean. Although no exact parallels are known, and no two toggle pins are identical, the more slender examples from Cyprus (Catling, 1964, 72 and fig. 6 nos. 3 and 6) are the closest.

The type is obviously a later third millennium BC development. They are either first made, or else introduced into the area as a whole, in the

in the EBA II-III, most probably EBA III. Perhaps a Balkan origin should be sought. The type appears after the disruptive phase in the mid-third millenium BC.

Banks (1967, 57) suggested that these pins could have had some function in the production of yarn or thread, as they were found with other artefacts used for this purpose. Catling (1964, 73) said that it was difficult to believe that the heavier varieties would have been used as dress fasteners as they were difficult to use and to wear. However, as many had decorated shafts they were probably worn rather than used in textile work. Perhaps they were used for heavier material garments or leather wear.

2.8 TWEEZERS

Tweezers, used for depilatory and cosmetic purposes, first become common in the EBA II Aegean. While no two pieces are identical, the tweezers fall into two basic types. Type T.1 has a plain open spring and Type T.2 has a pinched spring. The width of the arm at the tip varies and so provides two further simple sub-divisions, (a) arms of the same width; (b) splayed arms. Table 2.8.1.

Tweezers were used from the third millenium BC in Egypt also (Petrie, 1901, vol. ii, 36, pl. xlii, 15) and in the First Dynasty at Abydos and Ur (Woolley, 1934, 1936, II, 310, pl. 231.3). There is no evidence that the more eastern examples were earlier than the Aegean ones.

2.8.1 TYPE T 1

TYPE T 1a plain spring, arms same width

TYPE T 1b pinched spring, splayed tip

(Figure 2.8.1.1.; 2.8.3.1; 2.8.3.2)

Site	Length	Date	Ia/b	Fig.	Cat. no.
Ay. Kosmas	7.1	EH II	a	✓	13
Ay. Kosmas	4.6	EH II	b	✓	14
Ay. Kosmas	4.1+	EH II	b	✓	15
Eutresis	c7.1	EH II	a	✓	231
Ay. Kosmas	-	EH II	a(frag)	NA	15b
Thebes	7.0	EH II	b	✓	254
Manika	NA	EH II/III	a	✓	267
Manika	NA	EH II/III	a	✓	268
Manika	NA	EH II/III	a	✓	269
Manika	NA	EH II/III	a	✓	270
Ay. Stephanos	8.0+	EH ?	b	✓	76
Asine	8.0+	EH ?	b	✓	73a
Eutresis	7.8	EH II	?	NA	233
Asine	10.0	EH II	a	✓	73b
Thebes	NA	EH	b	NA	255

DISCUSSION

There are thirteen well-dated examples of this basic type. The narrow and splayed arms appear at the same time and we should presume that they were perhaps intended for a slightly different purpose. There are as many narrow as splayed arm tweezers.

Type T 1a has only one example in silver and this comes from Manika. Surprisingly the Siphnos example is made of copper as Siphnos is known in the EC II for its silver production (Gale and Stos-Gale, 1982). The earliest examples of type T.1a+b come from the mainland, Troy and Crete in the EBA II. Its distribution is predominately Cretan. Both Type T1a

Ib are known from Aghios Kosmas. The type is well-established in MH Greece and becomes the standard Aegean type of the LBA. All of the examples known then are of copper or bronze.

Thus, Type T 1 tweezers appear to be Cretan or Helladic in origin.

2.8.2 TYPE T 2

TYPE T 2a pinched spring, arms same width

TYPE T 2b pinched spring, splayed arms

(Figures 2.8.2.1; 2.8.3.1 and 2.8.3.2)

Site	Length	Date	2a/b	Fig.	Cat no.
Lerna	8.55	EH II	b	✓	140
Zygouries	7.3	EH II	a	✓	204
Rouf	6.34	EH II	a	✓	39
Eutresis	7.8	EH II	a	✓	232
Lerna		EH II		NA	141

DISCUSSION

There are fewer examples of this type than of Type 1 (a or b). Their distribution is much more limited. However, more examples are known from the mainland than from the rest of the Aegean. One example is known from Crete (Mochlos, Seager, 1912), one from Troy (Blegen, 1950), one from Chalandriani (Tsountas, 1899, 10.42) and Amorgos (Tsountas, 1898, 12.4). All examples except that from Troy are made of copper/bronze. The Trojan example is made of silver.

Banks (1967, 86/82) classed the two Lerna examples in her "unidentified objects" group. Tripathi (1976, 249) suggested that they were scrapers. Banks (1967) noted that there were no parallels, but that the closest artefact were tweezers, such as our type T 2a. These two artefacts could therefore represent broken tweezers.

The example from Rouf has not been fully published before. It is very similar to Type T 1b tweezers found at Aghios Kosmas except that it had a pinched spring. This implement is being analysed, (no. 39)

There are more Type T 2 (a and b) tweezers on the mainland than there are in the Aegean. For example, only one other type 2b tweezer is known from the Aegean. It comes from Platanos in Crete (Branigan, 1968, 92, III, 1).

Type T 2 tweezers therefore seem to be Helladic in origin.

2.9 RAZORS

Weak blade scraping tools have been called "scrapers", "razors", "spatulae" and "trowels". The term razor applies to an implement for personal toilet. The other terms are no doubt tools used for example in the preparation of animal skins. It is difficult to establish a dividing line between these two functions. Perhaps there is no dividing line. Whether they were used to shave or to scrape, their form gives us some insight into cross-cultural relations in the third millenium BC Aegean.

Altogether 13 razors are known from the mainland. Three razors are included in this study for the first time. None of them appear in the mainland before the EBA II.

Bone and wooden scrapers and razors were used in the east and west Aegean in the Neolithic (Deshayes, 1960, I, 369). Bone types have been found alongside their metal counterparts. It is peculiar that no metal razors are known in Anatolia, where bone razors persisted.

Razors form a fairly homogeneous group. No two are identical however. Tripathi (1976, 52) said that they all have straight butts, but this is not so.

They fall into three basic categories, based on the overall shape of the blade and the method of hafting employed.

2.9.1 TYPE R 1

Square/rectangular blade, with rivet holes (Fig. 2.9.1.1., 2.9.4.1./2)

Site	Length	Date	Rivets	Fig.	Cat. no.
Zygouries	5.0	EH II	2	✓	185
Zygouries	4.7	EH II?	2	✓	205a
Levkas	3.5+	EH II	3	✓	363
Levkas	3.3+	EH II	2	✓	364
Manika	-	EH II/III	3	✓	282
Manika	-	EH II/III	3?	NA	302

DISCUSSION

There are six razors of this type, two of which which have not been included in any previous typological study (Manika).

The blades are simple, and square/rectangular with most probably a convex cutting edge. They were hafted and the number and position of the rivet holes has often been used to further sub-divide the groups.

The example from Zygouries has been considered rather rare because its two rivets are placed longitudinally, nearer and parallel to one edge of the blade. Branigan's illustration does not show the position of the rivets clearly (Branigan, 1974, pl. 17, no. 1365). This particular blade most probably had three rivets, not two, as is apparent when the corroded butt is examined. This riveting system is not unique on the mainland, as previously thought, because two silver razors from Manika provide almost exact parallels. The Levkas example discussed below also had three rivets, but they were arranged in a different way. The excavator at Manika said that both were identical, but only one drawing is given (Sampson, 1985, 316). The Manika blade closely resembles the example from Zygouries, except that the rivets are placed closer together. The similarity between them confirms

Tripathi's (1976, 52) opinion that the warping of the Zygouries razor was accidental and not intentional, as Blegen (1928, 182) suggests. Blegen also compared the "spoon-like" feature of the Zygouries blade with spatulae from the Cyclades which Tsountas (1899, pl. x, nos. 30-34) discusses. The Cycladic spatulae have different forms and rivet arrangements.

Outside the mainland, eight similar razors with rivets set longitudinally are known from EM II-EM III Platanos (Xanthoudides, 1924, 108, pl. lvi). The mainland and Cretan examples were contemporary, though more examples are known from Crete. Manika possesses the only known silver razors.

The razor from Levkas has been considered unique, because of the number and arrangement of the rivets. Within the Aegean, the closest parallel for this rivet arrangement comes from contemporary Mochlos, Crete (Branigan, 1968, 93, Ic, 1). Two other razors from Crete: Aghia Triada (Monumenti Antichi, 141, 705, fig. 15) and Platanos (Branigan, 1968, 96, I,3) have similar arrangements. The closest parallels in both blade form and rivet arrangement comes from an undated context on Syros (Tsountas, 1899, 102-103, pl. x, 33, 34) and Koumasa (Xanthoudides, 1924, 28). As the cutting edge tends to be missing, it is not possible to comment more on their form.

The remaining razors in this set come from Levkas (fig. 4) and Zygouries (fig. 2). Their rivet arrangement is transversal to the cutting edge. The type is very common in Crete, though mainland examples have more parallel sides.

The razors of our type R 1 are contemporary in both the mainland and Crete. Most of the known examples do come from Crete and only a few are known from the Cyclades. The use of metal razors starts in all three areas of the Aegean in the EBA II. What distinguishes the mainland from the Cretan examples is the straightness of the blades and there is no reason to accept them as other than local developments.

2.9.2.1. TYPE R 2

Blade shaped; tanged; sloping shoulders;
no rivets

(Figure 2.9.2.1. 2.9.4.1; 2.9.4.2.)

Site	Length	Date	Tang	Fig.	Cat. no.
Eutresis	8.4	EH II	broad	✓	229
Petromagoula	4.8	EB II	narrow	✓	392
Petromagoula	6.1	EB II	medium	✓	393
Lepraion	-	EH II	narrow	NA	161

DISCUSSION

All these razors resemble dagger or knife blades. They have been classed as razors because of the marked thinness of the blades. The examples from Petromagoula have not been published before. The example from Lepraion is being published by C. Zachos (1987, pers comm).

French (1968) believed that the Eutresis razor resembled an Anatolian dagger form. Indeed it closely resembles our weapon type W.4 which is characteristically north west Anatolian in form. It is often difficult to assess what these blades were used for - shaving/scraping or as small blade tools. Both the weapons type W. 4 and the razors of this type (except for the Lepraion example) are distributed in the central region of the mainland. The Petromagoula finds further support the possibility that southern Thessaly was included in the Early Helladic sphere of activities.

Parallels for these blades are not very clear. A similar blade from a Lapithos tomb on Cyprus, dating to the Early Cypriot IIIb, is very similar, though more advanced in form (Catling, 1964, 67, fig. 5.4). An EBA parallel is also known from Tarsus (Goldman, 1956, II, 282, fig. 432-16) and an undated parallel, roughly similar, is known from Byblos (Dunand, 1937-1939, II, 413, fig. 452, no. 11031).

Broadly similar Cretan parallels cannot be dated with more resolution than EM II/MM II (Branigan, 1968, 96, IIa) though an EC II parallel is known from Chalandriani (Bossert, 1967, fig. 2.1).

Whilst it was possible to argue that the single example of this type from Eutresis represented a foreign import, the new finds suggest that the type may be local. Lead isotope analyses of the material from Petromagoula demonstrates that local mainland copper was no doubt used (see 4.5). There are as many examples of this type in the mainland in the EBA II than elsewhere in the Aegean. The resemblance between the razor and the weapon type W 4 may be fortuitous as no weapons are known from the sites which had razors of this form.

2.9.3.1. TYPE R 3

Long narrow blade; long thin tang

(Figure 2.9.3.1; 2.9.4.2; 2.9.4.2)

Site	Length	Date	Tang	Fig.	Cat. no.
Lerna	c.8.3	EH III	thin, wire twisted		144
Lerna	12.5	EH II	long, thin		142
Eutresis	4.0	EH II	finely twisted	NA	220

DISCUSSION

It is difficult to find parallels for this type of razor. Like R.2 they could represent copies of tanged dagger prototypes. The twisted tang on the Eutresis and Lerna examples is a rare feature, but is known from spatulae from Byblos (Dunand, 1937-1939, II, 260, pl. clxxx, no. 9240) in undated contexts and from the end of the Bronze Age in Cyprus (Schaeffer, 1952, 29, pl. lxiv, 8). The technique is otherwise unknown in Greece, apart

from the small aurian silver ring from Sesklo (see 4.7 analysis number 65).

Evidence suggests that this type of razor was a local type.

2.10.1. NEEDLES

As it is not possible to distinguish between sub-types of needles, they will all be discussed in one group. They are made of thin, circular wire which has been either pierced at the top to form an eye or bent back at the butt and beaten to form a neat eye loop.

TYPE N 1

Circular sectioned wire; tapering at one end to a long fine point; eyelet at blunt end.

(Figure 2.10.2.1 and 2,10.2.2)

Site	Length	Date	Eyelet	Fig.	Cat. no.
Corinth	14.2	EH II	pierced	✓	79
Corinth	10.5+	EH II	pierced	✓	80
Rouf	2.7+	EH II	pierced	✓	49
Rouf	11.7+	EH II	pierced	✓	40
Lerna	7.35	LN/EH II	pierced	✓	132
Lerna	10.8	EH II	loop	✓	133
Lerna	7.3	EH II	loop	✓	134
Lerna	8.1+	EH II	loop	✓	135
Lerna	10.2+	EH II	loop	✓	136
Lerna	11.1	EH II	loop	✓	137
Levkas	7.2+	EH II	pierced	NA	361
Levkas	6.1+	EH II	pierced	NA	362
Tiryns	-	EH II	-	NA	172
Zygouries		EH II		NA	208b

DISCUSSION

All needles are considered here as one type even though the eyelet was formed in two different ways. As all the needles come from EH II contexts, it is most likely that the LN/EH II Lerna example is also EH II. Loop eyelets come exclusively from Lerna and represent a particularly local type. The needles are distributed in southern Greece and Levkas.

Bone needles no doubt provided the prototypes. Copper needles appear simultaneously in the Cyclades, Crete and the mainland. The earliest Aegean example may be a LN example from Emborio on Chios (Hood, 1981), and two or three from the Troad dating to Thermi I, Troy I and contemporary Poliochni (Lamb, 1936, 175, 31.48; Schliemann, 1880, 108; Blegen, 1950, 43, 36-417, 8; Brea, 1964, 20-3, 26). There is no support for the view expressed by Banks (1967, 60) that the Lerna needles come from the Cyclades. Bone needles were used in southern Greece and the change to copper-based needles was not universal. Bone forms persist alongside the copper forms. Although several copper needles are known in the Cyclades (for example, Tsountas, 1899, 102, pl. 10.20) they are only proportionately greater in number than on the mainland. This form is one which the mainland and the Cyclades share in common.

Needles would have been used for mending fishing nets and cloth, lapidary, and textile work, all specialised trades in the increasingly complex society of the later third millennium BC on the mainland. The large number from Lerna suggests a specialised industry at this site, though the needles themselves were not found in consistent association with any specific work area.

No needles are known from EH III or MH contexts. They likewise fall into disuse in the Cyclades after the EC II period, though they are still known in the Troad and Crete after the EBA II, even though much more rarely.

2.11.1. HOOKS

Copper hooks were used for fishing and hanging and fall into two distinct categories, based on their size. The smaller hooks are called fish hooks, though they may have been used for a variety of purposes. The larger hooks were used for hanging meat or greater weights. They were all formed from copper wire, beaten into circular or V-shaped hooks. One end was usually pointed and the other suitably shaped for attachment or simply left plain.

2.11.1.1 HOOKS TYPE H.1 (FISH-HOOKS)

Circular or square sectioned wire, bent to form a hook; tip sharpened to point; with or without barb; with or without loop for butt
(Figure 2.11.1.1; 2.11.2.2)

Site	Length	Date	Butt	Fig.	Cat. no.
Raphina	7.7	EH II	straight	✓	28
Raphina	4.5	EH II	straight	✓	29
Eutresis	5.8	EH II?	straight	✓	228
Eutresis	5.5	EH II	straight	✓	230
Levkas	4.0	EH II	straight	✓	357
Levkas	2.9	EH II	straight	✓	358
Lerna	NA	EH II	-	NA	152
Strephi	NA	EH II	-	NA	167a
Petromagoula	7.2	EB II	loop	✓	388

DISCUSSION

Fish hooks are most common in the Cyclades and the mainland, but are absent from Crete and Cyprus. The simple bent wire is a practical tool.

The fish-hooks date to the EH II and are distributed in southern Greece where the majority of sites were coastal in this period (see 8.2). Fishing was no doubt an important part of the economy (see Ch.7).

No double raised rings or barbs are known on mainland fish-hooks, even though this form of attachment is known from Troy (Schliemann, 1880, 937) and the Cyclades (Syros: Tsountas 1899, pl x, 39; Samos: Milošević, 1961, pl. 50, 8,9) and later from Crete. The most common Aegean form was that known from the mainland and there is no reason to assume that these hooks were not local developments to suit local needs.

The looped fish-hook from Petromagoula is unique in that this form of attachment is not known in the Aegean in this period. It comes from a coastal site.

2.11.1.2. HOOKS TYPE H.1 (FLESH HOOKS)

Thick wire; single or double hook

(Figure 2.11.1.2; 2.11.2.2)

Site	Length	Date	Fig.	Cat. no.
Levkas	12.8	EH II	✓	359
Levkas	13.0	EH II	✓	360

DISCUSSION

These hooks are called flesh-hooks because they resemble butchers hooks today, although Dörpfeld (1927, 237) had suggested that no. 359 was a double needle.

Circular wire is bent at each end to produce an effective hook which is sharpened to a point and capable of holding heavy weights.

Parallels, though not identical, are known from EB II contexts

in the Troad (Poliochni; Brea, 1964, pl. clxxv,2; Troy: Schmidt, 1902, 6445) and possibly Crete (Mallia). They are so rare that it is not possible to suggest imports from one area to another; nor can a strong enough case for local development be put forward in the absence of many finds. The most probable explanation for this type is that it represents an adaption of to smaller hook to carry greater weights This adaptation took place on Levkas alone.

2.12. JEWELLERY, WIRE AND SHEET

The evidence for jewellery comes from a handful of sites in the EBA, for example Thebes, Levkas, Zygouries, Thyreatis and Asine.

This brief study will review the use of both copper and precious metals for jewellery from the Late Neolithic to the end of the Early Bronze Age.

The jewellery is divided into several basic groups: beads; rings and pendants; bangles; wire and sheet. Many jewellery forms have stone prototypes and these help assess the prehistory of certain types. There has been a tendency to ignore LN finds even though they provide helpful data on the origins of several EBA types.

Mainland jewellery has Balkan, west Asiatic and Cretan parallels and shares much in common with the Cycladic repertoire.

The distribution of jewellery made from precious metals (gold and silver) tells much about the distribution of sources, and where no sources exist, about the supply routes and external contacts of the communities involved. For example, silver is common in the Cyclades and northern Crete; gold in the Troad, northern Greece and southern Crete; gold and silver in central and south west Greece. The relative distribution of different metals and different artefact types is further discussed in 6.4 and 6.5.

2.12.1. BEADS

Gold beads are known on the mainland from the Middle Neolithic (Dimitra site); gold, silver and copper beads from the Late Neolithic and gold and copper beads in the Early Bronze Age. The relative use of gold, silver and copper for jewellery indicate the scarcity or abundance of these materials in the various areas of the mainland. Figure 2.12.1.1. shows that beads are relatively rare on the mainland and they are distributed in three discreet areas: 1) the Plain of Drama; 2) Ionian islands and 3) south east Peloponnese. In the first area, gold and copper are used for beads from the MN. All metals were necessarily imported into Levkas and other Ionian islands and silver is the premoninant precious metal in southern Greece. The lack of beads in central and parts of southern Greece may be due to the use of precious stones, although there is no strong evidence for this.

Most beads had to be perforated in order to be threaded and worn - usually in sets as a necklace. Metallographic analyses of some beads from Sitagroi (Slater, 1972, Appendix 1) provided data on the manufacture of simple copper beads. The examples studied were both hot and cold worked, hammered and annealed. There is no evidence that gold was melted for beads which were formed by hammering, not casting. Copper beads could have been made from native or smelted copper, but silver beads would all have been made from cupelled silver (see 4.2).

Except for those groups of beads found in necklaces or necklace arrangements, there is little homogeneity in type. Many beads are poorly illustrated or described and this makes it difficult to assess them typologically. So many beads are of simple, basic design that one should be wary of attaching too much significance to typological similarities. Basically there are five types:

- Type 1 solid, perforated tube-like beads
- Type 2 solid, perforated circular beads
- Type 3 washer-like beads
- Type 4 hexagonal beads
- Type 5 spiral wire beads

TYPE B.1

(Figure 2.12.1.1)

Site	Date	Metal	No.	Fig.	Cat. no.
Dimitra	MN	Cu	several	✓	418b
Sitagroi II	LN	Cu	1	NA	447a
Sitagroi III	LN/EB I	Cu	1	NA	456
Sitagroi III	LN/EB I	Au	1	NA	455
Sitagroi III	LN/EB I	Cu	3	NA	465, 458
Alepotrypa	LN	Ag	1	✓	62
Alepotrypa	LN	Ag	1	NA	63
Alepotrypa	LN	Ag	1	NA	64
Alepotrypa	LN	Ag	1	NA	65
Dikili Tash	EBA	Au	1	✓	410
(Thyreatis	?	Au	6	NA	171b)

DISCUSSION

This basic shape of bead is known from the LN until the EBA. It copies simple stone bead shapes and is known in the Neolithic of the Balkans and the Mainland. This type of copper bead remains quite rare in Crete where the preference for stone and gem necklaces prevails into the MBA.

The earliest beads from southern Greece come from Alepotrypa and are made of cupelled silver. These finds are somewhat enigmatic as silver-working did not otherwise start in the Aegean until the EBA II (see 4.3). Similarly, the finds from Thyreatis, which have not been well-dated, represent an uncharacteristic hoard of gold objects in a region which otherwise makes little use of gold in the EBA.

This type of bead is so simple that it tells us little about contacts between the prehistoric communities of the Aegean.

TYPE B.2

(Figure 2.12.1.1)

Site	Date	Metal	No.	Fig.	Cat. no.
Dimitra	LN	Au	several	NA	412
Levkas	EH II	Au	85	✓	325, 328
Pelikati	EHII/III M	Au	2	✓	370

DISCUSSION

These beads are mainly EH II/III and have a very discreet distribution in the Ionian islands - except for the Dimitra finds which are contemporary. There is no reason to see the two sets as related though it is curious that the form persists exclusively in gold in the mainland. Aegean examples from Troy and Crete are similarly of gold, though one EM example from Palaikastro is known to be made of lead (BSA, 9, 343). Most of the examples of the type and some of the earliest examples come from the mainland and this seems to support the view that this type of bead was a mainland type. As a result, the gold used to make them probably came from a mainland source, the main sources for gold being in northern Greece, quite close to Dimitra, (see Ch. 3).

TYPE B.3

(Figure 2.12.1.1)

Site	Date	Metal	No.	Fig.	Cat. no.
Sitagroi	LN	Cu	1	NA	447a
Alepotrypa	LN	Ag	123	✓	61

DISCUSSION

This shape of bead is carefully formed from flattened, rectangular wire. The necklace from Alepotrypa suggests that the Sitagroi bead may once have formed part of a necklace. They are too small to have been worn on their own.

The Alepotrypa beads are apparently a mix between the Louros and Mochlos beads, both from necklaces; the former of silver and the latter of gold. (Seager, 1912, fig. 6, 1m; Arch. Delt. 17a, pl. 67). They represent a type established in the Aegean in the EBA II which persists into the MBA. They are made in gold, silver and copper. If the Alepotrypa finds are indeed LN (see 6.2, Appendix) then they represent the first silver examples and together with the find from Sitagroi clearly represent the beginning of the tradition. Such necklaces or beads are not well known outside the Aegean and only reach Cyprus just before the Middle Cypriot I ^{period,} (Catling, 1964, 74-75).

TYPE B.4

(Figure 2.12.1.1)

Site	Date	Metal	No	Fig.	Cat. no.
Levkas	EH II	Au	18	✓	326
Levkas	EH II	Au	34	NA	325
Levkas	EH II	Au	41	NA	327
Levkas	EH II	Au	74	NA	328

DISCUSSION

These beads are very numerous and are known from Levkas only, on the mainland. Several are reported from Thyreatis, in gold, but they are of uncertain date (Higgins, 1980). They are also known in gold from Crete, from Aghios Onouphrios (Evans, 1895, fig. 89), Mochlos (Seager, 1912, fig. 25, 27) and from Troy IIg (Schliemann, 1880, 825-6). They continue in use until the MH and are seen at Sesklo, where they are made of sheet copper (Tsountas, 1908). Of the 107 known, 93 are from Levkas. The concentration in these graves suggests a local monopoly and indeed a local type. They are all in gold.

TYPE B.5

(Figure 2.12.1.1)

Site	Date	Metal	No.	Fig.	Cat. no.
(Thyreatis	EH?	Au	63)	✓	-

DISCUSSION

The beads composed on concentric hoops of wire with eyes at two opposing points in the circumference to allow for a cord are only known from Thyreatis. They are all in gold. Because this hoard cannot be securely dated, they do not quite qualify as EH jewellery items. However, of the 2000 plus examples known, all are EBA II in date, being known from Poliochni and Troy as well as Mochlos in Crete (Seager, 1912, fig. 6). It is quite possible that the Thyreatis hoard is Early Helladic.

2.12.2. RINGS AND PENDANTS

Rings for the ear, hair or finger cannot be effectively distinguished from one another. Often location in a grave setting does suggest what use the ring was put to. These simple coils of circular sectioned wire

are classed into the following types: Rings Type 1; Earrings Types 2 and 3 and Pendants Type 4 and 5.

TYPE R.1

Circular sectioned coil of copper or gold; often overlapping terminals; no other specific feature; one or two coils.

(Figure 2.12.2.1)

Site	Date	Material	No.	Fig.	Cat. no.
Dimitra	LN	Au	1	✓	415a
Zygouries	EH II?	Au	3	✓	200
Pelikati	EH II/III	Cu	1	✓	369
Lerna	LN/EH II	Cu	1	✓	145
Lerna	EH III	Cu	1	✓	148
Saratse	EBA	Au	1	✓	445
Zygouries	EH?	Cu	1	✓	203
Levkas	EH II?	Au	2 x 3	✓	334-335
Levkas	EH?	Au	1 x 3	✓	330-333
Asine	EH?	Cu	1	✓	70a

DISCUSSION

The smaller varieties of these rings would have been used to ornament the finger and the ear while the larger size, often strung together in a chain, would have been used as hair braids or necklaces. One could introduce a scale based on the diameter of the rings, but this would be arbitrary as there is no real way of knowing how the rings were used. Suffice to say that they were employed for personal decoration, most often female. It has been suggested that single earrings may have been common practice

in this period, as single earrings are found in graves (Higgins, 1980, 49).

This type of ring is known from northern to southern Greece, from the LN to the EBA and appears in both gold and copper. It is not known in silver.

Other simple rings of this type are known throughout the Aegean. Most date to EBA II. Little typological information can be gained from such a simple design.

TYPE R.2

(Figure 2.12.2.1)

Site	Date	Material	No.	Fig.	Cat. no.
Syvres	EH II	Cu	1	✓	376
Syvres	EH II	Cu	1	✓	377

DISCUSSION

No close parallels are known for these two ellipsoidal olive-shaped beads which are made from a sheet of copper, doubled over and rolled. They are undoubtedly local types, quite distinct from those found in the nearby graves at Nidri. They were no doubt necklace beads or earrings.

TYPE R.3

(Figure 2.12.2.1)

Site	Date	Material	No.	Fig.	Cat. no.
Syvres	EH II	Cu	1	✓	375

DISCUSSION

This single ellipsoidal earring with a bevel edge is similar in general design to the rings type R.1 from Levkas (see above) but it has a marked

rhomboidal section which distinguishes it. No exact parallels are known. The bangles in silver from Nidri often have a similar design though they are usually more circular in section. This earring appears to be a local Levkas development.

TYPE R.4

(Figure 2.12.2.1)

Site	Date	Material	No.	Fig.	Cat. no.
Sesklo	LN	Au	1	✓	404
Dimini	LN	Cu	1	✓	379
Alepotrypa	LN	Ag	1	✓	60
Dimitra	LN	Au	2	✓	414
Zygouries	EH ?	Au	1	✓	199
Lerna	EH III	Cu	1	✓	149

DISCUSSION

These pendants closely resemble Balkan stone and bone prototypes and are widespread throughout the Balkans from the Late Neolithic onwards. They have often been classed as earrings (especially when the penannular rings have overlapping terminals). However, the basic shape is so like a pendant that they ought to be considered as such.

Most examples date to the LN and in this they have a contemporary parallel from Emborio, Chios (Hood, 1981). The Alepotrypa example in silver has a good parallel in the Amnissos pendant from EM III Crete (Praktika, 1930, 98, fig. 9). The type continues into the MB A. At Dimini a stone and^acopper example are found in the same contexts.

The finest ones known are the sheet metal pendants, probably backed by wood or leather, from LN Dimitra. Branigan classes similar pieces as figurines (type IV, 194). This can be considered an original Balkan

shape which spreads throughout the Aegean and it on the Greek mainland that this form is translated into metal.

TYPE R.5

Triangular shaped pendant, in solid or sheet metal

(Figure 2.12.2.1)

Site	Date	Material	No.	Fig.	Cat. no.
Zygouries	EH II	Au/Ag?	1	✓	198
Thebes	EH III	Au	1	✓	252
Thebes	EH III	Au	1	✓	253
Thebes	EH III	Au	1	✓	251
(Thyreatis	?	Au	1	✓	171b
Thyreatis	?	Au	1	✓	171b)

DISCUSSION

The basic ornamental form in this type of pendant - the double and quadruple spiral is reminiscent of Troadic and Cycladic pins and pendants. Troadic and Poliochni examples are very similar to the material from Thyreatis. Cretan examples are known from Kalathiani. These pendants are thus quite unlike known Greek material and it is possible that the filigree and granulation techniques were used to produce them. There is no evidence as yet that these techniques had been mastered on the mainland and this lends further weight to the view that these pieces represent imports.

Two further diadems, or possible diadems, from Zygouries are difficult to assign to type. They are both in silver (cat. no. 194 and 195). These could be local types.

2.12.3. BANGLES

Bangles and bands, backed by wood leather or cloth would have provided another vehicle for personal adornment. Copper, gold and silver sheet could prove an effective and durable medium. The more solid metal bangles or bracelets are usually in silver. Bangles therefore fall into two groups: 1) solid metal and 2) backed sheet, bangles which are discussed under 2.12.4.1

TYPE Ba 1

Circular or rectangular wire; usually thick;
with or without knob or link terminals

(Figure 2.12.3.1)

Site	Date	Material	No.	Fig.	Cat. no.
Levkas	EH II	Ag	1	✓	340
Levkas	EH II	Ag	1	NA	337
Levkas	EH II	Ag	1	NA	339
Levkas	EH II	Ag	1	NA	338
Zygouries	EH	Cu	1	NA	197
Pefkakia	LN	Cu	1	NA	397
Alepotrypa	LN	Ag	4	NA	56-59
Ay. Marina	EH II	Cu	2	NA	211-212
Manika	EH II	Cu	2	NA	303-304

DISCUSSION

This type does not form a very homogeneous group. The amount of information on each type also varies.

Simple torque bangles are known at Alepotrypa and this is one of the earliest forms of bangles known. The most common, in silver, are the spiral bangles with plain or bevel terminal which are well represented

at Levkas. Perhaps the earliest silver bangles from LN Alepotrypa provided the prototypes for the more complicated spiral bangles from Levkas.

Apart from the Pefkakia bangle, all bangles are restricted in distribution to southern or central Greece. This is perhaps further proof that southern Thessaly was involved in the EH exchange and contact network. The Manika finds confirm the distribution of silver in Greece and silver is clearly the main metal used for bangles of this type.

Parallels in the Aegean are known from the Cyclades (Renfrew, 1969, pl. 2,9), Crete (eg. Mochlos; Seager, 1912, fig. 10,11,21) and the Troad (Schliemann 1880, 861) to quote but a few examples. Gold examples are known from Crete (Pyrgos) and Troy. The earliest example of the simple bangle in the Aegean date to Troy I (Schliemann, 1880, 116), but are most common in the EBA II. The Alepotrypa example is thus the earliest example in the Aegean. The spiral bangles are generally known from EBA II/III contexts and thus the mainland examples are contemporary with the flourish of this type in the Aegean as a whole.

2.12.4. SHEET METAL (Figure 2.12.4.1)

The technique of beating metal into sheet was first perfected in Egypt (Hood, 1981). The earliest evidence of sheet metalwork on the Greek mainland comes from MN Dimitra.

Gold was the most common metal used in sheet metal work (see Table 2.12.4.1) as it is malleable and soft, but silver sheet was used to make diadems from the middle of the EBA. Copper sheet is known from the LN in northern Greece and was used to make increasingly more complex forms, including vessels in the EBA. The most sophisticated sheet metalwork in the Aegean is known from Troy II treasures and later from the EM graves, such as at Mochlos

(Seager, 1912). There seems to be little direct relationship between the Cretan sheet metalwork and that of the Greek mainland. Sheet metalwork is restricted to southern Crete where it demonstrates Egyptian and Mesopotamian influences in its designs and shapes (Hood, 1981). Crete had strong contacts with these two areas in the later EM period - especially southern Crete. (see Ch. 7).

It has not been possible to date the gold and copper vessels from Euboea (Mitten and Doeringer, 1968, 26; Renfrew, 1967 pl. 10a) and Arcadia (Renfrew, 1967, pl. 10a). The cup from Levkas is the only well-dated ^{EBA} sheet metal vessel known (Dörpfeld, 1927; 4.7, analysis number 79). Similar cups, but not identical are known mainly from Troy (Schmidt, 1902, 5865-5864) though these are made mainly of gold or silver. Copper examples are known from later contexts at Mochlos (Seager, 1912, fig. 26, vii c) and Gournia (Boyd -Hawes, 1908, pl. c,1).

The techniques used to fashion the sheet metal were quite basic and need not imply influence from outside of Greece but the techniques of decoration are markedly Troadic in character. Some of these pieces could have been imports; others may have been copies. We should note that most of the material of this type survived because it was in grave contexts and there is no reason to doubt that sheet metalwork was more widespread in the EBA of the mainland than these few pieces suggest.

2.12.5. WIRE

Table 2.12.5.1 and Figure 2.12.5.1 catalogue the extant evidence for wire. Little typological data can be derived from this type. Suffice to say that wire was made from the LN and became increasingly common in the succeeding EBA. Copper, lead, silver and gold were made into wire. Many of the wire sections in precious metals may represent remains of rings.

2.12.6. LEAD

Lead was used for pottery repairs (rivets) weights, ingots, spools and clamps. No doubt it was traded or exchanged in the form of ingots, as the bun ingot from Rouf was formed to a specific shape and weight. Table 2.12.6.1 lists the finds of lead from LN and EBA contexts and Figure 2.12.6.1 shows the distribution of lead on the mainland during these periods. A further discussion on the relative distribution of lead (and its by-product silver) is given in 6.4.

The jewellery, wire and sheet of the mainland in the LN and EBA demonstrate that the area was in no way behind the rest of the Aegean in repertoire or techniques, except perhaps in gold decoration (filigree etc), which is more advanced in the Troad and, later, in Crete. The paucity of finds does not demonstrate that jewellery was rare - rather it reflects the custom of not burying precious objects with the dead. Local types and local adaptations of "foreign" types are known and both signify a healthy local industry, supplied by local copper and precious metals. Both the Ionian islands and southern Thessaly were involved in the Helladic world during the EBA period.

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CHAPTER THREE
METALLIC RESOURCES

3.1 INTRODUCTION

This chapter will review the geological evidence for the metallic minerals available to LN and EBA metalworkers. This will provide the basic data required to discuss the relationship between sources, the distribution of contemporary metalwork, settlement and the evidence for source exploitation and metalworking in Chapter 6.

It has not often been realised by archaeologists just how many accessible deposits of metal, in particular, copper, silver and lead exist in mainland Greece, though direct proof of their exploitation in early times is largely lacking.

It will have been shown that silver and lead were exploited in the Laurion in the LBA and that some lead and silver from the Laurion was being used by the Cycladic islanders and Minoans in the EBA.(see 4.4). Proof that the Laurion and other Greek ore deposits were sources of metal to mainland Greek industries in the LN/EBA periods would clearly bear in a significant way on discussions of the possibility that metallurgy evolved semi-independently on the mainland. Further, if it should be found that the same sources were used in both the LN and EBA, the case for a continuity of tradition between them would be considerably strengthened.

It was previously believed that tin was not alloyed with copper during these periods on the Greek mainland, but recent analyses have shown that it was (see 4.6). No sources of tin have been recorded for Greece and so this account must include a review of the sources of tin which would have been available.

Gold was used for artefacts from at least the end of the Neolithic and

so a survey of gold sources is also given below.

Arsenic, antimony and nickel are common minor elements in artefacts, possibly indicative of source. The sources of these metals and semi-metals are reviewed, particularly in their relationship to copper sources.

3.1.1 PREVIOUS WORK

The amount of previous work on the metallic resources of mainland Greece available to, or exploited by, prehistoric man is very limited.

Davies (1932, 145 and 1935, 253) was the first to review the evidence for the exploitation of Macedonian copper and gold in Antiquity. From his analyses of some copper artefacts and sources in Macedonia, he concluded that local ores had been used for several artefacts in the EBA. Branigan (1974, 61) disagreed with this view, pointing out that there is some discrepancy between the silver and nickel levels in the copper ores and artefact analysed by Davies.

Cooke & Nielson (1978, 232-233) briefly reviewed the potential sources of copper in Greece and the Aegean. This work was based on the Metallogenic Map of Greece, and several copper deposits throughout Greece were visited to determine their nature and seek evidence of ancient metalworking. No analyses were conducted - at least none were reported. This team judged it doubtful that either the Macedonian or Fthiotidic sources were exploited in prehistoric times due to the low grade nature of the mineralogical deposits. The Fthiotidic deposits were revisited for the purposes of this thesis and quite different results were obtained, (3.2.1.). They favoured the exploitation of the southern Euboean deposits around the village of Kalianou and excluded all Peloponnesian copper sources as possible sources in the prehistoric period.

Branigan (1974, 59-64) reviewed most, but not all, Aegean sources of copper, lead, silver and gold available in the literature. He concluded, on the basis of several slags which he considered smelting products, that several mainland copper deposits in Macedonia, central Greece and the Peloponnese were no doubt exploited in the EBA. Unlike Cooke et al (1972), he believes that even if the copper was low grade, it would have been enough to meet the needs of EBA metalworkers. His assumption that the slags were the result of smelting copper from its ores, was not supported by analyses.

Davies (1935) suggested that the high arsenic levels in some of the Macedonian copper artefacts can be explained as a result of the smelting of arsenic-rich copper sulphide deposits from Macedonia, and Branigan (1974) further suggested that this could account for the high arsenic levels in the EBA hoard from Petralona, though the alternative source of arsenic-rich copper could have been the Balkans as, in his opinion, there is little evidence for arsenic-rich copper in the Aegean. The possibility of obtaining arsenic in copper smelted from sulphide copper deposits is discussed in 4.2.1.

Little serious work has been done on the subject of ancient gold sources in the Aegean or Greece. This is due mainly to the difficulty of locating areas of exploitation (3. 2.3.). What work has been done has concentrated on the source(s) of gold used by the Myceneans, who displayed an obvious wealth in the metal through their funerary offerings. Davies (1932; 1935) was the first to work on the sources of Macedonian gold, where the early finds from Vardina, Vardarophitsa and Saratse (Heurtley, 1939) demonstrate that gold was known in the EBA. Gold slags were also found at the two latter sites. Davies claimed that these slags could represent melting scums (Davies, 1935) and the process of melting gold in order to purify it is quite advanced for this period (4.2.4).

Most of the famous sources of gold in the Aegean are those recorded by Classical writers, in particular Herodotus, Strabo and Aristotle. The main sources are located on Thasos, Siphnos and Pangaion mountain. The Thasos mines, mentioned by Herodotus (Book vi, 46-47) have recently been confirmed by analytical work, (Wagner *et al*, 1980). Branigan, (1974, 63) believes that the Macedonian sources supplied the Aegean in the EBA, supported no doubt by north-west Anatolian deposits.

Hartmann (1972) analysed 3,300 objects of gold from Europe, including a few pieces from Mediterranean lands, of which thirty-one were from Greece. He did not publish the Aegean material in his preliminary report, but his conclusions for European material have met with criticism. His goal was to establish the sources of gold being used in the Bronze and Iron Ages of Europe. His basic hypothesis was that the presence/absence of tin and platinum, particularly of tin, provided the key not only to provenance, but even to types of deposits used. Those gold samples which had these two elements, said to represent alluvial or placer gold, were termed type A; those without them, said to represent mined gold, were termed type B. His results showed that some Neolithic and EBA gold artefacts from the Aegean were type B and suggested that mined gold from the Near East had been used. This led to major criticism (Muhly, 1978) and his results are very much at variance with archaeological opinion.

Davies (1932) was the first to record tin in some of the EBA Macedonian artefacts which he analysed, though no tin showed up in his analyses of ores. He also mentioned a rumour that a tin source may exist on Pangaion mountain. The problem of tin sources and tin supplies to the Aegean from the middle of the EBA has not been fully resolved. The search for sources of ancient tin has been fraught with difficulties and uncertainties resulting mainly from inadequate geological prospection. Anomalous high tin percentages in numerous third and second millennium BC bronzes from the Troad encouraged

the hypothesis that this area had access to, or control of, a tin supply. (Ryan, 1957; Renfrew, 1967; de Jesus, 1981).

Interpretation and reinterpretation of second millenium BC texts which refer to an apparent trade in tin has proved fruitless in helping to locate an actual source or sources, but it has directed the geological and archaeological search both further north and east. Much of the textual evidence suggests an eastern source of tin (Muhly, 1973; 1974), though some still believe that the Caucasus or the Balkans had vital sources, (eg. Dayton, 1971).

Data on the locations of evidence for lead and silver working and the evidence for the exploitation of lead and silver sources in the Aegean in Antiquity has been summarised by Gentner *et al* (1978), Gale *et al* (1978) and Pernicka *et al* (1981). These works collectively demonstrated that lead and silver were obtained from three main Aegean sources during Archaic and Classical times. More recent work by laboratories in Heidelberg, Germany and Oxford, England (4.4.3) have shown that lead and silver was exploited in the EBA.

The time has now come to review all possible sources of copper, lead, silver, gold and tin which could have been used by LN and EBA metal-workers on the Greek mainland in order to assess which sources were used in the third millenium BC.

3.2. METALLIC RESOURCES IN MAINLAND GREECE

The data source used for this account of Greek mainland metal sources was the Handbook of the Metallogenetic Map of Greece, produced by the Institute of Geological and Mining Research (IGME), Zachos and Marinos, (1973).

The fieldwork for this work was carried out in the late 1950s and early 1960s and so it is slightly out-dated. Members of the IGME staff have kindly provided new data on copper and galena sources which have resulted from their recent research.

Data on the locations of copper slags and the evidence for the exploitation of copper sources in the past was obtained from Papastamatakis (1975; 1986).

Information on the properties of copper, silver, lead, gold, arsenic, antimony, nickel and tin were obtained from Deer et al (1977).

3.2.1 COPPER SOURCES

Greece possesses numerous sources of copper, some of which were potentially rich in the types of minerals sought by early metalworkers, though many were small and inaccessible.

The copper-bearing ores known are shown in Fig. 3.2.1 and in greater detail for each region in Figs. 6.9.1 (A -E).

The figures include all sources mentioned in the IGME report (1973), both oxide and sulphide, as well as new locations discovered in more recent IGME surveys. The ore type and present-day abundance, where known, are presented as a catalogue in Appendix 3. Oxide ores (malachite, azurite, cuprite, olivenite and chrysocolla) occur with most of the sulphide ore deposits (eg. chalcopyrite).² The sulphide ores are more common in Greece, especially in the north, where they extend into the north-west region of Anatolia.

Apart from these oxide and sulphide ores, copper is known mainly in the sulphide form, in mixed sulphide deposits. Copper is associated in

these cases mainly with ironpyrite and galena, though there are several important occurrences of copper/lead/silver/gold or arsenic. These deposits are shown distinctly on both the copper source figures and the lead/silver source figures. Fig. 6.9.2.(A-E).

Exploitation of a galena source in the EBA could strengthen the possibility that a nearby copper source would have been exploited - especially as the temperature required to cupel silver from lead is similar to that required to smelt oxide copper (see 4.2).

The sources which seem likely to have been exploited in the prehistoric period are those which would have been both accessible and obvious, that is, within close proximity to settled areas and preferably a surface outcrop of recognisable colour and texture. A native copper or an oxidised copper on the surface would have been preferred to a primary sulphide or subterranean lode, as it would have been easier to work and obtain. Further, a reasonable size of deposit would have been preferred.

Major sources with partially visible, oxidised deposits are indicated by a number on Fig. 3.2.1 and by an asterisk in Appendix 3. In particular, sources 12, 13, 14, 15, 17, 22, 23, 34, 35, 36, 39, 40, 42, 43, 44, 45, 46, 47, 48, 54, 62, 63, 64, and 65 would have been the most likely to have been exploited in the prehistoric period. Significant oxide copper is associated with them and all early mining, from the Balkans to the Near East exploited first these weathered (oxide and carbonate) ores, Rothenberg, (1978) Jovanović, (1980) (see 4.3).

One main geological formation bears the majority of copper ores in mainland Greece. This is the group of general metamorphic rocks, comprising gneiss, schists, marbles and phyllites. Of the sixty-five published

oxide sources, thirty-three are associated directly with, or border, this formation. The same can also be said for the vast majority of copper lo in mixed sulphide deposits. Figure 3.2.1.1.

3.2.2 LEAD AND SILVER SOURCES

The distribution of all known sources are shown in Figure 3.2.2 and these are shown in greater detail for each region in Figures 6.9.2 (A-E). Also marked are the occurrences of copper, gold and arsenic which are associated with galena deposits.

Our knowledge of the EBA exploitation of argentiferous lead ores for lead and most likely silver is more substantial than our knowledge of contemporary copper source exploitation (see 4.4).

Galena, or lead sulphide, also known as lead glance or blue lead, is the main source of lead and silver. The ore resembles lead, in its grey colour and streak, as well as in its softness and weight. If the metal was not itself immediately recognisable on the surface, prehistoric metalsmiths could have been lead to it by sphalerite which occurs in association with ninety per cent of Greek galena deposits. Silver in its native form is very rare and is not known in Greece. If, however, it had been, it would have been easily recognisable. It is silvery-white in colour, readily tarnishes and is heavy and soft. Silver glance, or argentite, is dark grey, as is its streak, and it has a metallic lustre.

Native lead is so rare than lead metal found on an archaeological site almost certainly represents the smelted product. As silver is cupelled from argentiferous lead ores, silver found on an archaeological site in the EBA no doubt represents the product cupelled from lead ores.

The sources of lead and silver derive predominately from mixed sulphide ores.

3.2.3 GOLD SOURCES

Figure 3.2.3 shows the distribution of all known gold deposits in Greece (primary, secondary and those associated with mixed sulphide deposits).

Native gold may have been the first type of gold used on the Greek mainland. Little is known of its sources, but one can be sure that it was easily recognisable. It is yellow or less often copper-coloured, but if mixed with silver it can be almost white. It has a metallic lustre and is opaque, but when thin sheets of gold leaf are looked through, they appear green. The metal is soft enough to be cut with a knife, and it is very heavy; its weight varying according to the metals with which it is alloyed.

Gold is known from both primary and secondary deposits in Greece in association with hydrothermic or volcanic rocks. Primary deposits of gold, with its compounds, are incorporated in galena, chalcopyrite or ironpyrite. These appear in veins, usually in association with quartz. The richest quartz veins which bear gold are known from the centre of the Kilkis region, between the villages of Vathys and Yerakiou. It is also known from mixed sulphide deposits on Pangaion mountain (Nikisanu site), Euboea (Kalianou site) and Chalkidiki (Madem-Lakkos and Zepkos sites, among others).

Secondary deposits of gold are found in river banks or in ancient sedimentary layers (clastic Holocene or Neogene sediments), or in small native gold deposits scattered amidst other minerals. The most important alluvial deposits come from the Gallikos river, whilst the most important native gold deposits are reported from Afissio near Sparta, in association with alluvial deposits.

Davies (1935, 253) also mentions the Axios (Vardar) river valley and the Lankadas valley as possible sources of secondary gold. These sources have not been verified.

3.2.4 TIN SOURCES³

There are no confirmed sources of tin in Greece. Khirra, the ancient port of Delphi, was announced to be the only tin-producing site in Greece (Davies, 1929). However, analysis of the slag in question produced no traces of tin, and ^{the} findings of Davies were called into question (Benton, 1964). Forbes (1950) writes of reports of tin at Pangaion and Volokastro. Recent work by IGME workers on Pangaion mountain resulted in the discovery of a lump of cassiterite ore. No further traces of this mineral were found (information provided by A Papastsmataki, per comm., IGME, 1987). The geology of Greece is not suited to the formation of cassiterite, and no tin traces have been confirmed in Greece, Crete or any of the Aegean islands (Wertime, 1973; Muhly, 1973; Muhly, 1985; Renfrew, 1967). Consequently, the occurrence of tin in Greek and Aegean bronzes implies its importation.

A brief synopsis of those tin sources available to Greece will now be given.

The British Isles: The occurrence of tin in southwestern England is well documented (Dines, 1956; Edmonds et al 1975). Devon and Cornwall represent the only area in the British Isles where sufficiently workable quantities of tin occur (Slater, 1974). The primary cassiterite lo are closely associated with five major granite bosses which run from Devon to Lands end. This area was particularly rich in readily accessible stream tin (Henwood, 1873). The Scilly Isles, an extension of the mainland granite plutons (Hess and Graton, 1904) contain only insignificant deposits at St. Agnes and Tresco (Ashbee, 1974; Maxwell, 1972). Traces of tin are also found in Scotland (Fergusson and Bateman, 1912; Bowie, et al (1978) and Ireland (Briggs, 1976; Jackson, 1978).

France: Two areas in France contain both load and alluvial cassiterite.

The richest French deposits are to be found on the Armorican Massif, clustered around the St Renan granitic complex, and scattered in a distinct band which runs parallel to the Atlantic coast, with major concentrations near Quimper, Le Faouët, Vannes, Questembert, La Willeder, Nantes and Mortagne. Deposits also occur further inland at Abbaretz and south of Fougères and Mayenne (Chauris and Guigues, 1969; Giot *et al* 1979). In addition, two regions of the Massif Central produce tin ore, one in the north-west, around Limoges; and the other in the south west, (Jones, 1925; Ramin, 1965).

Iberia: The main deposits of cassiterite lie in northwestern Spain and form a band which runs through the provinces of Coruña, Pontevedra, Orense and Zamora (Lucas, 1928; Almeida, 1970). Scattered deposits also occur in the Portuguese provinces of Minho, Trás-os-Montes, Beira and Salamanca (Down, 1916; Fergusson and Bateman, 1912). These areas correspond to the tin-fields of Galicia and Lusitania described by Pliny (34.156-157) and Strabo (III.2.9). The relative abundance of tin in Spain and Portugal has led many scholars to equate the Iberian Tartessos with biblical Tarshish (Rickard, 1928; Rothenberg and Blanco-Freijeiro, 1981; Arribas, 1964). Well outside this major tin-producing area, Monteagudo (1954) and Allan (1970) mention cassiterite deposits near Faro in the Algarve and Cadiz. These reports are insufficiently documented to be taken seriously, particularly since acidic granites are largely a northwestern Iberian phenomenon (Kelly and Rye, 1979). More certain are the reports of tin from the provinces of Murcia and Almería in south-eastern Spain (Hess and Graton, 1904) and the accounts of tin mining near Cartagena, the ancient Punic Carthago Nova, are most interesting, (Davies, 1919; Monteagudo, 1954).

The Erzgebirge: The tin-bearing region of the Erzgebirge, a mountain range between Saxony and Bohemia, has been worked since the end of the

twelfth century AD (Agricola, 1556). Primary cassiterite lodes have been discussed by Singewald (1910) and Baumann (1970). Major exploitable alluvial deposits are also found in the regions of Eibenstock and Geyer-Ehrenfriedersdorf (Taylor, 1983). Cassiterite has also been found at Weissenstadt on the nearby Fichtelebirge in Bavaria (Davies, 1919; Shell, 1978).

Italy, Sardinia and Elba: As a source of tin Italy is often underrated, and in a recent survey of tin sources (Dayton, 1971) it was noticeably absent. The main tin-producing area is found in the Colline Metallifere, Tuscany (Neppi-Modona, 1959; Sestini, 1981; Bietti Sestieri, 1981). The principal deposits occur at Monte Valerio (Stella, 1927; Minto, 1954; Stella, 1955; Cambi, 1957). It has been estimated that the original tonnage of exploited reserves was about a million tonnes of ore (Venerandi-Pirri and Zuffardi, 1982). Other minor deposits have been located in the Tolfa Mountains and Mount Amiata in southern and central Etruria, respectively (Hencken, 1968a; 1968b; Potter, 1979). The deposits of Tuscany, Elba and Sardinia are believed to be Tertiary and metallogenetically related (Jones, 1925; Schuiling, 1967; de Jesus, 1978a; de Jesus, 1980). On Elba, cassiterite has been found in association with ferrous minerals (Davies, 1919; Boni and Ippolito, 1976). Sardinian lodes appear to be restricted to the south, particularly the Iglesiente region, near Cagliari (Lo Schiavo, 1981). Tylecote et al (1983) have recently been working on the cassiterite deposits in Sardinia. Cassiterite also occurs adjacent to the granite massifs of Quirra, Aburese and Monte Linas. Stream tin has been found in the Monte Linas drainage system (Biste, 1982).

South West Asia:^{*} The search for tin deposits in South West Asia has been plagued by many spurious and unconfirmed reports (see Gowland,

(*see addendum p 111b)

1912; Lucas, 1928; Wainwright, 1934; Crawford, 1938; Forbes, 1950; Lucas, 1962; Forbes, 1964). Actually, the number of verified sources is very small. Suspicions of an Anatolian tin source, (McKerrell, 1978), have recently been vindicated with the discovery of tin near Bursa, (Yakar, 1984; Moorey, 1985), and the location of stannite mineralisation in the Bolkardag district of the Tarsus Mountains (Yener, 1986). Minor deposits of tin have been confirmed in the region of Bokhara, Uzbekistan (Masson and Sariandje, 1972; Crawford, 1974), and in the Kalba district of Kazakhstan (Dayton, 1971; Muhly, 1976). However, the most promising eastern deposits are in Afghanistan (Cleziou and Berthoud, 1982; Muhly, 1985; Moorey, 1985; Stech and Piggott, 1985).

Egypt: Cassiterite deposits were confirmed in the Eastern Desert during the Second World War (Amin, 1947; Lucas, 1948) and have recently been surveyed (Nibbi, 1976; Maddin, Wheeler and Muhly, 1977; Wertime, 1973; Muhly, 1978). At least eighteen significant deposits are involved (Vali, 1978). The most important are at Igla, Nuweibi, Abu-Dabbab, El-Mueilha and Um-Bassilla (El-Ramy *et al* 1959; Said, 1962; Sabet 1974a; 1974b; Muhly, Wheeler and Maddin, 1980).

Yugoslavia: Less than four hundred miles north of the Aegean lie the tin deposits of Cer, Bukulja and Srebrenica. These lodes like those of Tuscany, are Tertiary deposits, and belong to the Alpine metallogenic epoch (Janković, 1982). They are located in the metal-rich Serbo-Macedonian geological province, and are generically associated with volcanic-intrusive complexes of granodiorite magma and with granites.

On the southern slope of Cer mountain, cassiterite mineralisation is associated with a griesen zone in the granite mass, with widespread dissemination of fine grained cassiterite. Quartz veins containing tin also occur in the Bukulja granite, and traces of cassiterite mineralisation are

also four in pegmatic dykes (Janković, 1982). In addition, three significant tin deposits occur in the region of Srebrenica (Dordević, 1969; Kubat and Dordević, 1973 and Kubat, 1974).

Perhaps the most important source, and the one most readily accessible to Early Bronze Age prospectors, are the placer deposits of stream tin at Cer. These are sufficiently extensive to be of "potential commercial value", even in present economic terms (Janković⁴; Penhallurick, 1986). These alluvial tin deposits have not been worked in modern times, and there is some small chance that traces of earlier exploitation may still survive, though alluvial workings do not leave particularly durable traces of the kind that might result from lo mining.

The tin deposits are well placed to serve the Aegean (see 4.7.)

The crux of the problem is that once tin has been smelted and alloyed, it is presently not possible to identify its source from trace element analysis (Rapp and Gifford, 1985; Muhly, 1985). Moreover, the recycling of scrap metal can further confuse the issue (see 4.2). Consequently, one can only speak of "possible" sources of tin used by the metalworkers in the Aegean during the third millennium BC, though it is impossible to state with certainty when a particular deposit was first exploited.

Cassiterite is usually found in acidic igneous rocks such as granites and microgranites in high temperature hydrothermal veins. It may sometimes result from the weathering of stannite and teallite. It can also be found pseudomorphing haematite and orthoclase. Woodtin is a colloform variety formed by secondary processes in the zone of oxidation. Cassiterite is a common detrital material in sediments derived from tin-bearing acid rocks. It is quite often known as a minor trace element in chalcopyrite and in stannite.

As with the other metals used in the EBA, tin is easily recognisable. Cassiterite, known as tin stone or tin oxide, is the only important source of tin. It is black or brown or somewhat lighter in colour, and its streak has similar hues; it has a brilliant lustre. The mineral is very heavy and hard. If tin did exist in Greece, there is no reason why it would not have been recognised and exploited.

3.2.5. ARSENIC SOURCES

The distribution of arsenic-rich ores is shown in Figure 3.2.5. More detailed figures which show the distribution of arsenic in association with copper and other metallic minerals are given in Figures 6.9.1-2 A-E).

Arsenic was the main alloy of copper in the EBA. No pure arsenic ores are known in Greece. It is found in minor and trace amounts in mixed sulphide ores, in the form of veins of arsenopyrite. It is often associated with copper, gold and galena. All compounds of this semi-metal are extremely poisonous. It can be recognised easily, for when the ore is struck, it emits sparks and gives off a smell of garlic. It is the colour of tin or steel, but tarnishes pale red on exposure; it has a dark grey streak and a metallic lustre.

3.2.6 ANTIMONY SOURCES

The most important locations of antimony are in northern Greece, where the mineral is associated with copper deposits, Figure 3.2.6.

Antimony occurs as a minor element in many of the early coppers and bronzes of Greece. That is why a brief account of its sources is given here. Antimony can be confused with tin at first. Its extraction is difficult and complicated and its use in the EBA would have occurred only as the result of contamination of copper deposits.

The most common type of antimony is stibnite or antimony glance. This is also known as grey antimony, because of its colour and its streak; it has a metallic lustre and tarnish makes its surface iridescent.

3.2.7 NICKEL SOURCES

Nickel occurs as a minor element in many of the early coppers and bronzes of Greece. That is why an account of its sources is given here.

Greece is one of the most gifted countries in Europe when it comes to nickel. It appears in the form of pyritic salts (garnierites, etc). It is usually associated with iron-bearing ores. The largest deposits in Greece come from Locrida, Euboea and the island of Skyros in the Aegean. It is usually found in small amounts in mixed sulphide ores. On its own it is only found in four locations on the Greek mainland, Figure 3.2.7. It is important to note that the four main nickel deposits are associated with important copper deposits, in particular Limogardion in Fthiotidha.

Something of the history of this metal should be noted here, in order to bring out its relationship with copper. When identified in 1751, nickel already had a bad reputation among German miners. One of its ores has a delusive resemblance to copper ore, but it could not be smelted and could not be made to yield copper. The German miners decided that it must be bewitched and referred to it derisively as Old Nick's copper or kupfernickel. The term has stuck.

It is pale, coppery-red in colour, but may become tarnished; its streak is brownish-black and its lustre metallic.

3.3 CONCLUSION

The above review demonstrates that adequate sources of all metals used in LN/EBA Greece, (except tin), were accessible and available. Certain areas had more metallic mineral wealth than others. Tin sources were available in the Balkans and Anatolia and Greece must have been supplied by them. (see 4.7).

ADDENDUM

Since writing this thesis a major new tin source has been reported in the Taurus mountains. on the south coast of Anatolia at Bolkardag (Yener and Ozbal, 1987). They discuss the source of tin as a potential supplier to the rest of Anatolia before the Old Assyrian tin trade developed.

CHAPTER FOUR

THE ANALYTICAL PROGRAMME

4.1 INTRODUCTION

This chapter presents the aims, methods and results of an integrated analytical programme involving Late Neolithic and Early Bronze Age copper, bronze, lead and silver artefacts from the Greek mainland.

The main body of lead-isotope and chemical results were carried out by Dr N H Gale of Oxford University. Supplementary chemical analyses were carried out by Dr K Assimenos of the National Museum of Athens Greece. Use is also made of previous analytical work on artefacts from the Greek mainland. These are listed in Tables 4.1.1. & 4.1.2. and Fig. 4.1.1.

The aims of the programme are: 1) to make some chronological assessment of technological ability (chemical analyses) and (2) to gain some insight into the structure and organisation of metallic mineral acquisition (lead-isotope analyses).

There are three central questions which must be answered in order to achieve these aims. These are: (1) do the LN finds represent the beginnings of autonomous mainland metallurgy, or do they simply represent artefacts imported from contemporary, neighbouring cultures; (2) was the LN industry ancestral in some way to the EBA industry, or was the development of the EBA industry due to external influence, and (3) were there any significant changes within ^{the} metal industries during the EBA and do they represent internal evolution or the effect of external influences.

To allow the correct interpretation of the new analytical data, section 4.2 will provide a brief account of the metallurgical techniques involved in the working of copper, bronze, silver, lead and gold.

In order to view the development of Greek metallurgy in its proper

regional and chronological context, a background to the industries of the Near East, Balkans, Aegean and the west Mediterranean is given in section 4.3

As it is necessary to be aware of both the advantages and limitations of the analytical methods employed, a brief outline of the methods used is given in section 4.4, together with an account of the sampling goals and procedure.

The lead-isotope results and their interpretation are presented in 4.5 and the chemical results and interpretation are given in 4.6 (LN) and 4.7 (EBA)

4.2 PRIMITIVE METALLURGICAL TECHNOLOGY INVOLVED IN THE WORKING OF COPPER, BRONZE, LEAD, SILVER AND GOLD

Some understanding of the metallurgical processes used to produce the main metals of the LN and EBA is necessary in order to make a chronological assessment of technological development and to interpret correctly the analytical data.

4.2.1 COPPER AND BRONZE

Copper occurs in three main forms: native, oxide and sulphide, **Figure 4.2.1.1.** Different methods and techniques are involved in the acquisition and working of each type of copper and the production of different alloys. On present evidence, apparently two types of copper were used in Greece before the end of the third millenium BC. These were native and oxide copper.

A Native Copper used in the prehistoric period was obtained from the surface collection of nuggets predominately associated with zones of oxidised copper because primary native copper is insignificant and usually buried

underground. Occurrences of native copper are now rare in Greece, though several of the conditions which govern its formation (Cornwall, 1956), can still be recognised in Greece. There seems to be no sound evidence for or against the occurrence now or in the past of significant amounts of native copper in Greece or the Cyclades, though around the Mediterranean it certainly occurs in Anatolia, Italy and Spain (Maddin et al, 1980). In general, European native copper deposits are thought to have been produced by the weathering and breakdown of copper sulphide ores.

It is highly possible that whatever native copper there was in Greece was associated with oxidised chalcopyrite copper deposits, such as in northern Greece, for example. Indeed Tylecote (1976) suggests that a certain small amount of native copper may accompany every copper deposit.

Evidence for the use of native copper in LN Greece can at present only come from a study of the chemical composition and metallographic structure of the artefacts themselves.

The great majority of specimens of native copper are very pure with less than 0.25% total impurities (Voce, 1948; Patterson, 1971; Rapp, 1982), though very rare occurrences have significant amounts of arsenic (Tylecote, 1970)

B Oxide Copper Copper can be smelted from both oxide and sulphide copper. We will look first at oxide copper. Oxide copper deposits are either a surface scatter of crystalline ores or weathered ore veins, which would have been clearly recognisable, as weathering (oxidisation)/the^{reduces} ore types into characteristically bright colours (see 3.2.1.)

Acquisition of oxidised copper is not uniformly easy. During fieldwork in Thessaly and Fthiotidha, three basic forms of oxidised copper were encountered. The first was fine thick powder - carbonate malachite or azurite which could be scraped off and smelted in a crucible. The second, usually

apparent in veins, consisted of scattered cubic nuggets of almost pure copper which could easily have been separated from the ore matrix by light hammering. The collected cubes could then be smelted in a crucible. The third was the oxide copper ore which, when smelted, renders 1-3% copper. The procedure for smelting oxide copper from its ores is shown in Figure 4.2.1.2.

An example of the approximate range of naturally occurring impurities in oxide copper is given in Table 4.2.1.1. This type of copper can be contaminated by neighbouring loads of other metals, such as iron, lead, zinc (from underlying sulphide ores) or arsenic (from oxidised arsenopyrite). Perhaps certain uncharacteristically high percentages of some minor or trace elements can help provenance some metal artefacts to source⁵.

Copper obtained from the smelting of oxide copper usually has 1-3% impurities, mainly iron, lead, arsenic and silicate. Thus a copper artefact with > 97% copper need not have had anything added to it. The type of flux⁶ used could contribute to the impurities, however.

Allied to the question of smelting is that of whether the capability existed in LN and EBA Greece of exploiting copper ore deposits rather than simply working native copper or re-melting imported pieces of copper, such as axes from Bulgaria. These questions can most positively be answered if there is evidence for local exploitation or the requisite technological ability (such as furnaces or smelting slags). In the absence of such evidence one must turn to the possibility of using the chemical composition or metallurgical structure of copper and copper alloy artefacts to decide whether particular artefacts were made of smelted copper.

The criteria for differentiating smelted copper from the melting and use of native copper seems never to have been carefully discussed in relation to Aegean metallurgy. The determination by chemical analysis that an artefact is made of very pure copper does not prove that it was made from native copper,

since copper which has been carefully smelted from a pure malachite (oxide) or chalcopyrite (sulphide) ore can be as free from impurities as native copper (Tylecote **et al**, 1977). That this is so is easily illustrated by the exceptional purity (=99.7% copper) of the LBA oxide copper ingots from Sardinia and Crete (eg. Balmuth and Tylecote, 1976), which must certainly have been made from smelted copper.

The differentiation of artefacts of hammered native copper from those of worked and recrystallised smelted copper of high purity is very difficult and can only be based on a careful metallographic examination. For unmelted native copper such an examination will often reveal the presence of long, thin structures, or of cracks formed at the sites of non-metallic inclusions, (Maddin **et al**, 1980)

On the other hand the high purity of most native copper makes it possible that **smelted** copper can be recognised in artefacts if certain impurities are present in significant concentrations. The particular impurities, and their concentration levels, which might be diagnostic of smelted copper can be determined only in the light of analyses of native copper. Unfortunately, there exist no analyses of native copper from Greece⁷, Crete or the Cyclades; the 580 samples analysed by Rapp (1982) are drawn largely, though not exclusively, from American sources. The mean figures from these data for certain elements in native copper are shown in Table 4.2.1.1. Comparative data by Friedman **et al** (1966) and Fields **et al** (1971) are included.

Only six percent of the 367 native copper samples analysed for arsenic by Rapp contained more than 0.3% and of these half come from one locality in the USA, whilst six samples contained more than 1% arsenic. One sample from near Tepe Sialk in Iran contained 3% arsenic and Tylecote (Tylecote, 1970) has reported native copper from Anarak, Irak containing 0.1%-1%, but these are rare varieties and probably contain the minerals domeykite (Cu_3As).

Artefacts containing above 0.5% arsenic are very likely to be of smelted copper.

For iron about 6% of the analysed samples contained more than 0.4%, but only six contained more than 1% iron. Out of 366 native copper samples, only seven contained more than 0.05% tin, and only four contained more than 0.1% tin up to a maximum 0.74% tin. Apart from a few anomalous American samples, most samples of native copper that have been analysed contain less than 0.1% zinc and less than 0.1% silver. For nickel, the great majority of 366 analysed native copper samples contain less than 0.1%; only fifteen anomalous samples from American specimens contained nickel between 0.1% and 0.63%. Other analyses by Patterson (1971) show that the lead content of native copper is substantially less than 0.01%.

It can be concluded that artefacts which exceed these concentrations of arsenic, iron, zinc, silver, lead or nickel are very probably made of smelted copper, whilst recognising that very pure copper artefacts may be of either native copper or smelted copper.

The simple observation of the presence of metallurgical slag in an excavation is strong presumptive evidence that either melting or smelting was practiced, but it does not distinguish between them since slag can be produced in a crucible used for melting copper (either to refine it or preparatory to casting), as well as in smelting furnaces. Slags found adhering to a crucible are most likely to represent melting, though small scale crucible smelting is possible and known, (Coghlan, 1972; Zwicker, 1982).

However, the completely unambiguous differentiation of melting from smelting slags has otherwise yet to be demonstrated. The best account of the criteria that will often allow this distinction to be made is given by Cooke and Nielson, (1978). These authors suggest that crucible slags are usually extremely heterogeneous, with a siliceous matrix exhibiting little

devitrification and containing only minor amounts of crystalline silicates, in marked contrast to smelting slags. Parts of crucible slags are often extremely vesicular, whereas smelting slags usually contain relatively few, comparately large, blowholes. Chemically, Cooke and Nielson suggest that the vitreous phase of crucible melting slags has a low iron content and a very high ratio of $(\text{SiO}_2 + \text{Al}_2\text{O}_3)$ to $(\text{FeO} + \text{MnO})$ are crucible melting slags, but that the certain identification of small amounts of excavated slag as smelting slag may be difficult.

The firing of malachite in oxidised conditions easily produces sponge copper, which agglomerates if the temperature is high and the conditions right (Coghlan, 1972; Charles, 1980). Charles maintains that melting and smelting would have been discovered together. The use of a flux to smelt the mineral gangue and facilitate the separation of the metal would probably be discovered as a result of association of iron oxides (gossan) with the copper. The iron is subsequently oxidised in the right conditions. The smelting of a pure malachite or azurite ore does not require flux and it can safely be said that this is why these copper oxide ores were first used.

The melted or smelted copper would have to be cast and ^{metallographic} analyses of the artefact can often tell us a lot about the mode of casting.

Melting in an oxidised atmosphere can be determined if high oxide contents are observed on the surfaces. Open moulds of stone prevent some of the casting defects as all blowholes, or a large amount of cuprous oxide, are driven to the casting surface from which they can be scraped off and thus partially eliminated. It was not possible to use a closed (bi-valve) mould until copper was alloyed with arsenic or tin which had de-oxidising properties.

Metallographic and microstructure analysis of copper artefacts can tell us whether or not the object was hot-or cold-worked. The absence of preferred orientation of the grains indicates that the metal was annealed.

If much iron is present in the smelted copper artefact, this suggests a high oxidisation process / ^{where} proper slagging was not properly carried out. It indicates a primitive technique. The same conclusion can be made when a great deal of copper is included in the smelting slag.

C Sulphide Copper Sulphide copper ores occur deeper than the zone of weathering and thus are less accessible than oxide ores. Open cast mining, trenches and eventually galleries were required to extract this form of copper.

The procedure for smelting sulphide copper is more complex than for oxide copper (Figure 4.2.1.2). The iron content of a sulphide copper has to be separated before the copper can be worked. This involves one more step in the metalworking process. The sulphide copper in the secondary enrichment zone would easily have been discovered because of its proximity to copper oxide. Charles (1980, 163) maintains that during early attempts to work it, the green flame identifying copper would have been recognised.

The chemical elements which usually help distinguish sulphide from oxide copper are iron, zinc and lead. Sulphide ores lose large amounts of arsenic and antimony if dead roasted before smelting (though zinc is not appreciably lost in the process). The alternative process of smelting was to smelt the ores to a matte, but it is not thought that this technique was known until much later. Solid state roasting to oxide seems more likely to have been the initial development.

D Alloying. Before the second millennium BC, arsenic and tin were alloyed with copper on the Greek mainland. The purpose of adding optimum amounts of these elements was to deoxidise the copper, making it much easier to cast in a closed mould and alloying is thus an integral feature in the production of complex forms. Arsenic was used as an alloy before closed moulds started, probably for the improved hardness it conferred.

The initial use of arsenic as a deliberate alloy is not clear, because

it is often associated with copper, either as an arsenite in oxide copper or as arsenopyrite in sulphide copper (Maréchal, 1958). The use of an arsenic rich copper ore will carry through arsenic and other elements in more than trace amounts (antimony, nickel, silver and lead, mainly), Hook **et al**, (1987.) The addition of an arsenic-rich copper concentrate to a pure copper would be difficult to distinguish ^{from} the use of an arsenical-copper ore only. It has been shown that the smelting of oxide copper which already contains arsenic will not result in much arsenic loss, (Tylecote, **et al**. (1977). Gale **et al** (1984^b, 154) believe that the earliest arsenical coppers containing up to 5% or 7% arsenic could have been produced "accidentally", that is by the smelting of an arsenical copper ore. However, the general range of arsenic contents in early metals is from 1-8% and Greek arsenical coppers, (arsenites), have rendered approximately 1 to 2% arsenic under modern smelting conditions, (IGME, 1973). The highest recorded arsenic yield from an arsenical copper in the Aegean was 5% from Kythnos (Gale **et al**, 1984^b). As most Greek, including Cycladic, arsenic ores have relatively low arsenic, it appears that the estimates of Gale **et al** (1984^b) are over-optimistic.⁸ If most arsenical coppers were produced by adding arsenic-copper concentrate to a different copper, then we would have a mixing problem as the lead-isotope ratios of the two copper sources would be obscured (see 4.4.3).

Both Charles (1980, 173) and Zwicker (1982, 64) have described methods of deliberate arsenic-copper alloying. It is likely that arsenic-rich copper ores were smelted and traded and that these were added to the molten copper oxide in set proportions. This would not have been necessary if arsenic-rich copper was exploited locally, however. Eaton and McKerrell (1976) believe that arsenic-rich copper concentrate was the metal referred to in Assyrian texts, ^{it} though others previously believed ^{it} to be tin.

If arsenic-rich copper was mixed with copper for alloying the whole

procedure could be carried out in a crucible, though it would have been more effective in a smelting furnace (Tylecote, 1977). Much would depend on the amount to be produced. The copper-arsenic alloy would have been produced by adding orpiment or realgar to molten copper at about 800°C. If the arsenic was mixed with molten copper under charcoal, then much of the vapour would be dissolved in the copper, rather than being lost in poisonous arsenious oxide. This operation, of course, would have been hazardous for the smith. Arsenic is volatile and the fumes are still poisonous even though most of the arsenic content is not lost to the smelted copper.

Charles (1980, 10) suggested that the development of arsenical copper alloys with 3%-7% arsenic was probably due to the exploitation of arsenic in the enrichment zone. The arsenic minerals from such zones are enargite and tennantite. Arsenic contents in arsenic-copper loads change with depth, but high arsenic from arsenides is not possible as McKerrell and Tylecote (1972), Franklin ^{et al} (1977) and Tylecote ^{et al} (1977) have demonstrated. Arsenic loss is high during the roasting process required to smelt sulphide copper thus arsenic contents over 1% in an artefact made from sulphide copper represents a deliberate alloy. Arsenites would have been the first form to be used.

Thus, the Greek and Aegean arsenic copper ores yield on average under 2% arsenic, and so a deliberate alloy is considered to be 2.5% and above. One should remember that arsenical coppers would not necessarily have been recognised as a separate mineral, but as a special kind of copper.

Some believe that the toxicity of arsenic was the reason why tin eventually replaced it as the main alloy element in the second millennium BC. The answer may be simpler than that. The production of batches of high arsenical copper for alloying would involve a lengthy and dangerous process and the smelting of the oxide copper to which arsenic was to be added would involve yet another similar process.

Tin can be added to molten copper in the crucible or furnace. It could even have been added with the flux to the surface of molten copper under charcoal (Charles, 1980, 174). Tin bronzes and arsenical coppers have similar hardness properties (Charles, 1967), though no poisonous fumes are released from tin and it is easier to control in the alloy. More important, perhaps, is that tin somehow became more readily available in the second millenium BC.

The alloying of tin and copper was once seen as a clear technological divide. It is true that tin, as cassiterite, would not be accidentally alloyed with copper. However, attempts have been made recently to show that the early low-tin bronzes could have been accidental, (Charles, 1975,21; Charles, 1980, 173; Gale et al, 1984^b, 154). Allied to the question of how the first tin got into the copper is the problem of low tin bronzes which are apparently tertiary alloys. The optimum percentage of tin in a good tin bronze is 6% yet many early artefacts have tin levels well below this.

Charles first suggested that the early alloys of tin and copper may have followed the successful use of stannite, which looks like primary high arsenic copper ore. Muhly (1973, 98) first noted that the earliest Near Eastern tin bronzes could have used stannite as reports of the findings of the Iranian Geological Survey noted stannite in association with cassiterite and the use of stannite could therefore have lead to the use or discovery of cassiterite. Gale et al (1984^b, 174) reported that stannite is often found associated with primary sulphide copper ores. Some stannite may possibly be associated with sulphide copper ores in northern Greece (see 32.4). Stannite decomposes easily and is readily altered in the oxidised zones of primary copper sulphides to yield separate layers of oxide wood tin. It is easily worked to produce bronze (Charles , 1980, 172).

Alternatively Charles (1980, 173) suggested that tin could have got into

the copper during the smelting stage when iron in the form of gossan would have been added as a flux. Gossan is a convenient form of iron as it is associated with most copper lodes. Analyses of Greek iron deposits have not revealed any traces of tin (unpublished data, IGME) and the presence of tin in gossan is in fact quite rare.

Gale et al (1984^b, 56) maintain that the tin traces in copper deposits, (such as those in Anatolia discussed by de Jesus, 1980, 154), will be carried through into the smelted copper and although no smelting experiments have provided evidence to test this claim, they maintain that tin in the range of 1%-3% in early artefacts did not perhaps derive from intentional alloying with cassiterite. They also claim that tin bronzes with over 5%_{Sn} represent deliberate alloys. The figure of 3% from unintentional alloying seems generously optimistic as the characteristic traces of tin in the majority of low range tin bronzes from the Aegean and Anatolia do not exceed 1%. Charles (1980, 174) and Muhly (1985, 127) argue that low tin levels in numerous bronzes which date to the third millennium BC were the result of the use of tin bronze scrap when re-melting. This involves the mixing of coppers/bronzes and such a practice would alter the lead isotope ratios (see 4.4.3.) Whether or not the low levels of tin were the result of the use of stannite, gossan, scrap or low tin copper ores, one still has to explain from where the tin came.

Cassiterite quickly became the raw material for tin bronzes in the succeeding MBA.

Esin (1969), Eaton and McKerrell (1976), de Jesus (1980, 124) and Muhly (1985, 127-128) all argue that Anatolian metalsmiths kept a clear distinction between arsenical coppers and tin bronzes and that tertiary alloys of tin-arsenic and copper were rare.

Gale et al (1984^b) argue that low arsenic percentages in Anatolian tin bronzes are present because arsenic was often an accidental constituent

of smelted copper at levels of virtually up to 5% -7%. They claim that metalsmiths would recognise "copper" which had above 2%-3% arsenic, but at lower levels (0.5%-1.5%) the presence of arsenic would go unrecognised and tin would be added to the coppers with no apparent arsenic. This would, they believe, account for the tertiary alloys. It is true that arsenic levels above 2%-3% are obvious when arsenical copper is hot worked (McKerrell and Tyleote. 1972). However, Charles has shown that arsenic is effective at 1.04% and would have been noticeable when working (Charles, 1967). Further, there are several instances in Anatolia and the Near East where high tin is combined with more than 1% or 1.5% arsenic and where high arsenical coppers have a few percent of tin. Clearly the question is not yet resolved. It is highly possible that early metalsmiths recognising that arsenic and tin had similar effects in the copper (Charles, 1967), used whatever percentage of each was available and that there was a certain amount of interchangeability between arsenic and tin, especially when resources of both were for some reason scarce.

We note that Chernykh (1978) records the presence of low amounts of tin (<0.4 - <0.5%) in several of the EBA artefacts. These levels come from the copper source(s) used, or from the flux. Although good tin bronzes are known at this time they are rather rare. The low tin levels in some Balkan sources are similar to the few deposits mentioned by de Jesus (1980, 154). This supports the view of Gale et al (1984)^b regarding low tin levels getting into the copper via the ore. The evidence for this is more plentiful in the Balkans than in the Near East yet the Balkans were slow to develop tin bronze technology, despite the sources in the vicinity.

4.2.2 LEAD AND SILVER

Smelting and cupellation are the means by which silver is extracted from argentiferous galena (which contains from 0.01%-0.1% silver), Figure 4.2.2.1.a,b.

To extract silver from argentiferous lead ores it is necessary to first smelt lead, which carries with it most of the silver and some other elements such as copper, arsenic, antimony, gold, tin and bismuth. The other constituents of the ore (fuel, flux) are either volatilized or are predominantly incorporated in the slag.

In the second process, cupellation, the lead bullion is oxidised by blowing over the molten metal at around 900°C to form litharge (PbO). Since the melting point of litharge is 885°C it forms a liquid and can be drained off. In the cupellation process, most of the impurities are effectively removed, while all gold remains in the silver.

Typical impurity levels in cupelled silver are 0.1%-1.0% for copper, lead, bismuth and less than 0.001% for arsenic, antimony and tin. Although the composition depends to some extent on the stage of cupellation, most of the litharge is rather pure PbO with less than 0.1% total impurities. Litharge can easily be reduced with charcoal to produce lead, which is characterised by its low silver content (less than 0.01%). Where silver contents are higher, it is most probable that the artefact is made of uncupelled lead. The trace element pattern gives more information on the ore source when the lead is cupelled. Since only one pyrometallurgical process is involved, the impurity pattern of the ore is largely conserved.

The lead-isotope ratio remains constant in the lead and silver throughout the process. Only mixing of leads or silver will obscure the ratios. (see 4.4.3.)

Native lead is rare and it can be worked by cold hammering. Native silver is rarer still. It can be worked by annealing and hammering. Neither are known in Greece.

The most important technological question important to our understanding of early lead and silver working are, whether or not silver from third millennium BC contexts or earlier, was made from cupelled lead and when did the technique develop.

Location and extraction of galena deposits would not have been difficult. Galena is obvious on the surface and its deposits are usually concentrated in blocks. Extraction would start from the separation of surface deposits from the clay matrix. This would have been made easier by "washing", that is, separation by running water, where the specific gravity of the lead would separate it from the clay matrix.

4.2.3 TIN

No finds show how tin is produced. As tin rarely occurs in the metallic state, it is most frequently obtained from ores -the most important of which is cassiterite. Tin must first be made into a concentrate and then smelted. There is no evidence of how ancient tin was actually smelted. The nearest chronological account is that of Agricola (1950, 416).

Stannite or wood tin is often associated with cassiterite, with iron in the form of gossan hat and sometimes with copper ore deposits.

Exploitation of alluvial or stream tin would leave no trace and only the distribution of tin bronzes would give some indication of possible sources.

Three questions still remain to be answered regarding tin use in Greece:

1) where did the tin come from; 2) in what form was the tin imported or traded if it was, and, 3) what was the nature and context of tin use in the third millennium BC.

4.2.4 GOLD

There are two types of gold deposit, primary and secondary (see 3.2.3.). Secondary gold, being alluvial, is more likely to have been found than primary sources of gold. Alluvial gold could simply be hammered and annealed to produce the shapes desired. It is possible that it was melted and cast early.

According to Ogden (1976, 139) the presence of platinum in gold is indicative of an alluvial or native gold. Hartmann (1972) set other criteria(see 3.1.1).). It cannot yet be said if impurities in gold artefacts are due to smelting procedures or the impurities in the native deposits. Gold probably underwent some heat treatment for purification.

Gold could be recovered from smelting lead ores and copper ores which contain it,(Reed, 1934, 382). There is no evidence that gold used in the third millenium BC was obtained from such sources, however. If gold and silver are associated in the mineral form, they will both be carried through the smelting process to the artefact. The techniques required to alloy gold and silver have been considered too advanced for the third millenium BC.

4.2.5 CONCLUSION

The above outline of the techniques used in third millenium BC metallurgy provide the necessary criteria with which to judge and interpret the analytical results and appreciate the chronological development of metallurgical practices throughout the period concerned.

4.3 THE OLD WORLD BACKGROUND TO GREEK METALLURGY

This section reviews the technological developments in Old World metallurgy up to the beginning of the second millenium BC. In particular, the beginnings of melting and smelting, the origins and development of alloying and the relationship between metals and sources will be discussed. This will provide a reference with which to compare the status of the Greek mainland metallurgical industries in the Late Neolithic and Early Bronze Age periods. The copper/bronze, lead/silver and gold industries of the Near East (Mesopotamia, Anatolia and the Levant), the Balkans (Bulgaria, Yugoslavia and north), the Aegean (Cyclades and Crete) and the western Mediterranean (Italy and Spain) will be briefly reviewed. It is important to understand the context in which real metallurgy develops (Barker, 1977), rather than pinpoint the first use of copper and other metals (in their native form) as a trinket and so the main emphasis of this section lies in the development of true metallurgy. For this reason, most of the data for the initial stages of metalworking are given below in tables.

4.3.1 COPPER AND BRONZE

The seven technological and historical phases of early copper metallurgy devised by Wertime (1964) are adapted here to reflect more precisely the chronological sequence of metallurgical development, Table 4.3.1.1. For stages 1-2, all references are given in the relevant tables.

Stage one implies little more than the recognition of native copper as a different type of stone. Only lithic techniques of cold hammering were applied. The earliest finds are listed in Table 4.3.1.2.

In the Near East there is an apparent coincidence between the areas first using native copper, the beginnings of agriculture and the location of the main copper belts (Muhly, 1973, 87; Sherratt, 1976). The main copper deposits in the Near East have been discussed by Selimkhanov (1977)

for the Caucasus; de Jesus (1980) for Anatolia; Holzer, Momezdeh and Gröpp (1971) for north west Iran; Constantinou and Govett (1972; 1973) for Cyprus and Muhly (1973) for the Near East in general. Fig. 4.3.1.3.

It is in the seventh millennium BC that native copper appears more often in several Near Eastern and south east Anatolian sites, though the earliest find dates to 10,000 BC.

In the Balkans the data on metallurgical development is better for Bulgaria and Yugoslavia than for farther north. Todorova (1978), Jovanović and Ottoway, (1976), Chernykh (1978) and Chapman (1981) have presented the evidence for copper sources in the Balkans. Chapman and Tylecote (1983, 375) believe that the earliest phase of metalwork in the Balkans begins in the mid-fifth millennium BC, but Chernykh (1978) dates the beginning of the Eneolithic (Chalcolithic) to c. 4800 - c.3800 BC.

The earliest find in the Balkans are copper mineral lumps from the early Vinča culture (Cernica find), though the majority of finds date to the mid-fifth millennium BC. The earliest find further north comes from Vinča C contexts in the Maritsa settlements.

In the Aegean there is only limited evidence for this stage. Malachite powder was discovered from EN contexts at Knossos (Evans, 1964, 146). Similar powder, this time azurite, is known from Early Cycladic contexts at Louros (Naxos) and another unknown site in the Cyclades (Doulas, 1969, 39; Papathanassopoulos, 1961-2, 132). Faure (1958) and Branigan (1968) reviewed the copper sources of Crete and Branigan (1974) reviewed the copper sources for the Aegean as a whole.

The Diana, Ripoli and Lagozza cultures are approximately contemporary with the Final Neolithic cultures of the Aegean. "Copper" artefacts are known from several locations; some may have been simply cold-hammered native copper artefacts, (Renfrew and Whitehouse, 1974).

The richest sources in Italy are known from the Rinaldone area and recently

copper sources have been discovered on Sardinia (Renfrew and Whitehouse, 1974; Tylecote et al, 1983).

There is only limited evidence from Spain for stage one. Malachite ore fragments are found at the Millarian site, El Malagar (Arribas et al, 1978). An outcrop of malachite ore is situated near the site (Hook et al, 1987).⁹ Copper sources in Iberia are discussed briefly by Craddock (1980).

Stage two. While beads are easily fashioned from nuggets of native copper, longer and thinner artefacts like pins, awls and wire would require hammering and thus would have to be annealed to prevent fractures in the copper. The earliest evidence for stage two is given in Table 4.3.1.4.

Though the annealing technique was known in the Near East in the seventh millenium BC, it is more common in the sixth millenium BC. The pace of metallurgical development in the Near East at this time is still slow and de Jesus (1980, 145) warns against basing our impression on the evidence from a few sites available. The earliest reference from Egypt comes from the two Old Kingdom (Fifth Dynasty) tombs at Saqqara. Hieroglyphs on the tomb walls at Ti and Wepemnofret contain references on the annealing of copper (Weinstein, 1974).

In the Balkans this stage was reached in the mid-fifth millenium BC (Final Temperate Neolithic) where it is known from only a handful of sites, as in the Near East.

Aegean finds are restricted to those from Chios (Hood, 1981, 657), dating to the EN-LN; a piece of copper from an EC I context in Paros (Panagia site) and possible Chalcolithic finds from Cyprus (Peltenberg, 1983; Swiny, 1983).

In Italy some of the Neolithic finds mentioned in stage one could represent this stage also. Possible copper wire drillings, but not the wire itself, is the only evidence for this stage from Sardinia near Grotto Rifugio, Nuoro province (Tylecote et al, 1983). This "find" dates to the third

millenium BC.

Stage three is the beginning of true copper metallurgy. As the melted metal had to be directed to form, moulds accompany this development. Annealing, hammering (hot and cold) and polishing or filing would be used to obtain the final shape. It would quickly be realised that the more accurate the mould the less work required afterwards. The development of moulds from this time on can tell us much about casting techniques.

It is in the first quarter of the fifth millenium BC that we first see evidence for melting in the Near East. The earliest find from Can Hasan is complex for its time and suggests prior development of the technique for which no evidence is now available. It was not until the first half of the fourth millenium BC that large tools, mostly cast, become common. While analyses of artefacts from Can Hasan and Mersin testify the use of melted native copper, it is possible that trace elements in some of the coppers from Mersin and other sites demonstrate the use of a smelted pure oxide copper (French, 1962, 33; Esin, 1969). It is, after all, towards the end the fourth millenium BC that we have the first evidence for copper oxide mining at Timna and Çhinflon (Rothenberg, 1978, 180; Jovanović, 1980).

We should note that the copper from Aceramic Neolithic levels at Çatal Hüyük was believed to be smelted (Neuninger, Pittioni and Seigl, 1964), but the slags analysed demonstrated that the copper was only melted (Selimkhanov, 1977 1-6). Evidence for melting and casting of presumably native copper is also represented on the mastaba tombs at Saqqara (Weinstein, 1974).

It is difficult to distinguish stages three and four in the Balkans because the oxide copper deposits are very pure. Although moulds are generally rare, some two- and three-piece moulds are known from the Gumelnitsa focal area (Karanovo VI cultures), Chernykh, (1978, 277, 293). The earliest

evidence for extractive metallurgy comes from fourth millenium BC contexts at Rudna Glava and Ai Bunar - both have copper oxide ores, mainly malachite (Jovanović and Ottaway, 1976; Jovanović, 1980). The scale of metallurgical production in the later fourth millenium BC implies earlier development in the preceeding Karanovo V/Maritsa/Vinča C periods. Melting of native coppers and casting in open moulds no doubt also took place at this time.

In Bohemia, the early Eneolithic site of Makotřasý gives the earliest evidence for casting so far north. Several melting crucibles dating to around 3000 BC are known and analyses of the earliest artefacts shows that they were very pure ($\approx 99\%$ copper), Pleiner and Bialeková, (1980, 16-18).

In the Aegean, the earliest evidence for stage three comes from Thermi I where crucibles are known (Lamb, 1936, fig. 44, 31.72). A pouring cone is known from Poliochni (Brea, 1964, pl. lxxxii, r, s, t). This could also be a tuyère, though that implies the smelting of copper ores as tuyères are used to create reducing conditions. In the LN, an axe is known from Knossos in Crete and copper artefacts from Emproio on Chios (Evans, 1921, 35, II, 14, fig. 3.5; Hood, 1982). These suggest melting and preliminary casting in an open mould.

The evidence for melting and casting of native copper in Italy is well documented. Three Eneolithic (Chalcolithic) axes are known from Chiozza contexts at Bocca Lorenza site, near Santorso, Vincenza. Matteoli and Storti (1982, 65) have demonstrated conclusively that they were made of pure copper metal, most probably native and that the copper was melted in an oxide rich atmosphere and most likely cast in an open stone mould. In the succeeding phase, a hoard of axes from Lagozza contexts at Isolino could have been made by the same techniques.

Eaton (1980) analysed 109 artefacts from the Italian copper age and showed that about fifty per cent of them were made of "pure" copper. One

cannot be sure yet if they were made of native copper, but this seems highly likely.

There is at present little evidence from Spain for this stage.

Stage four. The technological step following the melting of native copper was the smelting of pure oxide copper ores. It has been shown that the technological step need not have been as dramatic or as distinct as previously believed (Charles, 1985).

In the Near East the smelting of oxide copper ores is first hinted at from some of the analyses of coppers from Mersin, level XVI. Yakar (1984, 160) believes that de Jesus (1980, 147) should not date level XVI so high, as level XV, XIV and XIII were seriously disturbed and stratigraphically doubtful. Further, the Troy I shapes at Mersin in the Late Chalcolithic are probably intrusive from level XII, or imported. Level XVI is 'Ubaid, though the coppers are later than the high chronological scheme of Mellaart (1964) suggests.

It is not until the second half of the fourth millenium BC that smelting gets under way. Smelting slags are first positively demonstrated at Tal-i-Iblis at the end of the fifth millenium BC and analyses of associated copper ores confirm that copper oxide and not native copper was used. (Caldwell, 1967, 17-20, fig. 2; Caldwell and Shahmirzadi, 1966, 11-14).

In the fourth millenium BC, copper smelting, using a rudimentary smelting furnace, has been identified at Timna in Israel (Rothenberg, 1978). Smelting is also known from contemporary Abu Matar in Palestine, though only crucibles were used at this site (Bar Adon, 1971). At Norşuntepe in the Keban, crucibles, benches, fireplaces, moulds and copper slags are known from an EBA context (Mellink, 1975, 206). Smelting slags are known also from Mrashshash which date to the EBA II (Several, 1973).

The Nahal Mishmar hoard in southern Palestine, which dates to the end

of the fourth millenium BC, was made either of native copper or of a pure smelted copper. In view of the number of finds it is reasonable to presume that most of them would have been made with smelted copper (Mellaart, 1966; Bar Adon, 1971).

At Jericho in the Levant possible EBA smelting slags of copper oxide (cuprite) are known (Khalil and Bachmann, 1981, 103).

Most of the evidence for copper smelting coincides with the first evidence for extraction. The repertoire of types starts to become more complex and it is just a matter of time before the advantages of using a bi-valve(closed)mould would be noticed and with it the attendant problem of deoxidising the copper.

Analyses of slags from Rudna Glava copper mines in Yugoslavia demonstrate that ^{the} technique used to smelt the oxide ores was complicated and quite advanced (Ottaway, 1975, 30; Tylecote, 1976). The evidence strongly indicates an even earlier primitive phase of copper smelting for which little evidence has yet been found.

In general, the Eneolithic in Bulgaria is characterised by the large scale production of heavy shaft-hole axe adzes, axe hammers and chisels. There are correspondingly more finds from the Balkans for this technical stage than from the Near East as a whole. Comparatively few moulds have survived, however.

Chernykh (1978) carried out analyses of many Balkan copper artefacts of the period. His Group I, which roughly corresponds to Gp N of the Stuttgart analyses (Junghans et al, 1968), comprises of copper artefacts made of very pure copper (As = 0.4%, Sn = 0.4%). Lead, bismuth, silver, antimony and arsenic are especially important for the definition of his groups. In Yugoslavia most of the Eneolithic material falls into this group. Nearly 75% of the Romanian and Hungarian objects fall into his Group II, which in turn is

roughly equivalent to Gp E₀₀ of the Stuttgart team. More than 90% of the Eneolithic coppers from Bulgaria were manufactured from unalloyed, metallurgically pure copper and pure unalloyed smelted copper was still the most common type in the EBA I (c.3000 - 2500 BC), especially in the Ezero focal area (east Balkans), Chernykh (1978).

In the Aegean the evidence for smelting copper oxide ores comes from several moulds, tuyères and slags. The earliest finds come from Thermi II and from a LN context on the island of Giali (Lamb, 1936; Sampson, pers comm.). The Giali find consists of a large clay pot, obviously fired, which contains copper corrosion. No doubt the pot was used as a large crucible. Troy I has an open stone mould and slags are known from Poliochni in the EBA I (Blegen et al, 1950, fig 221. 38.100; Brea, 1964, 591). We can assume that the copper used was smelted copper as analyses of contemporary finds have demonstrated that smelted copper was known and used (Schliemann, 1880; Brea, 1964; Junghans et al, 1968).

In Italy, the earliest evidence for smelting comes from Fontega in the north (Matteoli and Storti, 1982). The Eneolithic axe from this site was made from smelted chrysocolla and cast. We have already noted from Eaton's analyses (1980) that about half of the Copper Age finds were of pure copper. About ten % had trace element levels suggestive of a pure had been smelted copper oxide. Thus, the technique known in the third millennium BC/ mastered in the preceding Eneolithic. There are well over one hundred and 30 Copper Age finds from the Rinaldone culture. This area has the best copper sources (Monte Amiata and Colline Metallifere) many of which have copper sulphides accompanied by copper oxide zones.

Preuschen, (1973 note 4) and Barfield, (1981, 44) suggested that the Remedello culture could have obtained its copper from the southern Alps or beyond, though Tylecote et al (1983) suggests that the Sardinian sources

could have supplied the north. There is evidence however for pre-Bronze Age smelting in the southern Alps at Valbusa di Vela (Fascani et al, 1969) and also for Chalcolithic metalworking, possibly smelting, from Riparo Gaban. Barfield (1981, 46) believes that it is likely both locations were already worked in the Chalcolithic.

Recent evidence from Spain is very illuminating. Copper was smelted in the later third millennium BC and it is highly possible that local ores in Spain were used in the south east (Hook et al, 1987).

Stage five involves alloying with arsenic. This enabled and perhaps encouraged the use of two piece moulds and thus permitted a wider range of more complex forms.

In the Near East, the systematic use of arsenic-copper alloys is one of the most important technological features in the fourth millennium BC. Arsenical coppers become the most common alloys of the third millennium BC in most areas of the Near East. The relative distribution of arsenical and pure coppers varies markedly from region to region in this period (Eaton and McKerrell, 1976). This appears to be very much the picture in the preceding fourth millennium BC also. It is through the relative use of arsenic that we can talk about the origin of the technique and perhaps the sources used.

Arsenical alloys, apparently deliberate, have a long history in the Caucasus, extending back to the fourth or perhaps the late fifth millennium BC (Selimkhanov 1977).

Similar high arsenic contents are not known anywhere in the Near East until later in the fourth millennium BC. The first evidence for arsenic alloying comes, indirectly, from bi-valve moulds and *cire perdue* moulds. The earliest examples of two-piece moulds come from Iran and Mesopotamia, for example, at Sialk III, Susa B and in the 'Ubaid culture of Mesopotamia. A late fourth millennium BC awl from the Levant (Abu Matar) contained 12% arsenic and half of the artefacts from

the Nahal Mishmar hoard (the jewels) were arsenical coppers, Bar Adon (1971). Analyses suggest that 5% arsenic was added to the smelted copper. These are "true" and deliberate arsenical bronzes and not the products of accidental smelting of arsenical copper ores. It is almost impossible to distinguish accidental from intentional arsenical coppers with arsenic in the range of 1% to 2% (see 4.2.) The Nahal Mishmar finds testify to the deliberate alloying of arsenic with copper from the end of the fourth millenium BC.

Artefacts from Late Chalcolithic contexts at Beycesultan (late fourth millenium BC) have high arsenic contents. De Jesus (1980, 130) suggested that the availability of good arsenical coppers to this site enabled the site to resist the switch from arsenic to tin at the end of the third millenium BC. Gale et al (1984,^b 164) have recently shown that the Kizileva deposit near Beycesultan, which contains oxidised copper ores and is much closer to the site is the best candidate of those proposed by de Jesus.

Further, if one studies the distribution of high arsenical-copper ~~lodes~~, copper sources, the evidence for mining and the distribution of arsenical-copper artefacts for Anatolia in the third millenium BC, (de Jesus, 1980, Appendix V, 202, Map 11), one sees that they cluster closely to one another (approximately 200 kilometre radius per group). Some important sites cluster around sources. For example, Ahlatlibel and Polatli sites are near İsikdağ arsenical-copper source and Karaali copper mine. Kültepe, Çatal Hüyük, Can Hasan and possibly Mersin are close to Bolgar-Dağ arsenical-copper source and Beycesultan. Alaca, Horoztepe and Mahmatlar are close to Kozlu, Ağaca Ağaclı and Bakır Çay mines and arsenical-copper sources.

The relationship is not precise, but it does demonstrate that arsenical-rich copper sources are close to known copper sources and that many nearby

sites have arsenic-rich copper artefacts. Recent lead-isotope work in Anatolia has shown that major EBA sites relied on ^{both} local and distant copper sources (Pernicka *et al*, 1984; Gale *et al*, 1984). We have evidence for a trade in copper in Anatolia, even though local sources were known. It seems more likely now that arsenical-rich copper was also traded. Eaton and McKerrell's (1976) interpretation of Assyrian texts may still be proven correct (see 4.2).

Arsenical copper is also known in the Keban from a late fourth millenium BC context at Tepe Yahya (Lamberg-Karlovsky, 1973). In Mesopotamia, generally, several ordinary objects from late fourth/early third millenium BC contexts contain 1%-2% arsenic (Moorey, 1982, 284). Specialist products, like the bowl from Sialk ^{which} is made of copper alloyed with arsenic, are known for the first time at the end of the fourth millenium BC.

Regional variation in the use of arsenic and in the amounts of arsenic employed is clearly brought out by de Jesus (1980, 124-139) in his survey of arsenic use amongst various centres in Anatolia.

From the analytical programme of Eaton and McKerrell (1976) the primary features of the relative use of arsenic in the Near East as a whole is shown. The same number of artefacts were not analysed for each area however and this does induce some bias into the results. It is disappointing that the actual chemical results were not fully published.

Alloys vary markedly from area to area. A useful level of arsenic (defined as 1%-5%, by Eaton and McKerrell, 1976) was widespread and for certain areas (Syria, North West Iran, the Cyclades, Crete and the mainland of Greece) it was used in about two-thirds of all analysed objects. Only in the Troad was more use made of tin bronze in the third millenium BC. When they looked at the artefacts with the highest levels of arsenic (in excess of 12%), they explained that in most of these instances arsenic was not used simply as an alternative alloy, but also as a colouring technique producing the

effect of artificial "silver" on the surface. They go so far as to say that widespread use of arsenic as an alloy in the third millennium BC, from Iran to Britain, was encouraged by its silvery properties and that perhaps the value of arsenic as an alloy agent (at lower levels) was subsequently understood. The general dating of the majority of high arsenic finds belongs to the second half of the third millennium BC.

So far no metallurgical study has been conducted to see what are the effects of high arsenical levels in a closed mould. Perhaps the "inverse segregation" was not as deliberate as implied. "Silvered" arsenical copper use does coincide with the first large scale use of silver in the Aegean and Near East, however.

In the Balkans, we have already noted, 90% of the analysed objects from Bulgaria were unalloyed (Chernykh, 1978). A few objects in the Eneolithic did have high levels of arsenic, however. One must be wary of what Chernykh defines as an arsenical copper. It is well below the limits set by others (see stage three, above). He also defines tertiary alloys which will ^{be} discussed more fully below. In the EBA, his data for the Ezero focal area demonstrates that while arsenical-copper alloys (as defined) are rare in the EBA I (c.3000-2500), the predominately unalloyed copper is replaced by high arsenical coppers in the EBA II (c.2500-2000 BC). This change is accompanied by an increase in the number of moulds for shaft-hole axes and the axes themselves. Altogether, in the EBA, arsenic in copper is three times as common as tin. The EBA Ezero and Caucasian industries were probably linked by the Usatovo culture which is located north of the Black Sea, though the arsenic levels of the Usatovo culture are closer to those of the Ezero focal area than the Caucasian industries. The Caucasian metal-smiths who generally used high arsenical copper, had close contacts with Near Eastern industries, though it is not possible to conclude that this region, rich in arsenical-copper, supplied the Near East.

Stage five is well recorded in the Aegean. Closed moulds are known from the Cyclades and the Troad in the mid-third millennium BC. The very earliest moulds are known from Troy (Schliemann, 1880, 603), Poliochni (Brea, 1964, pl. lxxxv,d) and Thermi (Lamb, 1936, fig.44, 30.23a) at the beginning of the third millennium BC. Pouring cones or tuyères are known from the same period. The **cire perdue** mould from Poliochni is the earliest of its kind (Brea, 1964). From Crete the EM metal mould from Aghia Kyriaki completes the list of initial finds . All the finds testify that a means had been found of deoxidising the copper oxide so that it could be formed in a closed mould. Analyses of Cycladic material has shown that arsenical alloys with arsenic in the general ranges of 3% was the most common alloy of the third millennium BC (Tsountas, 1898; Renfrew, 1967; Bossert, 1967; Junghans *et al*, 1968). Reanalyses of several of the Cycladic artefacts from this period has not significantly changed the picture (Gale and Stos-Gale, 1984). Similar results have been found for Crete (Mosso, 1910; Xanthoudides, 1924; Mitten and Doeringer, 1968; Junghans *et al*, 1968). Analyses of Troadic artefacts have shown that tin was the dominant alloy of the third millennium BC (Schliemann, 1880; Schmidt, 1902; Dörpfeld, 1927; Lamb, 1936; Bittel, 1959, Junghans *et al*, 1968 and Eaton and Mckerrell, 1976).

Analyses by Eaton (1980) of Italian copper-based artefacts from third millennium BC contexts showed that forty-five out of one hundred and nine contained arsenic in the range of 1%-5% and seven had arsenic in the range of 5%-10 %. In other words, arsenical coppers were rare in the Copper Age but flourished in the succeeding EBA (c.2200-1800BC).

Craddock (1980) analysed six pre-Beaker axes from Spain. Five were pure copper and one was an arsenical copper alloy. These results were similar to those obtained by Junghans *et al* (1968). Recent work by Hook *et al* (1987) demonstrates that the deliberate alloying of arsenic and copper

was practiced in the third millenium BC. No trace elements associated with arsenical copper ores were noted at significant levels. Arsenic ranged in levels from 0.43%-3.76%. This new data means that Craddock's previous view regarding the dissimilarity between Iberian pre-Beaker axes ("pure coppers") and contemporary Aegean axes (arsenical coppers) no longer holds. It is still not possible to say exactly how the two metalworking industries could be related. The new analyses in this thesis show that some Aegean axes were made of unalloyed copper. Apparently, co-smelting of copper and arsenic took place in the crucible in Spain (Egnaras, 1983; Hook et al, 1987). We cannot exclude the possibility that arsenical coppers were imported to Spain, however.

Stage six is the alloying of tin and copper. The tin bronze finds in the Old World are listed fully in Table 4.3.1.4. Yakar (1984) dates the beginning of tin bronzes in Anatolia to the period 3500-3000 BC, which means that the Troadic industries did not develop tin-bronze metallurgy before the Near East. The very earliest find from Thermi I (Lamb, 1936) is however earlier than Troadic and Near Eastern finds. Tin bronzes are known ^{in the Near East} /contemporary with later Troadic finds, but they are rare, (Moorey, 1982). At Troy I apparently only one artefact containing tin was found, and the actual zenith of tin-bronze usage occurs at Troy II (Stech and Pigott, 1985). Though the chronology of Troy is debated, (Blegen et al, 1950; Eaton and McKerrell, 1976; de Jesus, 1980; Yakar, 1984; Coleman, 1985) it would appear that this peak in the occurrence of tin bronze takes place about 2800-2450 BC (Yakar, 1984). In the East, only Mundigak in Afghanistan appears to have produced very early tin-bronzes, sometime after the latter half of the fourth millenium BC (Stech and Pigott, 1986), that is, roughly contemporary with Sitagroi IV and perhaps Gomolava. At Susa, several tin bronzes were found, only one of which was a true bronze. These finds are very distant from the Troadic group and no doubt developed quite

separately. The earliest finds from the Caucasus (Maikop) are not well dated. They belong to the beginning of the third millenium BC. In the Levant the earliest finds from Tell Judeideh may belong to the same period and are thus contemporary with the Troadic and Susa finds. Tin bronze is known also from Tepe Gawra X and Tepe Yahya and they represent the earliest finds in east Turkey. The sites are located geographically between Susa and Tell Judeideh and could thus have obtained tin from a trade route serving these sites.

In the Troad and the Levant tin sources are known but no tin is known from the immediate vicinity of the other sites. Tin therefore was traded from at least the beginning of the third millenium BC and not in the middle of that millenium as previously thought.

It now looks possible that true tin bronzes began in several regions of the Old World from the later fourth millenium BC, but the connection between the various early occurrences is not clear. Troadic industries are distinctive (Stronach, 1957), but they do not seem to have been the originators of the tin bronze technique (de Jesus, 1980, 150). Branigan (1974) had suggested that the early Trojan industry was stimulated by the contemporary Balkan industries. The evidence for tin bronze production in the Balkans is roughly contemporary with the earliest finds in north west Anatolia.

The levels of tin in the Eneolithic tin bronzes from Bulgaria (Karanovo and Ruse Mound) are true tin bronzes with 6.0%-10.0% tin. They therefore represent alloying with cassiterite (see 4.2)

The earliest finds from east central Europe date to the early third millenium BC. Finds are widespread, but very rare. The very earliest find, from Gomolava (Vinča-Pločnik), seems extremely early (Ottaway, 1975). Chapman (1981) casts some doubt on its context and suggests that it may be an intrusion from later levels. The site is contemporary with Late Neolithic cultures in Greece. The tin-bronze find appears at a time when literally hundreds of massive Balkan copper axes and adzes were being

made with only traces of silver to alter their pure composition. The Gomolova find could represent one of the earliest European experiments with tin, or it might be considered an unusual occurrence occasioned by the accessibility of the nearby Cer deposits.

Cherynkh (1978) analysed a number of third millenium BC Bulgarian artefacts and demonstrated the use of tin in the manufacture of bronze, though arguments for a later, second millenium context, have been advanced (Gale et al, 1984)^b. There are other sporadic finds of tin bronzes in Hungary, Bohemia, Romania and Czechoslovakia in the third millenium BC and there is no reason to question the contexts of these finds, Table 4.3.1.4:

It is not easy to assess how much tin from the Balkans made its way to north west Anatolia in the early third millenium BC. Eaton and McKerrell (1976) have shown that there is a great deal of variation in tin levels used in the Near East. About one quarter of all metalwork is tin bronze in Anatolia before 2200BC and Anatolia has more tin bronze than the Near East in the third millenium BC. The Stuttgart programme also showed this (Esin, 1969). Gale and Stos Gale (1984) demonstrated that the Stuttgart programme recorded tin levels at slightly lower levels than those found when some of the artefacts from Anatolia were reanalysed, but their findings do not change the general picture.¹⁰ New finds from six sites in Syria confirm the picture obtained by Eaton and McKerrell (1976).

Tin bronzes in the Aegean start in the middle of the EBA, though they are relatively rare before the second millenium BC. The earliest tin bronzes in Crete and the Cyclades contain on average 3% tin and thus represent deliberate alloying with cassiterite. No cassiterite sources are known in Crete or the Cyclades (see 3.2.4) and so all tin used must have been imported. It has been argued that the high tin levels in some Cycladic artefacts from EC II-III Syros are the result of using bronze

imported from the Troad (Gale ^bet al, 1984). A similar explanation does not necessarily apply to tin bronzes from other areas of the Cyclades or from Crete.

Tin bronzes are not known in Italy or Spain in the third millenium BC, Eaton (1980), Craddock (1981) and Hook et al (1987).

Stage seven concerns the smelting of copper from sulphide ores. Not enough analytical work has been done to help us distinguish the early use of sulphide copper in the third millenium BC. It is generally believed that smelting copper from sulphide ores was mastered in the second millenium BC, though it could well have started before that in areas which were progressive in metallurgical technology.

4.3.2 LEAD AND SILVER

Table 4.3.2.1 contains a list of the earliest lead and silver finds from the Old World. From this it will be obvious that the working of lead started at approximately the same time as primitive copper working. Silver finds are known from the late fourth millenium BC in the Near East.

Definite smelting is known at Byblos, where 223 artefacts were made from cupelled silver (Dunand, 1950, 583). It is possible that the finds from Jedmet Nasr and contemporary contexts in Mesopotamia and the Levant were also made of cupelled silver.

In the EBA II cupelled silver was used at Alaca, Mahmatlar and Troy, Treasure A, (Koşay, 1951, 189; Schliemann, 1880, 470-471.) Although the silver find from the Royal Cemetery at Ur was not cupelled silver (Koşay, 1951, 189; Woolley, 1934, 293, Limet, 1960, 47), analyses showed that copper had been added. This practice is also known at Troy I and Alaca. De Jesus (1980, 75) argues that the presence of copper was to improve the colour not the strength as Patterson (1971) had previously suggested.

Silver and lead became more common in the middle of the third millenium BC. There is a coincidence between the first finds of silver and lead in west Anatolia and the distribution of galena sources in that area. For example, a galena source is located to the north of Alaca, to the west of Beycesultan and to the north east of Troy (see de Jesus, 1980; Fig. 4.3.1.3.). No nearby sources are known for other major silver/lead finds, such as those from Mahmatlar, Alishar Hüyük, Ahlatli Tepecik and Poliochni, for example. This suggests a trade in silver (and lead?) in the second half of the third millenium BC, at least.

It is during the third millenium BC that most of the Cycladic islands are first settled (Cherry, 1981, see Ch.7.). These islands produce more lead and silver artefacts in the third millenium BC than any other area of the Old World and it is in the Aegean that we have the earliest evidence for exploitation of lead and silver sources, for example at Aghios Sostis on Siphnos (Wagner *et al*, 1980).

Several sources of lead and galena are known in the Aegean and a few in west Anatolia. It is perhaps significant that one of the main galena sources in west Anatolia is situated at the most probable point of departure for sailors making for the Cycladic islands. Perhaps Anatolian immigrants brought with them the knowledge of lead and silver working.

In pre-Dynastic Egypt, silver was more highly praised than gold up until the XVIII Dynasty (Partington, 1935, 46). The earliest find of silver is a bead from Naqqada. This is an important discovery because there has been a debate as to whether the Egyptians exploited their own sources of galena or not (Gale and Stos-Gale, 1978; Hassan and Hassan, 1981). On present evidence there seems no real justification for the claim made by Gale and Stos Gale (1978) that the Egyptians obtained their silver from the Aegean in the third millenium BC.

If one looks at the distribution of lead and silver artefacts on Crete

during the EBA-MBA, one observes that though the number is relatively small, (about 3% of total EBA finds), almost all are located in the north of the island - mainly between Mochlos and Herakleon. This an area of the island where the use of gold is rare (Branigan 1970). Contact between Crete and the Cyclades increases in the second half of the third millenium BC and some silver/lead was exported from the Cyclades to Crete at this time, (Stos-Gale and Gale, 1984). Branigan (1970) noted that the orientation of later Cretan ports and major centres (Knossos and Phaistos) was guided by the need to serve and control northern and southern trade, respectively. It is possible that this orientation started in the third millenium BC - northern Crete being orientated towards the Cyclades and southern Crete to Egypt and the Levant. The distribution of Levantine daggers and Egyptian ivory is predominately southern. Sea routes from the Cyclades to Crete would draw craft into the north of the island, whereas routes south from Crete sweep into the east Mediterranean (see Ch 7).

Therefore, it is not likely that the Egyptians obtained silver, or all of their silver, from the Aegean as most of this would have gone via southern Crete and the use of silver in southern Crete does not support such an interpretation.

There is only very limited evidence for silver in the Balkans.

Very little silver is known from the west Mediterranean. It is interesting that the silver crutch-headed pin from a Remedello context is a north Alpine type in a material which is most common in the Aegean. Lead and silver finds are very rare in the third millenium BC. Lead was used mainly for pottery repairs (see Atzeni in Tylecote *et al*, 1983, note 26). Important cassiterite deposits are known from Sardinia (3.2.4.) though there is no evidence for exploitation before the second millenium BC, Tylecote *et al* (1970).

Branigan (1968) believed that the silver daggers from EM Crete came from Italy, because of the known cassiterite deposits there and typological similarities between Cretan and contemporary Italian daggers. Renfrew and Whitehouse (1974) disagree, mainly because there is little evidence for the use of silver in Italy during the third millennium BC.

The first substantial production of silver in Iberia did not start until the Argaric culture (Hook et al, 1987).

4.3.3 GOLD

As primary gold was not used until well after the period under consideration, the distribution of gold finds represents the use of native or secondary gold. Hartmann (1972) has tried to show that primary gold was used in the Late Neolithic, but his interpretation of the analytical results has been heavily criticised (Muhly, 1980; 3.1.1.). No evidence for the exploitation of secondary gold would remain and therefore only the distribution of gold finds will provide a guide to possible sources used. Table 4.3.3 .1 lists some of the early finds.

The evidence for the use of gold is limited, because of its precious nature. It was used mainly for jewellery in the third millennium BC, though it is known earlier. Gold was a prestigious material from very early times. It is often associated with rich deposits in settlements and graves and so is a guide to social hierarchy.

There seems to be no direct relationship between the distribution of known gold deposits and gold artefacts. Some exchange of gold is implied. Many sites with gold artefacts (in Anatolia, at least) are on known trade routes.

Unrefined, native gold was used in pre-Dynastic Egypt. Melted gold which implies refining, was used for the Sumerian Royal Cemetery at Ur (Young, 1972, 9). Alloys with gold are known from the third millennium BC in the Near East: electrum from Troy II (Schliemann, 1880, 272, 472, 493);

gold and silver and gold and copper from Ur (Plenderleith and Woolley, 1934, 294).

There is relatively more use made of gold in Anatolia than in the Near East during the third millenium where Troy and Alaca have the majority of gold finds between them in their famous treasures.

Gold is relatively rare in the Balkans, but the Varna hoard suggests that this absence is fortuitous (Gimbutas, 1977; Renfrew, 1978). The goldwork from this cemetery is distinctive and very early (=Karanovo VI). that is, later Chalcolithic in Bulgaria or c. 4600-4200 BC. Goldwork of comparable size and accomplishment is not seen in the Near East or Aegean until the EDII period, the time of the Royal Cemetery at Ur and the treasures of Troy II and Alaca which cannot antedate c2500 BC. Another contemporary hoard is known from Chotnitsa in the Balkans (Angelov, 1959). and numerous small gold pendants are known from Copper Age contexts in south east Europe and the Carpathian basin. These are probably of the same date.

All the early Balkan gold finds appear to have been made from native gold and ^{by}hammering as there is no evidence for melting and casting.

Branigan (1970, 182) suggested that the Early Minoans obtained their gold from Egypt. Gold is certainly more common in southern Crete, and is most plentiful during the EM II which correlates with the gold treasures of Troy and Alaca. Most of the goldwork in Crete was made from gold sheet - cold hammered, but possibly annealed. Trade and contact between Crete and Egypt in the second half of the third millenium BC is quite well documented.

The earliest gold in the Aegean comes from Thermi I and Troy I (Lamb, 1936, 165; Dörpfeld, 1902, 324). A few later Trojan artefacts may have been cast (Schmidt, 1902, 345). Only one find of gold is known from the Cyclades. It is an EC I-II bead from Naxos (Papathanassopoulos, 1961, pl.71a).

There is little difference between the range of techniques and forms

current in the Aegean and Near East, except perhaps the use of repoussé which was known in the Near East, for example at Ur.

There is little evidence for the use of gold in the west Mediterranean during the third millenium BC.

4.4 THE ANALYTICAL METHODS AND SAMPLING PROCEDURE

The analytical methods used were X-Ray fluorescence(XRF), Electron Microprobe (EM) and Lead Isotope Analyses (Pb-isotope). Metallographic analyses are available for a few of the artefacts and so the technique is also briefly described. The sampling goals and procedure are outlined.

4.4.1. X-RAY FLUORESCENCE

This technique has been applied successfully to a range of archaeological material. It is discussed in Tite (1972, 267-271) and numerous applications to metals are given in PACT (1977, vol. 1).

The irradiation of a sample with X-rays produces secondary X-rays which correspond to certain chemical elements. The measurement of such secondary radiation defines the chemical composition of the irradiated object (trace elements in ppm and minor elements in percentages).

This method is non-destructive though the analysed thickness of material is very small, lying between 20-200 μm . The limited penetration into the artefact is one of the disadvantages of the method as the analysis is not always representative of the typical composition of the object. This can be overcome, to some extent, if several analyses for each artefact are taken, each from different sections of the artefact. Oxidised metal surfaces are not suitable for analysis. In the present study, samples were taken from the interior of the artefact, by drilling. Non-uniformity in the mixing of an alloy is certainly a problem, and in a few cases more than one drilling was taken.

The accuracy of the method is better than $\pm 5\%$. It is a fast method of qualitative and quantitative analysis. It is useful for the swift determination of lead concentration for further lead-isotope analyses. It is not a method which could help provenance metals, though it does bring out the main difference in composition.

4.4.2 ELECTRON MICROPROBE ANALYSIS

Details of the method and application are given in Tite (1972, 278-281).

The instrument used for this technique combines the techniques of XRF and electron scanning microscope. Irradiation of the sample is made by a beam of electrons which produce the emission of secondary X-rays which in turn represent certain chemical elements. The advantages of the method are that the beam focuses on a very tiny part of the surface of a specially prepared sample of $1\mu\text{m}$ in diameter and can scan the area of the sample giving an average composition for it. One can thus study the variation in composition of each sample area. A further advantage is the optical presentation of the analysed surface.

The error involved is better than $\pm 5\%$. Concerning the range of elements analysed, and the lower limit of detection (100-1000 ppm), this method is comparable to XRF.

4.4.3 LEAD ISOTOPE ANALYSIS

This is a method which distinguishes copper and lead ores formed in different geological epochs. As the technique has only recently been applied to archaeological material, something of its history must be said here.

The technique of lead-isotope dating was first applied to archaeological metals, after being developed for geological dating, by Wampler and Brill (1964, 109f.) and Grögler et al (1966, 1167-1172). These scientists

pioneered the study of lead isotopes for interpreting sources of lead objects used in Antiquity. Brill and Shields (1972, 279-303) first applied the technique to numismatics. Lead-isotope work in the Aegean began under the Max-Planck Institut für Kernphysik at Heidelberg University, as part of a project looking at the sources of Archaic silver coins (Gentner et al, 1978). The results of this study showed that there were two sources of silver for the Archaic Greek world -Siphnos and Laurion. Thasos was later identified as a further source. As the technique proved so effective and as there was evidence for the exploitation of the Aghios Sostis silver mine on Siphnos in the Early Bronze Age, Wagner et al, (1980) extended the programme of research to silver and lead sources in the Aegean Bronze Age.

In the early 1980's, workers in the Heidelberg project divided into two groups. The first was centred at Heidelberg and the second at Oxford University. In 1981 the Oxford Group (Gale and Stos-Gale) studied Early Cycladic silver and lead sources and artefacts. The technique was extended to coppers and bronzes (Gale and Stos-Gale, 1982). So far their work has shown that lead, silver and copper were exploited in the Laurion in the LBA (Stos Gale and Gale, 1982; Gale and Stos Gale, 1982) and that ~~some~~ lead and silver from the Laurion was being used in the EBA by both the Minoans and the Cycladic islanders (Gale and Stos Gale, 1981; Stos Gale and Gale, 1983; Gale Stos Gale and Davis, 1984 and Branigan, 1982). An attempt to demonstrate which sources of copper were used in the Cyclades and north west Anatolia (based on the analyses of EBA artefacts) was made (Gale, Stos Gale and Gilmore, 1984)^b

The Heidelberg group has concentrated its attention on the sources of silver and lead in the Cyclades during the Bronze Age and on the analyses of both sources and artefacts from the Troad, Anatolia and east Aegean in the EBA-LBA (Pernicka et al, 1981; Pernicka et al, 1982 and

Pernicka et al, 1984).

Figure 4.4.3.1 shows the distribution of lead, silver and copper sources analysed and the general location of most of the artefact bodies studied.

Until now, no lead-isotope analyses have been done for lead, silver or copper artefacts from the Greek mainland in the LN or EBA. The results presented in this thesis (4.5) are a first attempt.

Full details of the principles upon which the lead-isotope method is based is given in Gale (1978, 529-545). The main points may be summarised here. Every copper or bronze artefact contains small amounts of lead and thus has a determinable lead-isotope concentration, just as a lead or silver artefact. The lead-isotope concentrations are expressed as ratios - Pb^{207}/Pb^{206} , Pb^{208}/Pb^{206} , and Pb^{206}/Pb^{204} and when the ratios of analysed artefacts are plotted on a cartesian diagram they can be used for comparisons.

The isotopic composition of lead varies in nature and lead isotope ratios can be taken to characterise different lead or copper ores. The ratios reflect their geological age and that is why the technique was initially used to find the ages of primeval minerals.

The composition of Pb-isotopes in an artefact is found by taking a sample and using a mass spectrometer. Lead objects have nearly 99% lead, while coppers and bronzes have up to 2% lead. As little as one gramme for a 0.01% lead sample is required to enable the analyses to be carried out (Arden and Gale, 1984, 2-9). and this is one of the advantages of the technique. Only small samples are permitted by museums. The characterisation of both ores and metal artefacts by this technique is aided by the fact that the lead-isotope ratios remain constant during the melting-smelting processes. The ratio reflects the age of the source and the technique works on the assumption that independent ore lodes have distinct ratios or narrow ranges of ratios. Thus the lead-isotope composition

of lead or copper in an antiquity will in principle give a unique indication of its provenance. Brill (1970) cautions that although the ratios of galena may characterise one lode or mine, they are rarely unique. It is often found that lode or mines located in geologically similar environments may yield identical isotope ratios even though the regions themselves are widely separate.

A major criticism of workers in the lead-isotope technique is that they very rarely mention the problem of mixing. Lead isotope ratios for artefacts which are composed of metals from two or more sources will give ratios somewhere intermediate between the values of each original source and this will lead to a misinterpretation of the results. It is highly probable that at least some leads and coppers were re-melted and thus mixed. One should note in particular that if arsenic was added to copper deliberately in the form a smelted arsenic-copper concentrate, rather than arsenic salts, the result would be a mixing of the lead-isotope ratios. While the argument for accidental arsenic alloying by Gale and Stos-Gale, (1981) is convincing, one should remember also that such a view must be taken by analysts if they are to justify the results of the method. Thus the problem is more acute for high arsenical coppers, that is, copper with over 2.5% arsenic, as these could not be accidental alloys. The same argument applies to lead-copper alloys where lead levels exceed 1%.

Lead isotope fields are determined by estimates of the boundaries based on the amount of isotopic variation found for copper, lead or silver ore sources. About fifty measurements per source are usually taken. Tentative guides to fields not geographically located can be given by rough fields which serve, chiefly, to emphasise strong groupings between artefact compositions. The exact identifications of lead isotope fields must await their exact geographical location.

It is most important to take into account pertinent geological

aspects of the ore fields studied. Gale and Stos-Gale (1984, 15) believe that Pernicka et al (1984) are quite wrong and dangerously misleading to construct a general lead isotope field based largely on lead isotope analyses of lead and pyrite-blende-galena deposits and then compare it with lead isotope analyses of copper artefacts or copper ores from, say, Cyprus or elsewhere. Lead-isotope analyses of copper artefacts are best compared, they believe, with copper ores which could have been exploited in ancient times. In this respect the Laurion is quite unusual because it is polymetallic, having both copper and lead/silver ores. Lead-isotope analyses of lead and copper artefacts from an EH II site in Attica (Rouf) demonstrated that both types of objects fell into the Laurion field.

The plottings of several important fields in the Aegean and east Mediterranean are often drawn up differently by the Heidelberg and Oxford teams. This may be because the Heidelberg team has determined its fields based on lead and galena analyses mainly. Even so, there is often no explanation given when "fields" for sources alter from one publication to the next. Changes in the shape of the fields are no doubt the result of an increase of data which further refines them. In such cases the scientists involved should state clearly that fields represented are preliminary or provisional and justification should be given for changes in the shapes of fields. Fig. 4.4.3.2.

One of the main drawbacks in the interpretation of the isotopic results at present is that so few isotopic results are available for lead and copper sources in Greece and the Aegean.

It must be stressed that the technique is primarily **negative**, in that it provides evidence which helps to eliminate an ore sample, if the isotopic composition of an artefact differs from the ore, but it can rarely, alone, prove unequivocally that lead in an artefact came from one particular source. Nevertheless, the elimination of mineral areas may have far-

reaching archaeological implications.

4.4.4. METALLOGRAPHIC ANALYSES AND HARDNESS TESTING

Metallographic analysis of an artefact can tell much about the techniques used to produce it and fashion it. Photographs of thin sections show the micro-structure. A dendritic structure is indicative of casting. Elongated dendrites in one direction indicate the direction of hammering. Hammering distorts the microstructure and increases hardness.

Unmelted native copper will often reveal the presense of long, thin isolated twin structures or cracks formed at the sites of non-metallic inclusions (Maddin et al, 1980).

Samples from metal artefacts can be tested for hardness according to the Brinell scale. Such data can be used for comparative purposes.

While no metallographic analyses or hardness testing were carried out specifically for this thesis, much data is available for early metals which is relevant to their interpretation.

4.4.5. THE SAMPLING GOALS AND PROCEDURE

The sampling strategy was devised to ensure that, whenever possible, samples would be taken from artefacts which covered a balanced geographical, chronological and typological spectra and would incorporate copper, bronze, lead and silver artefacts. As far as possible, within the limits imposed by the Greek Archaeological Service, this aim was achieved.

All samples analysed for this thesis were taken personally from museum collections throughout Greece. Samples were obtained by fine drilling or scraping. The sampling procedure followed in the majority of cases is that described by Gale et al (1982). A list of samples and their geographical distribution is shown in Table 4.4.5.1 and Figure 4.4.5.1.

4.5 THE LEAD ISOTOPE RESULTS

4.5.1 LEAD AND SILVER ARTEFACTS (an= no. in Table 4.4.5/no= no. in 1.3.1)

Three lead and one silver artefact were analysed. They date from the LN to EBA III and are supplemented by unpublished results from MBA Lerna. Fig. 4.5.1.1^a, 4.5.1.1^b and Table 4.5.1.1.

All the lead and silver artefacts plot firmly in the Laurion field in both Pb-isotope diagrams which is consistent with the lead having come from the Laurion in Attica. For the sites at some distance from Attica it must be noted that there are a number of lead and galena deposits close by for which lead isotope analyses do not, so far, exist. At the present stage of research one cannot rule out the exploitation of these deposits by the people of Petromagoula or Alepotrypa, for example.

As it is now known that lead and possibly silver from Amorgos, Naxos and Syros in the EC II-III and Kea in the EC II exploited Laurion lead, the use of this source by the mainland communities, especially those in Attica, seems confirmed.

Without the benefit of isotope analyses Theocharis (1954^a) suggested that Raphina obtained its copper and lead from the Euboean ore deposits at Kalianou. Lead-isotope results showed that the lead used at Raphina did not come from this source as the Kalianou and Laurion sources have different lead isotope ratios (Figure 4.5.1.2). This does not exclude the possibility that Raphina obtained its copper from Kalianou and the isotopic analyses of the copper artefacts are eagerly awaited. ¹¹

4.5.2 COPPER AND BRONZE ARTEFACTS

Forty-two copper based artefacts were analysed from seven sites, Figures 4.5.1.1^a and 4.5.1.1^b and Table 4.5.1.1.

The lead-isotope data for copper and bronze artefacts is more difficult to interpret due to the absence of relevant comparative copper ore analyses,

apart from the Laurion, Thasos, Cyprus, Timna and north west Chalkidiki. though several fields determined for galenas can also be indicative, (eg. Siphnos).

Some of the finds from Sitagroi, Petromagoula, Sesklo and Levkas appear to group together in a region of the lead isotope diagram which is no larger than that characteristic of a single copper deposit. In principle, this may be indicative of a common copper ore source, having lead of an isotopic ratio which, fortuitously, partially overlaps both the "Cypriote"¹² and the Laurion fields.

Overlapping of fields can sometimes be interpreted as mixing of copper from two sources (see 4.4.3). The artefacts from the "S/S" source are not apparently the result of the mixing of Laurion copper and "Cypriote" type copper as they cluster together consistently in both lead isotope diagrams. (pers comm. N H Gale).

The geographical location of this presumed source is not known. The estimates of the boundaries of the "field" are based on the amount of variation in isotopic composition found for other copper ore sources so far investigated. At present these estimates are tentative guides only. The exact identification of the lead isotope fields appropriate to the ore body exploited must await its geographical location. The rough "field" serves at present chiefly to emphasise the strong grouping of the coppers.

Provisionally, it can be called the "Sitagroi/Sesklo" or "S/S" source. If the presumption of a single copper source is correct, then one is able to say that, wherever the source is located, it was known from Thessaly, Levkas and northern Greece and was exploited from the LN (evidence from Sitagroi III) until the beginning of the MBA (Sesklo).

Some copper objects from Sitagroi, Petromagoula and Sesklo have isotopic compositions which fall into the "Cypriote" field. In fact

in Figure 4.5.1.1^a, the nine objects from Sitagroi, Petromagoula and Sesklo which are **inside** the dashed line, all plot either in the "Cypriote" or Laurion field, but these all plot **outside** both of these fields, or move from the "Cypriote" to the Laurion field, when using the alternative lead isotope diagram, as shown in Figure 4.5.1.1^b. Copper in these objects, therefore, may not have been derived from either Cyprus or from the Laurion. This leads one to guess that although the other eleven objects from these three sites fall analytically into the "Cypriote" field in both diagrams, as does an artefact from Mandalo, they may not actually be of Cypriote copper. It seems very unlikely that Cypriote copper could have reached northern Greece in the LN, though there is a possibility that such contact may have taken place in succeeding periods. Certainty that the ore used was in fact not Cypriote would require neutron activation analyses or micro-inclusion studies of these artefacts. Neutron activation analysis of Late Cypriote bronzes has recently shown that the trace elements of silver and gold are very characteristic of the Cypriote copper deposits (Gale et al, 1984). We must therefore assume that a copper source or group of sources in Greece or the Aegean has a lead-isotope ratio similar to the Cypriote ores and that these ores were exploited in the LN and EBA by Greek metallurgists.

Of all the known sources in Greece it would appear that this new "S/S" source, if it was a single source, was probably located in northern Greece. Of the candidates which exist, on the basis of assumptions rather than analytical data, Skouries in Chalkidiki (3. 2. 1) is a strong contender, though there are good copper sources near Sitagroi in the hinterland of Kavalla and in the neighbourhood of Lamia and Larissa, not far from Sesklo.

As lead and copper deposits of a known age can be provisionally placed on a lead-isotope diagram, it is possible to plot the ages of most of the

sets of Greek lead or copper sources which have been assigned a geological age before lead-isotope analyses. It would then be possible to see if lead and copper samples, for which lead isotope determinations had been made, fall into any local Greek fields. This could be followed up later by lead isotope analyses of the actual sources which would verify the assessments. Let us look at a few areas of Greece with important copper deposits and attempt to assess their ages (Fig. 4.5.2.1 a,b). Three sources in northern Greece, two in Thessaly, two in southern Greece, two in Crete and one in the Cyclades were examined. The copper sources in northern Greece were Kilkis in west Macedonia, Skouries and Pangaion in central Macedonia and Alexandropolis, Evros in east Macedonia. Both Kilkis and Pangaion copper deposits dated to the Mesozoic (246-60 Ma), but the Alexandropolis deposit dated to the Upper Eocene (25-50 Ma). They would thus have different lead isotope ratios from the "S/S" source.

In Thessaly/Fthiotida, the age of copper sources at Vrinena and Aghios Theodoros were assessed. Vrinena dates to the Maestrichtian-Cenomanian (64-98 Ma). Aghios Theodoros copper dates to the Upper Palaeozoic (246-320 Ma). They would both have totally different lead isotope ratios - even though they are only about 30 kilometres apart. They are unlikely candidates for the "S/S" source.

The age of the copper source at Kalianou (Euboea), three sources from the Laurion (Attica) and three sources from southern Laconia were also assessed. The age of the Kalianou deposit belongs to the same age as the Pangaion and Kilkis deposits in the Mesozoic, though it is quite possible that the three copper lodes date to different sections of the Mesozoic epoch. The lead-isotope age of Kalianou has already been determined (see 4.5. 1.2) and it occupies a small section of this epoch, from 60-246 Ma.

Laurion sources all belong to the Upper Eocene (25-50Ma) and thus are of a similar age with the Alexandropolis copper source. Three copper sources

in Laconia belong to the Permo-Triassic boundary, that is c. 250 Ma.

The three sources in western Crete and one in Anafi island all belong to the Permo-Triassic also (c. 215-285 Ma). It would therefore be difficult to distinguish copper used from the three Laconian sources and Cretan sources by the lead isotope method.

There are many sources which represent a variety of ages. However, those represented here give some idea of the attendant difficulties in interpretation. What this assessment of ore ages has done is to show that the "S/S" source does not have the same geological age as the Skouries deposit in Chalkidiki. The Alexandropolis source is the best candidate.

Most of the Greek finds which fall into the "Cypriote" field are of a date consistent with the Vrinena source in Fthiotidha. The two Sesklo artefacts of great geological age fall into the Thasos field. (an. 52, 64).

Lead-isotope analyses are of course required for all these sources to verify their ages, but this exercise was worthwhile as it brought out clearly the possible contenders for the "S/S" and "Cypriote" sources and they could easily be local Greek sources which we know were accessible and of good quality.

The lead isotope results of the artefacts from Sesklo (EBA III-MBA I) demonstrate that three, and possibly four, copper sources were used. The "S/S" source, the lower "Cypriote" source - that is possibly Maestrichtian in age, 64-72 Ma; a further source which dates to the Cenomannian (92-98 Ma) and a source which dates to the Upper Palaeozoic (246-320 Ma). From the data available above, these sources could all be Greek. A Cenomannian/Maestrichtian and an Upper Palaeozoic source are both known only 50 kilometres from Sesklo. Alternatively, if we use the provisional data for possible Anatolian sources determined by Gale and Stos-Gale (1984) some of this material could fall into their Trojan B (Upper Eocene to Triassic/Jurassic, 60-246 Ma). Some material from later EC Kastri on Syros also belongs to

this field. Some Sesklo material also falls into the general Troadic C group. The computer programme outlined in Ch.5. also picked up some similarity between material from Sesklo and Syros. It seems likely that local source or sources would have been preferred. It is not only the high tin bronzes which fall into the Trojan B field as tin was alloyed with the copper from all three sources,

Chemical analyses of copper sources at Skouries and vicinity have been done (Papastamataki, 1975; see also Table 4.5.1.5), and these were compared with results from LN/EBA material which came from the "S/S" source, but no similarity was found between compositions.

It is interesting that two EBA III-MBA artefacts from Sesklo, which are isotopically quite dissimilar from others also contain lead at higher levels than the other artefacts from Sesklo, Mandalo, Sitagroi, Levkas or Petromagoula. No data is available which would permit the placing of these two artefacts to a particular source. They testify to the use of a further source at Sesklo.

The analyses of two LN axes from Sesklo do not fall into the "S/S" source. They are not in the Laurion or "Cypriote" fields either, even though they are closer to the Laurion field than any other. The preliminary field A for Troy, as defined by Gale et al. (1984)^b, overlaps with the Laurion field at just the point where these two Sesklo axes fall. This does not mean that the copper came from a region of the Troad, but that yet another source of copper was used at Sesklo.

The two objects from LN Dimini each come from two quite different copper ore sources. These sources could, on present evidence, be the Laurion and "Cypriote" source or possibly a source similar to the ore used by the Sesklo samples in the insert of Figure 4.5.1.1^{a,b}. As noted, the use of

Cypriote copper seems improbable. The lead isotope data for the earring (an. 34) are consistent with having been made from Laurion copper. Typological parallels suggest that the Dimini earring is a local type (see Ch.2), and we should perhaps be hesitant in assuming that the copper from which it was made necessarily came from the Laurion. Perhaps a local Thessalian source has a similar lead-isotope ratio. The idea is supported by the fact that the lead from Petromagoula also falls into the Laurion field.

The second object, the axe (an. 35) is made of copper which is isotopically more similar to the two Sesklo objects in the insert. It falls, to be precise, between the Sesklo and Mandalo objects. Chemically, it has a composition quite distinct from contemporary LN axes, such as those from Sesklo, even though typologically it is similar to them. It is possible that the copper used for the Dimini earring and the LN Sesklo axes came from one source which had a similar isotopic character to the Laurion, but not the Laurion itself. One artefact from Sitagroi III which falls into the "S/S" field is quite similar isotopically to the LN artefacts from Thessaly.

The majority of artefacts from EH II Levkas fall into the Laurion field in both lead-isotope diagrams. Analyses an. 80 and 75 lie outside the Laurion field in both diagrams. An. 75 falls clearly into the "S/S" source field and an. 80 may be either in the "S/S" source or the "Cypriote" source. It is interesting that an. 75 is the highest tin bronze from Levkas. Chemically, the second high tin bronze is very similar, but no Pb-isotope analyses was carried out for it. The arsenic range in an. 72 is very similar to Petromagoula sample an. 36 and this Thessalian artefact has exactly the same isotopic ratio as an.80 from Levkas. No local sources of galena or copper are yet known from Levkas and thus if a similar source was used by these two communities or areas, it would probably lie closer to Thessaly.

The copper and lead artefacts from Rouf in Attica both plot in the Laurion field. This supports the view that Laurion copper was exploited in

the EH and strengthens the possibility that Raphina obtained its copper from the same source.

Preliminary data for lead artefacts from MBA Lerna (unpublished work of ZA Stos-Gale) shows that all the lead artefacts fall firmly into the Laurion field. One would suppose that the new lead finds from EH Tiryns (Kilian, 1981) would do likewise.

All this suggests that the organisation for the procurement of metals from the LN and through the EBA was itself quite complex. At least four sources of copper were used in this period and there is no reason to doubt that each of these sources were local Greek copper deposits.

4.6 THE CHEMICAL RESULTS (Table 4.6)

4.6.1 THE LATE NEOLITHIC PERIOD

The aim of this section is to determine the technological level reached by the LN metalworkers of the Greek mainland.

There is no direct evidence for the use of native copper in the LN, although some *artefacts* may have been made from native copper. Annealing and hot-working of copper is obvious from the shapes produced and, as we will see below, from metallographic analyses.

The first question to be answered is whether or not copper was smelted from copper oxide ores locally in the LN.

4.6.2 MELTING VERSUS SMELTING QUESTION (Figs. 4.6.2.1, 2, 3 and 4)

Evidence of ore smelting in the form of *in situ* smelting furnaces with slags is unequivocal *proof* that metallurgists had reached an advanced technological level (stage four). Where this type of evidence is not available, the chemical analyses of slags, waste metals or artefacts can often be used to distinguish between the two processes which produced them - the melting of a native copper or the smelting of copper oxide ore. Interpretation of the analyses depends on the accurate determination of

the trace elements present. For this to succeed, adequate data on the range of possible trace elements in both local oxide deposits and native copper deposits is necessary. Such data is not yet available for the Greek mainland or any other area of the Old World, and so one must rely on the interpretation of the analytical data alone.

Two Phase II slag samples from Sitagroi clearly indicate crucible melting - as suggested by their very low iron content and their having been found adhering to crucible fragments. Microprobe analyses of metallic inclusions in the slag revealed both copper containing significant amounts of arsenic, silver and gold and also silver containing some copper. The relatively high antimony, arsenic and silver contents in the slag matrix do not seem consistent with the melting of native copper. Tentatively, the metal being melted was probably produced by smelting -but the evidence is not yet conclusive. Whether the slags provide evidence for the melting of smelted copper imported from the Balkans (where we know copper was being smelted from oxide ores at this time) or elsewhere, or the use of copper smelted at Sitagroi itself (these crucible slags being evidence for subsequent re-melting or refining or casting) is not yet known. Only analyses of Balkan sources and, when possible, of the unidentified "S/S" source once located will resolve the problem of the source of copper used.

In addition to the slags, there are the analyses of metal objects. In some cases the samples available for analyses were too small to allow more than lead isotope analyses. Moreover, many of the samples consisted largely of oxidation products so that the bulk analyses of the objects are not reliable^{enough} to discriminate between native or smelted copper. This question can be discussed only for those objects where the samples contained minute metallic fragments capable of microprobe analysis, either at Oxford or in the earlier analyses by Slater (Slater, 1972).

One LN Phase II object (an. 11) analysed by Slater appears to contain

too much lead and silver to be consistent with native copper, but the analysis has a suspiciously low overall total of chemical elements. Of the Phase III objects (of either LN or EBA I date) the analyses of objects an. 9 and an.11 show contents of arsenic, lead and (for an. 9) gold and silver which, though low, are too high to be consistent with the great majority of analyses of native copper (see 4.2). Amongst Slater's analyses are five Phase III objects containing either too much tin, arsenic or lead to be of native copper, unless there was an anomalous source of native copper supplying Sitagroi. The metal analyses themselves thus suggest, but do not conclusively prove, that smelted copper **may** have been in use at Sitagroi in LN and EBA I times. This evidence does not by itself of course, prove that the copper was smelted at Sitagroi.

At present, there seems to be no conclusive evidence for extractive copper metallurgy at Sitagroi in the LN or EBA. A metallurgical furnace has not yet been found, though only a small part of the site has yet been excavated. The earlier claim by Frierman (1969) that a Karanovo sherd from Karanovo V or VI was fired at a temperature of 1000°C - 1100°C led Renfrew (Renfrew, 1969) to infer that refractory techniques had by then evolved sufficiently to provide the temperatures required for the smelting and casting of copper. In fact, although the casting of pure copper requires melting temperatures of only about 1080°C - 1100°C , and lower for arsenical or tin bronze (800°C), melting point determinations of ancient copper slags (Bachmann and Rothenberg, 1980) suggest, for copper smelting, that furnace temperatures of at least 1200°C (though probably no more than 1300°C), were necessary. Moreover, Kingery and Frierman (1974) later re-examined the same Karanovo sherd and showed that it had in fact originally been fired at a temperature less than 800°C , whilst the extensive researches of Maniatis and Tite (1980) have proved beyond doubt that high firing temperatures were not used in Neolithic/EBA times for pottery production

in Central and South Eastern Europe.

The fact that firing temperatures for pottery were lower even than the temperature required to melt copper is, of course, no proof that in the same culture metallurgists were not capable of attaining the necessary higher temperatures for their metallurgy. At Sitagroi the crucibles with slags adhering contained metallic droplets which prove conclusively that at least copper melting was practiced in LN and EBA I times.

- It is difficult to interpret the chemical results for the Sitagroi crucible material. Tylecote (1976, 5) commented that very often small blobs of original pure copper are left in a crucible after smelting and these subsequently become oxidised by weathering so that, chemically, they may resemble melting slags. The only safe way of discriminating, in his opinion, is to carry out a chemical and microscopic examination.

One sample from Sitagroi II (Slater, 1972, no. 2999; an. 17) contained sulphur which indicates that it was made of smelted copper. The copper is sufficiently pure to have been made of native copper, but the sulphur level suggested the smelting of a copper sulphide. The techniques for smelting copper sulphide did not become common in the Balkans or Near East until the second millenium BC (see 4.3). This example goes to prove how difficult it is to distinguish smelting from melting slags.

The analyses show that arsenical copper (defined as As < 2.5%) was not used in Phases II and III at Sitagroi.

4.6.3 EVIDENCE FOR SMELTING IN THE REST OF MAINLAND GREECE

Several other slags from EBA contexts are known (see 6.6.2.3), but these have not been analysed as most can not now be located in museums. Slags from EBA Mandalo have been submitted for analysis ¹³

The catalogue of moulds and crucibles from LN/EBA Greece demonstrates that molten metal was used, but not help distinguish between melting and smelting.

The remaining evidence available is in the form of chemical analyses of copper artefacts. Previous and new results provides data on twenty-six artefacts from nine locations.

Taking the ranges of minor and trace elements in native copper, (see Table 4.2.1.1.), we can distinguish artefacts whose composition exceeds those levels and, by implication, are made of copper oxide which was smelted from its ores.

Both the axe and the earring from Dimini are made of very pure copper although the levels of cobalt and antimony do suggest the use of a smelted copper. The arsenic level in one Sesklo axe (an. 68) and tin level in the other (an. 69) demonstrate that they were both made from smelted copper. As the iron level in all these artefacts was very low, we can assume that no flux was used.

This is also true for the Pefkakia chisel, though the higher levels of nickel, lead and antimony suggest that it was made of smelted copper; the high level of arsenic was uncharacteristic for the period. Arsenic-rich copper is known from Fthiotidha, in particular Limogardion (see 3.2.1.), and as all other LN artefacts in southern Thessaly are of unalloyed copper it could be suggested that arsenic was added to a pure copper to produce an intentional alloy. This would mean that the Pefkakia chisel is the earliest evidence of arsenical-copper alloying in the mainland.

The shaft hole axe from "Mesolonghi" (cat.160) is made of pure copper, but the levels of arsenic and antimony are above that characteristic of native copper. It is likely that pure copper oxide was used.

The high level of lead in an axe from "Spata" in Attica (cat. no. 164) probably represents the use of a smelted copper. It is also the earliest lead-copper alloy in the mainland.

The higher nickel, silver and lead levels in an axe from "Athens" (cat. no. 11), indicates that smelted oxide copper was also used here.

From the minor and trace elements in the Kitsos artefact (cat. no. 23a) there is no reason to assume that anything other than native copper was used.

The earliest evidence for actual copper working in southern Greece is in the form of crucibles and possible slags from Kephala on Kea. The date of 3300-3200 bc - in terms of the conventional radiocarbon chronology - falls, when calibrated near the beginning of the fourth millenium BC (Ralph, in Coleman, 1977). Whilst Sitagroi appears to have been involved in copper-working in some way throughout the whole LN period, Kephala was involved towards the end of it. The radiocarbon date for the Kitsos awl is 4220 - 4270 $\pm$ 200 BC (when calibrated), Lambert, (1981, 425, note 4). This suggests that copper working in southern Greece started at the same time as Phase II in Sitagroi.

The metals and slags from Kephala have been analysed, but there is some disagreement over the results. Conophagos (1977) concluded that smelting was being practised in the LN, though he does not stipulate on what grounds he bases his conclusions. Further analyses of the same samples by Tylecote and Cooke (1977) agreed with Conophagos' conclusions regarding smelting, but maintained that the metallurgical processes which produced the slags were more advanced than would be expected at such an early date, without actually detailing in what respects they were more advanced. It is thus possible that the Kephala slags are not LN.

One pin from Kephala (no. 7.147, ; cat. no. 21a) appears to be made of pure copper, perhaps native. Conophagos (1977) noted that it contains

small amounts of zinc and traces of iron. Without more details it is not possible to say if the levels of zinc and iron are outside the ranges for native copper or not.

There thus appears to be substantial evidence that many early coppers were made from smelted copper in the LN, though there is no concrete evidence that copper smelting actually took place locally.

4.6.4. CHEMICAL PROVENANCING OF LATE NEOLITHIC ARTEFACTS

Lead isotope analyses were made of artefacts from Sitagroi, Dimini and Sesko. In the absence of Pb-isotope results for other artefacts, we will attempt to compare their compositions with the composition groups devised by Junghans et al (1968)¹⁴ for various regions of the Old World to see if this will help provenance the artefacts (bearing in mind the difficulties associated with the interpretation of chemical results for provenancing, Gale and Stos Gale, (1982).).

The artefacts from "Mesolonghi", "Spata" "Athens", as well as those from LN Sesklo and Dimini, do not fall into any of the five main composition groupings.

The Pefkakia chisel fits well into the C6 field in all but its arsenic level. This could suggest that the arsenic was added separately to the pure copper and this would represent the earliest deliberate alloy of arsenic and copper in Greece.

The nickel level in the "Athens" axe (cat. no. 11) could represent a high nickel-copper source, such as the Laurion or two sources in Fthiodidha (see 3.2.1). Phelps et al (1979) suggested that it was a Cycladic object. No high nickel copper source is known from the Cyclades, no LN material is known from the Cycalades except Emborio (Hood, 1978) and the axe, typologically is not Cycladic.

Junghans *et al* (1968). The excavator of the site already noted this (Lambert, 1981, 425). E_{00} is said to be well-represented in Yugoslavia, though it has a wide distribution. Chernykh (1978) has defined a composition group (Group II) which is broadly equivalent to the SAM Group E_{00} . He claims that this group is most common in Hungary and Romania and that his group I (equivalent to SAM Group N) is particularly well-represented in Yugoslavia.

Lambert noted that native copper was found near the site of Kitsos and that the awl could perhaps have been made from it. The composition of the native copper varies from that of the awl (particularly in arsenic, nickel, iron and zinc levels), though cuprite found in later levels of the site is particularly pure.

The lead in the Spata axe could represent contamination of a copper source - this would mean that the axe was definitely made of smelted copper. Copper and lead are associated in sources in Attica (see 3.2.1.).

Chernykh (1978) drew attention to the low levels of tin in several of the Chalcolithic coppers. These levels do not imply alloying, but suggest that trace elements of tin were entering the copper via the ore or the flux. Figure 4.6.6. gives the relevant tin and arsenic levels present in LN coppers from Greece. Arsenic-tin levels vary amongst the artefacts. Two samples from Sitagroi, one from phase II and one from phase III had no arsenic or tin whatsoever. Seven samples had arsenic but no tin and four had low tin but no arsenic. Only three samples, all from Sitagroi phase III, contained both arsenic and tin, albeit at low levels. The arsenic and tin levels common in Eneolithic and EBA I artefacts from Bulgaria was $As < 0.4\%$. $Sn < 0.4\%$. Only one artefact comes into this group (an. 5) and it is a "copper slag" on a sherd (possible crucible).

One phase IV sample (a piece of copper slag?) has higher tin than

arsenic and another (also a piece of slag?), has more arsenic than tin though, surprisingly the ratios to tin-to-arsenic and arsenic-to-tin in the two samples are almost identical. These samples were corroded and so not too much emphasis should be placed on this coincidence perhaps.

The result of this enquiry is that only one LN sample contained tin and arsenic in levels characteristic of over 90% of Bulgarian LN metals. The fact that this sample was a copper slag(?) is suggestive that it could have been an import. No lead isotope results is available for it, however.

Thus, the chemical results, as far as they can be interpreted, do not suggest the use of Balkan copper. There is strong evidence that most of the early copper artefacts were made from smelted copper. Most likely crucible smelting was practiced. The lead-isotope results demonstrated that various sources were used - three in particular. A few artefacts have compositions similar to the main composition groups devised for Yugoslavia and the Aegean (Junghans *et al*, 1968) or the Balkans (Chernykh, 1978), though most of the artefacts do not fall into any of the main composition groups. One copper slag from LN Sitagroi has a similar composition to the basic copper type used in the Eneolithic Balkans. A Balkan origin for some copper used in LN Greece cannot be excluded until lead-isotope results are available for the main Balkan copper deposits.¹⁵ However, there is strong evidence to suggest the use of local sources also. Several sites used more than one source (for example Sitagroi, ^{which} used three) and evidence shows that some of these sources continued to be used in the succeeding EBA - a period when the Balkans industries wane. Further indications of local industry come from southern Greece where silver was cupelled from lead in the LN (or cupelled silver was obtained from elsewhere in that period). There is no earlier evidence for silver cupellation in the Aegean. Gold artefacts were made from native gold and, like silver work, only lithic techniques were used to shape them.

4.6.5 METALLOGRAPHIC EVIDENCE

Very few LN artefacts have been studied by metallographic techniques. Eight artefacts or copper pieces from Phase III at Sitagroi and three LN copper axes from "Athens", "Spata" and "Mesolonghi" are the sum total, (Slater, 1972, Appendix I; Phelps *et al*, 1979, 182-183).

In Phase III at Sitagroi, three objects had "as cast" dendritic structures, one had evidence for cold working and four were cold worked and annealed. Similar work could not be done for Phase II samples, because they were not suitably preserved. One ring from Phase II, however, could have been annealed.

The "Spata" axe was cast but not hammered. The "Mesolonghi" axe had the dendritic structure of a casting, but the main body was not hammered. The blade was cold-worked. The "Athens" axe had a distorted microstructure at the edge of the blade. It was thus cast and work hardened by hammering.

Hardness testing of the three copper axes from Greece showed that hammering to work harden was used on each axe, though not with the same precision.

This limited view into the working of copper once it was cast shows that all the main techniques used to fashion copper artefacts in the Old World were known in LN Greece.

4.6.6 CONCLUSION

The analytical results for LN copper artefacts provide new and interesting data on both the technological abilities of LN metalworkers and the apparent complexity of metal procurement strategies.

Apart from a broad repertoire of types, stages one to five were definitely known before the beginning of the third millennium BC. It now seems highly likely that smelting and alloying arsenic and lead, if not tin, were practiced. There is no apparent relationship between composition and type.

Copper working starts at about the same time in northern and southern Greece (that is =Phase III, Sitagroi). This is earlier than the Cyclades or Crete, but is contemporary with the Balkans and the Troad.

There is no reason to regard LN metalwork in Greece as just an offshoot of the Balkan industries with no character of its own. It provides a solid technological background to the EBA industries.

4.7 THE EARLY BRONZE AGE

The aims of this section are: to determine the technological level achieved by metalworkers in the EBA, to assess the relationship between the LN and the EBA industries and chart the developments in metallurgy within the EBA.

The chemical results are presented in Table 4.6. The data will be dealt with by region.

4.7.1 NORTHERN GREECE

Chemical analyses are available for eight sites in this region. New analyses are available for Sitagroi and Mandalo.

4.7.1.1 Sitagroi Sixteen results are available for EBA material from this site. All artefacts appear to be made of smelted copper, except one which is of extremely pure copper. None of the artefacts fall into any of the major composition groups as determined by Junghans et al (1968).

Arsenical coppers (arsenic $< 2.5\%$) are known for the first time in Phase IV and continue in Phase V. They are rare, however. Perhaps the lack of an earlier arsenical copper tradition was due to the use of a copper source, or sources, which did not naturally contain arsenic or to the unavailability of arsenic minerals to allow deliberate addition of arsenic. Arsenical copper sources are known nearby^{, however} (see 3.2.1.). The arsenic in the Phase IV and V artefacts may signify the beginning of the exploitation of these sources. No lead isotope results are available for the high arsenical coppers, so they cannot be compared with low arsenic or tin-coppers.

Arsenic levels in contemporary Balkan artefacts (especially in the EBA I) are much higher (Chernykh, 1978).

The lead-isotope data suggests that Sesklo, Petromagoula and Sitagroi

may have used the same copper source, and in general the arsenic contents of the two Thess^{the}alian sites resemble those of Sitagroi Phase V samples.

The relationship between arsenic and tin levels is the same in Phase IV and V, though it differs from levels observed in coppers of Phase III (Figure 4.7.1.1a). One tertiary alloy alone is known in the EBA though arsenic and tin, in whatever percentages, are generally kept quite separate in Phase IV. Low tin with low arsenic levels are more common in Phase V, although amounts still exceed levels found in the majority of Balkan coppers. A recently analysed copper slag from Drama (Classical) had traces of arsenic and tin (Papastamataki, 1986, 51). This may just be indicative of a possible source used at Sitagroi.

In Phase IV at Sitagroi, Slater identifies two tin bronzes, both containing much lead. In Phase V, she identified three tin bronzes in which smelted copper was used. Tin bronze was rare in the Balkans until the second millenium BC. It is well known that tin bronze was in common use at Troy (see 4.3.), though the question as to whether tin bronzes came into use earlier in Sitagroi than Troy is fraught with difficulties and disagreements about the relative (and absolute) chronology. Coleman (1985) has discussed this question most recently and has suggested that Troy I overlaps part of the EH I-II. For Sitagroi, Coleman suggests, and Sherratt (1986) independently confirmed, a break between Sitagroi III and IV. Sitagroi III would, in this scheme, begin at the same time as LN II in the Peloponnese and central Greece, dating, perhaps, from 4500 BC to about 3800 BC. Sitagroi IV would end somewhere towards the end of the EH I, dating perhaps from about 3100 BC-2700 BC; on the same scheme Troy I lasts from 3300 BC-2800 BC. No tin bronze is known from Sitagroi III, two tin bronzes are known from Sitagroi IV and one has been suggested to come from Troy I (de Jesus, 1980; 343); though this example is very doubtful (Yakar, 1984; see 4.3). In Sitagroi V three tin bronzes are now known, whilst in Troy II tin bronze is common. It seems safest to conclude that tin bronze came into use at roughly

the same time in Troy and Sitagroi, somewhere between 3000 BC and 2500 BC in Coleman's absolute chronology.

This is an interesting conclusion since little tin was then known in the Balkans where it was essentially not employed until the second millennium BC (see 4.3). Thus, the appearance of tin bronze at Sitagroi may represent the earliest known occurrence in continental Greece. One could argue, as some have, that Macedonian metalwork was closely related to Troadic in the EBA and thus the appearance of tin-bronze at Sitagroi at this time may have little bearing on the first use of tin-bronze in mainland Greece. Sherratt (1986) and Evans (1986) have shown, however, that Troadic influences are not the strongest on the LN and EBA pottery of the site. Sitagroi does not appear to have been within the general Troadic "province" in the EBA.

Thus, the only proof that copper was taken from a Greek source would support the hypothesis that Sitagroi ^{independently} developed tin-bronze working earlier than any other area of the Aegean. The other tin bronze finds from northern Greek sites in the EBA certainly support such a view.

There is a definite relationship between tin and lead levels at Sitagroi which is not observed in any of the other Greek tin-bronzes of the EBA. The only parallels are : a tin-bronze with lead from Thermi I (Lamb, 1936, 31.64), three from the Troad (Bittel, 1959, nos. 6, 10 and 18), nine from Chalandriani on Syros (Bossert, 1967, 76) and one from Amorgos (Renfrew, 1967, 20, 46). Gale and Stos Gale (1984) claimed that the tin-bronzes from Chalandriani fall into a Troadic copper field isotopically. There are no lead-isotope results for the high tin-lead copper artefact from Sitagroi. In general, the tin and lead levels are lower than the Troadic or Cycladic examples. There is no relationship between tin and lead levels in Crete. In Sitagroi, we have tin and lead tertiary alloys, tin bronzes and leaded coppers in the EBA. Analyses of copper sources in northern

Greece (Papastamatakis, 1975; 1986) showed that lead is often associated with copper - tin is not. Fig. 4.7.1.1.b.

It is apparent that lead and tin were both contained in coppers of Phase IV. In Phase V, their individual properties were no doubt recognised and they were alloyed separately.

Silver levels in coppers and bronzes vary. Papastamatakis (1975, 59) observed that silver and gold levels were higher than normal in the ore and slags from Skouries, Fthiotidha and the Laurion.

The nickel levels in the artefacts from Sitagroi are generally low, between 0.1% and 0.4%. This is distinctly different from the material from Petralona and Petromagoula (see below).

Thus, at Sitagroi in the EBA, we have strong indications of smelting copper, alloying copper with lead, arsenic and tin and the manufacture of tertiary alloys of tin-arsenic and tin-lead, though the tertiary alloys may not have been intentional. There is continuity in the use of both the "S/S" source and the "Cypriote" source from the LN to the EBA. From the chemical analyses, it is apparent that the basic techniques used in Phases IV and V, apart from alloying, were developed in Phase III.

4.7.1.2 Petralona Unfortunately no lead isotope results are at present available for this material.

The copper used appears to have been smelted as minor and trace elements are above the limits set for native copper.

The composition of the objects is quite uniform and pure. Of the main composition groups determined by Junghans et al (1968), C 6 is most akin to the general compositions of the material from this hoard. In particular artefacts no. 423 and 425 fit well with the C6 grouping.

The majority of the other artefacts have either higher bismuth/arsenic or lower antimony/silver and are thus marginally different from the C6 group. A further six objects are markedly different in composition from the rest, suggesting a different copper source or a different manufacturing procedure.

Arsenic levels vary from 0.36%-3.4%, but the average is 1.63% and the vast majority of artefacts cluster around this average. Most of the artefacts are of one type and one would assume that a standard level of arsenic would be found in each. The higher levels of arsenic are not consistently found, as one might have expected, in the more complex sleeved-axe forms.

There is a close relationship between the arsenic and nickel levels. Arsenopyrite is often associated with nickel, but the arsenical copper deposits in E. Chalkidiki have very low nickel (Papastamatakis, 1986), Fig. 4.7.1.2.a, b.

The high antimony levels may be the result of contamination of copper sources by antimony deposits. A group of antimony deposits are known in north east Chalkidiki (see Figure 3.2.6.)

The arsenic and tin levels are quite different from those at Sitagroi. Lead and tin are not related and the copper used at Petralona again differs in this case from that used at Sitagroi. Leaded coppers are known however, though they also contain arsenic and are thus tertiary alloys.

Artefact cat. 429 is totally different in composition from the other artefacts. Possibly it was made from copper from another copper source. Altogether it appears that three sources of copper could have been used. One is characterised by high arsenic, but lower lead and nickel. The second is a low tin copper source. The third is characterised by artefact cat. 429 which is not distinctly different typologically from the other axes in the hoard.

4.7.1.3. Remaining Sites from Northern Greece

The remaining analyses from northern Greece consist of one new result from Mandalo and previously published results from Vardarophtsa, Kritsana, Saratse, Servia and Gona. The artefacts from all of these sites were analysed separately at different times and by often different methods. No attempt is thus made to interpret them as a single body. Fig. 4.7.1.3.a,b.

Tin is observed in three EBA artefacts from Vardarophtsa and two from Saratse. The Vardarophtsa tin copper has such a high level of tin that it could represent a tin concentrate. It is also associated with 7.09% nickel, 13.91% iron and 5.8% antimony. The composition seems very advanced for the EBA, but no doubt has yet been expressed regarding its age. Unfortunately, this artefact could not be located in order to have it re-analysed. The tin is obviously cassiterite. The nearest nickel source is over 250 kilometres west (see Figure 3.2.7.), and antimony is known from north east Chalkidiki. Nowhere are they all known in association with copper at such levels. There is no relationship between the arsenic and nickel levels as at Petralona or between the tin and lead levels as at Sitagroi.

Arsenic appears with tin in the Saratse "tin-bronzes". These have no nickel. One of the Saratse analyses is of a slag. Smelted copper was used at this site, it seems, though the example could not be located in order to have it^{re-}analysed.

The composition of the tin bronzes from Sitagroi, Vardarophtsa and Saratse are different, but they all testify to the use of cassiterite in the EBA. Their distribution is perhaps indicative of the source (see 3.2.4.

The Mandalo awl falls into the "Cypriote" field, but could equally well have been made from copper from Fthiotidhā (see 3.2.1.). It is made of pure oxide copper. The slags associated with the awl have been

submitted for analysis and will surely shed some light on the techniques used to produce copper at the site. Isotopically and chemically the copper used at Mandalo is quite distinct from other copper artefacts in northern Greece. It does not fall into any of the main composition groups determined by Junghans *et al* (1968) either.

The Kritsana artefact is similarly^{of} pure, unalloyed copper. It has a very low overall total and so little more should be said about it.

The two finds from Servia are quite different from the other artefacts in northern Greece. Their iron contents are distinctive and could represent inefficient slagging during production. One is an arsenical copper (the axe). The needle has 1% arsenic and this could have come from an arsenical copper source. The date of the axe is not certain (see 6.2)

4.7.2 THESSALY

New data are available for two sites, Petromagoula and Sesklo. The Sesklo material extends into the early MBA and thus provides data on the continuity of techniques and of source exploitation.

4.7.2.1 Petromagoula All the artefacts from this site appear to be made of smelted copper except perhaps an.45, which in all but arsenic content is exceptionally pure. The arsenic level of 4.55% represents a deliberate alloy and continues the tradition of arsenical-copper alloying started in the LN at nearby Pefkakia. Fig. 4.7.2.1.a.

None of the objects fall into any of the main composition groups determined by Junghans *et al* (1968).

Lead isotope results have demonstrated that the site used sources with two different ratios, one being the "S/S" source and the other being similar to the "Cypriote" source. Lead from the site fell into the Laurion field.

The nickel levels cluster into two distinct groupings when plotted (see Figure 4.7.2.1.b) and this strongly suggests two different *lodes* of copper. The silver levels support this view.

The arsenic-nickel plot shows two groupings; a) artefacts with significant amounts of arsenic and no nickel. In general the arsenic levels here range from 0.35%-4.55%, though only one artefact had arsenic below 1.7%, and b) artefacts with arsenic levels from 0.86%-3.2% and nickel from 0.8% to 2.86%. The general compositions of arsenic with high nickel are similar and they are all of the same type. Unfortunately, no lead-isotope results are available for the high nickel artefacts. The copper sources in nearby Fthiotidha have two of the three main nickel deposits, associated with copper in Greece. It seems likely that an arsenical-nickel copper was used for the lower arsenic coppers and a separate arsenic source for the high arsenic coppers.

It is interesting to note that some of ^{the copper in} the artefacts which have high arsenic and which fall into the "S/S" source are of Eocene age geologically. An arsenical copper source in Fthiotidha is of the same geological age (see 4.4.3.). The other "S/S" artefacts could have used this source also.

There is no relationship between arsenic and tin levels. Tin levels do not exceed the ranges for native copper. Lead levels vary markedly between 0.01% and 0.29%, although there is no alloying with lead. Unlike Sitagroi, there is no evidence for any relationship between tin and lead levels.

Silver levels in the Petromagoula material are low, although 2.46% silver is recorded for a razor: this is a deliberate alloy and could not have been accidental. It is the first of its kind in Greece. There is no related higher level of lead as one might expect. Certainly a lead isotope ratio for this artefact would be misleading as the silver content would alter (mix) the lead-isotope ratios. The closest silver source known

to have been exploited is the Laurion. The lead artefact from the site fell into the Laurion field.

An. 36 falls into the "Cypriote" field. It stands out from all the other artefacts from the site because of its high iron content (3.39%). The artefact also has 2.47% arsenic. There appears to be no apparent relationship between the arsenic and iron levels, because higher and lower arsenic is known from other samples with no change in iron levels. This artefact is the only one with low nickel. It appears that the iron levels resulted from poor slagging procedures.

4.7.2.2 Sesklo These artefacts date to the EBA III/MBA I. They provide important data on the continuity of source exploitation and alloy techniques. Fig. 4.7.2.2.a,b.

The basic characteristics of this varied collection are: they were all made of smelted copper; tin levels are high, averaging about 6.6% by XRF and arsenic contents are low, averaging below 1.0% by XRF. Only one artefact, an. 57, could represent a deliberate ^{arsenic} alloy. Tin levels confirm the use of cassiterite in alloys.

When arsenic against tin levels are plotted, the following pattern appears. Four artefacts have both low arsenic and no tin; two have high tin and no arsenic; three have high tin and low arsenic and the rest have low arsenic and low tin. This suggests the use of a copper source with low arsenic to which tin was added in varying amounts. The low tin and arsenic levels in some artefacts suggest the use of either two copper ores (one with low arsenic and the other with stannite traces). Low arsenic and low tin levels are also observed at Sitagroi.

There is a direct relationship between the levels of tin and artefact type, although there is no clear relationship between tin bronzes and one particular copper source (see 3.2.4.). Almost all the high tin bronzes

are blades. Two spearheads however both have low tin (less than 2%) and very low arsenic. They would thus have been of limited practical use and were possibly used for ceremonial purposes. This practice is also known in Levkas (see 4.7.3.1.). One pair of tweezers has 8.7% tin and another pair has 4.3% tin and 2.31% arsenic. The arsenic levels are higher than those generally observed at the site in this period. It could represent the use of another copper with higher levels of arsenic than the main copper source used or the more probable addition of arsenic and tin as alloy elements. The effect of this tertiary alloy could have been to bring the the quality of the copper up to the same level as the other pair of tweezers. The copper used to make each pair could however have been from two different sources.

Two of the tin bronze knives had arsenic in levels of 1.06% and 1.5%. These levels are quite consistent. They are also higher than the arsenic in the basic copper(s) used. None of the knives have the same Pb-isotope ratio and so it would seem that the arsenic and tin were deliberately added to the copper. They therefore represent tertiary alloys.

No tin at all is present in the beads and their consistently low arsenic levels do demonstrate that they were all made of a pure copper with low traces of arsenic. They were not all made of the same copper however, as lead isotope results have shown that two sources were used.

The chemical and lead isotope results show that the site was obtaining copper from various sources and was using the basic copper for different types of artefacts. Arsenic and tin were apparently added separately to produce the alloys desired.

An unusual alloy of gold and silver was also produced. It is the first of its kind in Greece. Unfortunately, no lead isotope result is available for this sample.

4.7.3. IONIAN ISLANDS

4.7.3.1. **Levkas** Eleven results are available for Levkas. In 1927, Dörpfeld published the chemical analyses of some of the Steno finds without specifying which, and concluded that **only** copper was used in the EBA. The dating of the finds is discussed in Appendix 6.

Of the eleven artefacts analysed, five were of unalloyed copper, four were made from arsenical copper, or as arsenic-copper alloys, and two were tin bronzes. Each artefact was analysed from two-to-four times and the mean taken. Unfortunately, the poorly preserved condition of the artefacts in Levkas Museum made it difficult to obtain samples without corrosion product.

All of the artefacts were made of smelted copper and the majority of the finds are characterised as being pure copper, even if alloyed.

Three of the artefacts have a very similar chemical composition and fall into the C6 group, as defined by Junghans et al (1968), though their overall totals are somewhat low. These are an.80, 72 and 70. An.80 and 72 were tin bronzes. The tin levels, of course, well exceed the limits of the C6 group, but as cassiterite was obviously deliberately added, it is possible that a pure copper was used as the base. As the techniques used in the metal industry represented at Levkas are so advanced, the pure copper seems to represent a well-refined copper oxide.

Several artefacts were made of unalloyed copper. Surprisingly, these were not the simplest artefacts, but were stylistically amongst the most advanced. They were, for example, two swords (an. 74 and 77), a knife (an. 80) and a sheet copper cup (an. 79). The swords appear to be local types and represent an intermediary stage in the evolution of the dagger to the sword (see Ch2, Weapons). The blades were apparently never intended for actual use, but rather as votive offerings for the dead. The cup was

no doubt for drinking and indicates both the beginning of wine drinking in Levkas and the perfection of sheet metalworking techniques. The swords and the cup both appear to be local Aegean developments, but the knife could imitate Anatolian prototypes. As the copper used at the cemetery is apparently^{from} Greece (from the Laurion and the "S/S" sources), there is no reason to regard the blade as a direct import.

Four artefacts were arsenical coppers. The arsenic ranged from 2.96% to 3.82%. This level of arsenic could represent two things. It may represent a deliberate alloy with arsenic being added to the same copper as above, or it may indicate the use of an arsenical copper ore, that is, a different copper source from the above. Lead isotope results demonstrated that two sources were used on the island. Whatever the case, arsenical coppers, defined as arsenic < 2.5%, were produced.

Composition groups or sets are detectable from the analyses. These are obvious, for example, through the arsenic-tin relationship. The coppers with the highest tin have the lowest arsenic and those with high arsenic have the lowest tin. The two alloy elements were not kept entirely separate, however. Four arsenical coppers, two of which represent deliberate alloys, have very low tin; two arsenical copper alloys (arsenic range 2.96% - 3.78%) have low tin (0.5% - 0.7%), one tin bronze (Sn 3%) has arsenic at 1% and three low arsenic coppers (arsenic 0.27% - 0.5%) have tin in the range 0.5% - 0.77%. It seems that an. 80 and 72 represent the addition of tin in the form of cassiterite, to that from which at least an. 77 and others were made. There is nothing markedly dissimilar in their general compositions to contradict this interpretation though the total of chemical elements, for 77 and 80, especially, are low, Fig. 4.7.3.1.a.

Artefact an. 72 represents the only tertiary alloy of tin and arsenic at Levkas, though the arsenic level need not represent the deliberate addition of this alloy element. It does suggest that an arsenical copper source could

have been used.

Arsenic contents are in no way related to nickel contents and in this the material from Levkas varies from the Petromagoula material. The highest nickel level recorded for Levkas is 0.2% and no matter what levels the arsenic reaches, the nickel levels do not change.

The four arsenical coppers were each of a different type. They are three blades and a flesh hook. The composition of the four arsenical copper is very consistent with them having been produced from the same lode. Even an. 72, a tin bronze with 1.34% arsenic, is similar in composition in all other elements. Two blades and a hook have arsenic levels which appear to be deliberate and represent the careful measurement of arsenic for consistent copper strength. An. 80 has slightly less arsenic, but the total constituents of this artefact were not all detected in the analyses as it was partially corroded. The addition of around 3% arsenic would strengthen the blades, facilitate casting and make the hook able to withstand the strain of heavy weights. One of the blades could conceivably be Anatolian, but is similar in composition to other artefacts which are typologically local or Aegean and this suggests that the blade was made locally, perhaps from an Anatolian prototype.

The evidence supports the view that deliberate alloying with arsenic and tin was being practiced at Levkas and that the percentages of arsenic and tin could be carefully controlled.

Two artefacts are made of tin bronze. There is apparently no relationship between lead and tin levels, as seen for example at Sitagroi. Very low tin levels ($< 0.1\%$) have lead levels below 0.15%. Tin levels between 0.5% and 0.75% have up to 0.2% lead. In fact, analysis numbers 77 and 80, amongst others, displayed a common relationship in the arsenic tin diagram and similarly in Fig. 4.7.3.1.b,c. It is interesting to note

that another feature shared by these samples is that they all contain a standard level of cobalt (0.01%).

The two tin bronzes vary in type - one is a double axe with 7.81% tin/1.34% arsenic and the other is a dagger/spearhead with no arsenic but 14.73% tin. The total of the chemical constituents is low for the high tin bronze as the artefact was corroded, so we cannot be sure of the exact amounts of the other elements. The dagger could typologically be a local type or represent an import or copy of a Troadic prototype. It falls outside the chemical groupings for material from the graves and falls into the "S/S" source in the lead isotope diagram. No lead isotope results are available for the second tin bronze. The exact position of an.75 in the lead isotope diagram is not quite clear. Approximate fields for Trojan artefacts and some from Kastri on Syros have been determined provisionally by Gale and Stos-Gale, (1984). Artefact an. 75 falls in the intersection between the Troadic field A and the "Cypriote" field. In the alternative lead isotope diagram, it falls into the intersection between the "Cypriote" field and Troadic Field B. There is also an area of overlap between Field A and the Laurion field and between Field B and the Cypriote field. In the fields obtained from the analyses of copper sources in Anatolia, Pernicka *et al* (1984), the Levkas artefact falls outside the main body of results. On present evidence, the Levkas dagger is closer to the "S/S" source than any other field, yet one cannot be quite sure where it belongs because of overlap between certain fields.

The double axe is most probably a local type produced under the influence of north Adriatic industries (see Ch.2.). The dating of typological parallels is difficult as most are chance finds. This type has no Anatolian connection.

4.7.4 CENTRAL GREECE

Chemical analyses are available for material coming from three sites in central Greece: Euboea, Manika and Aghia Marina (Phokis). The results from Aghia Marina are incomplete and so difficult to interpret. No lead isotope analyses are available for any of these sites, but material from Manika will soon be available.

4.7.4.1 Manika (Figure 4.7.4.2.a; 4.7.4.2.b)

Recent excavations at Manika in Euboea have produced a wealth of metals and evidence for metalworking including slags ¹⁶(Sampson, 1985; 1986: pers. comm. 1987). It is obvious that this site was an important metalworking centre. The chemical results for the three copper-based artefacts and one silver piece were done in 1984. I am grateful to Dr A Sampson for providing me with the results before publication.

One true bronze and two arsenical coppers (one deliberate) sum up the copper-based artefacts. All were made of smelted copper and none fall into any of the main composition groups determined by Junghans *et al* (1968).

The arsenical coppers have very low tin and the tin bronze has very low arsenic. Artefact cat. 273 need not be an intentional arsenic-copper alloy. Cat. 280 has high arsenic accompanied by high nickel, perhaps indicative of a source similar to that used at Petromagoula.

The knife had the highest arsenic and this would both facilitate casting ^{endow}and/strength. The type has parallels in Levkas and is similar to two others from Manika itself (see Ch. 2.). One can assume that their compositions, in particular their arsenic contents, should be similar. The basic type has been established as Anatolian and is absent from the Cyclades and Crete. Unfortunately, no analytical data is available for the Levkas parallel or for typological parallels in the Troad.

The two pins are stylistically rather different, although they both display strong Troadic influences (see Ch. 2.). There is no technical

reason why a pin would require 8.49% tin as it could be fashioned easily with less. The arsenic level in the second pin may represent a deliberate alloy, but most likely it resulted from the use of an arsenical copper.

The new data from Manika provides yet another instances of tin bronze in EBA Greece.

Although arsenic and nickel levels are unrelated in the two pins, there seems to be a connection between the arsenic and nickel in the blade. There is no relationship between the tin and arsenic levels, however. Low tin has high arsenic and vice versa.

4.7.4.2 Eutresis. The chemical data for Eutresis have been available for some time (Goldman, 1931). Four of the artefacts appear to have been made of smelted copper on account of the minor elements for certain constituents, in particular nickel. Artefact no.229, a razor, is so pure that it could well have been made of native copper. It could belong to group C6 though too many elements are missing to judge.

Artefact no.219 is the most distinctive, chemically. It contains 6.10% lead and undoubtedly represents a lead-copper alloy. The use of lead as an alloy in the earliest metal industries of Greece is becoming more common than previously believed. This lead would be a deliberate alloy and so the artefacts would not be a suitable candidate for lead isotope analyses.

In order to assess the degree of similarity between these artefacts, the arsenic-nickel and arsenic-tin levels were plotted, Figure 4.7.4.3.a,b.

In general, arsenic, tin and nickel levels are very low. There is no direct relationship between arsenic and nickel levels or between arsenic and tin levels. If one source was used then it would produce arsenic from 0-2.2%, tin from 0-0.9% and nickel from 0-0.2%. in the characteristic copper produced from it.

The flat axe (cat. 217) was not strengthened by the addition of an alloy element. There is no evidence, but workhardening by annealing and hammering could have been used to improve its strength.

The industry at Eutresis was therefore quite simple, except for the leaded-bronze which hints at a more complicated technological level than the other artefacts suggest. It is possible that only one source was used and this was a copper oxide source from which a very pure copper was smelted.

4.7.5 SOUTHERN GREECE

Chemical data is available for Rouf, Aghios Kosmas, Makronissos, Corinth and Lerna. New data is presented for the first time on Rouf, Raphina and Lerna.

4.7.5.1 Attica Let us look first at the results for Attica. The finds from Raphina and Rouf have already been discussed. They all fall into the Laurion field. The fact that a copper and a lead artefact from Rouf have the same isotopic ratio substantiates the view of Pernicka *et al* (1984) that lead isotope ratios can be used to set fields into which lead isotope data on coppers and bronzes can be placed.

The copper from Rouf appears to be made of smelted copper on account of its tin, cobalt, antimony and silver levels. The results presented are the average of three measurements. The total does not reach 100% because of mild corrosion product on the artefacts. The copper, which is unalloyed, does not fall into any of the compositional groups determined by Junghans *et al* (1968). The artefact does not resemble the chemical composition of any other copper/bronze from the LN or EBA in Attica. The Kitsos (LN) awl is of purer copper; the Spata (LN) axe is a lead alloy and the Aghios Kosmas tweezer contains tin.

Applications were made to re-analyse the metal artefacts from Aghios Kosmas, both isotopically and chemically. It is hoped that results will be available shortly.

The tin levels of the artefacts from Aghios Kosmas have not been taken seriously, because there was no substantiating proof for the use of tin bronze in Greece in the EBA period. The type of tweezer which is made of bronze need not necessarily be Cycladic (see Ch.2.) and so there is no reason to assume that the tin came from that direction.

Further, there is as yet no case for tin bronze being used by the Cycladic peoples themselves in the EC II or early EC III. The Kastri material contains tin bronzes, yet these date to the late EC II-ECIIIa and are by all accounts Anatolian in origin (Bossert, 1967; Gale et al, 1984)^b.

4.7.5.2 Peloponnese. Very little data is available for the copper-based artefacts in the Peloponnese. Unpublished work by ZA Stos-Gale at Lerna has shown that lead from the MBA levels of the site no doubt came from the Laurion, and by implication EBA copper was also obtained from the same source. Samples from Teichos Dymaion have been submitted for analyses. ¹⁷

4.7.6 LEAD, SILVER AND GOLD

Lead and silver is not known from northern Greece, but gold slags are known from Saratse and Vardarophtsa. (6.6.2.3.). These slags were found by Heurtley (1930, 197). Davies (1932) analysed the slags and showed that they had traces of iron and copper in them. The slag from Vardarophtsa may have come from gold which was closely associated with copper. Sources of copper with associated gold are known in northern Greece (see 3.2.3.). It seems unlikely that the slags represent the refining of

primary gold when so much gold is known from secondary deposits in the vicinity. The iron oxide levels in the slag, together with the associated traces of copper, suggest the smelting of a copper sulphide ore.

In Thessaly, analyses of a "silver" ring from Sesklo revealed that it was an auriferous silver alloy - the first of its kind in Greece.

In the EBA there is thus a dramatic growth in lead and silver working and the distribution of lead artefacts is more widespread than those of silver. The galena ore was exploited and cupelled on the mainland, though neighbouring supplies from north Cycladic islands no doubt contributed some of the material - particularly silver to the mainland industry. Gold working is more sophisticated, but there is little evidence for exploitation of gold sources. Precious metals are used for jewellery and this jewellery is distributed mainly in central Greece and the Argolid.

4.7.7. CONCLUSION

In mainland Greece during the EBA the following metallurgical techniques were known: smelting of copper from an oxide ore; alloying with tin, arsenic and lead; casting in a single mould and a two piece mould (implied from some of the designs); hot and cold working; polishing; alloying with silver and gold (rare); melting gold to refine it; sheet metalworking; vessel making; smelting lead; cupelling silver from lead and extracting galena from local sources. Thus the techniques of the LN continue into the EBA and we see an obvious development in metallurgical techniques within the continuity in EBA. There is also strong evidence for the exploitation of sources from the LN to EBA periods.

CHAPTER FIVE

COMPUTER STUDY OF ANALYTICAL RESULTS

5.1 INTRODUCTION

The aims of all major analytical programmes on metals were two-fold: (1) to use chemical composition as a "fingerprint", providing a means of provenancing metal artefacts to source. It was hoped thereby to discover more about contact routes and to define interaction between prehistoric cultures of the Aegean, and (2) to gain a better understanding of the technological ability of these early metallurgists. The second aim has essentially been realised (eg. Charles, 1967), but there has been little success with the first. Statistical analyses have not broken through the deadlock in any way (Junghans *et al* 1968; Waterbolk and Butler, 1969).

The computer is used in this chapter to provide rapid taxonomic ordering of all suitable chemical results available for third millenium BC copper-based artefacts from Greece and the Aegean. The results of this original programme will provide valuable new data on two levels: (1) it will bring out the general differences in composition and alloy ranges in the four main regions of the Aegean, and (2) it will provide a means of testing a new approach to provenancing.

5.2 THE DATA

The bulk of chemical results available for the Aegean originate from the burst of activity and interest in the field of archaeometallurgy over the last two decades or so, with supplementary results coming from small programmes or individual artefact analyses. Analytical techniques varied from wet chemistry to Neutron Activation Analysis. Reproducibility of some results dating to the turn of the century has been demonstrated, although slight differences have been noted between the results

of Renfrew (1967) and of Esin (1969) by Gale *et al* (1984)^b.

Not all of the available chemical results were employed. Only artefacts which could be related to a reliable stratigraphy or contexts were used. A wide variety of types were included. Table 5.2.1., Appendix 5.

5.3 THE COMPUTER PROGRAMME

The computer programme used is outlined in Pollard (1986). All the computer work was carried out by Dr M Pollard at Oxford University. The interpretation of the results, following his guidelines, was carried out by the author.

The first application was cluster analyses. Particular care was taken in recording the basic measurements of the attributes, the calculation of similarity from the clusters and the levels of significance. The actual clustering employed Mahalanobis D-space and multi-discriminant analyses accompanied by principal component analyses¹⁸ and then concentration ratio tables. This reduced the dimensionality of the space without sacrificing too much of the information regarding location of the points, though it corresponds to the direction in which the data have the largest variation. The cluster schemes were given graphical representation in the dendrograms which portray the relationship between the clusters and evaluates, on an informal basis, the quality of the clustering schemes.

5.4 COMPARISON OF GENERAL COMPOSITION AND ALLOY RANGES WITHIN THE EBA AEGEAN

This section compares the basic compositional and alloy ranges characteristic of the four main metal industries of the Aegean in the EBA: Troad, Crete, the Cyclades and mainland Greece.

5.4.1 COPPER-LEAD Figure 5.4.1.

Figure 5.4.1 presents the data. There are few lead-copper alloys from

the Troad. Levels of lead are usually well below 1% which is the level of lead in a genuine lead-bronze. In the Cyclades, lead levels are usually below 0.8%, though as much as 3% lead is known in copper-based artefacts which are alloyed with another element also. Unalloyed coppers are rare in the Cyclades. In Crete, lead levels are very low, usually below 0.4%. Three lead-copper alloys are known however. Low lead copper is particularly characteristic of the copper used. On the mainland of Greece, low lead levels are known in even unalloyed coppers, though several lead-copper alloys are known. In a few cases, over 6% lead is recorded. There is more variety in lead levels in mainland copper artefacts than in those from the rest of the Aegean.

5.4.2. COPPER-TIN Figure 5.4.2.

The highest levels of tin are known from the Troad, where it is the main constituent in alloyed copper. In the Cyclades, the high tin-copper relationship is similar to the Troad though the number of high tin levels is limited. Low tin levels (under 1.5%) are also common. Arsenic levels are often higher in the low tin artefacts, and some of them qualify as "tertiary alloys". In Crete, tin levels are generally the lowest in the Aegean, though some true tin bronzes are known. In Greece, the use of tin is similar to that on Crete, though not all the new data was included in the computer input¹⁹. High tin bronzes are also known.

5.4.3 COPPER-ANTIMONY Figure 5.4.3.

There are two cases of high antimony in the Troad and this is rare for the Aegean in this period. They raise the mean antimony level for the area where the majority of copper-based artefacts have less than 1% antimony. Levels of antimony in the Cyclades are low and are present in artefacts with 91%- 93% copper, that is, those already alloyed. Unalloyed coppers in the Cyclades have no antimony and so the antimony is entering the copper via the alloy element. Cretan artefacts have a fairly consistent level of antimony

whether alloyed or not, which averages around 0.12%. In the mainland, low antimony levels, of around 0.5%, are characteristic in both coppers and bronzes.

5.4.4. COPPER-ARSENIC Figure 5.4.4.

Arsenic levels are predominately low in the Troad, though a few arsenic-copper alloys are known. In the Cyclades there are a few arsenic-copper alloys with up to 10% arsenic although around 3% arsenic is the average amount added. In Crete, almost all artefacts contain some arsenic-the average level being around 2.5%, though levels rise to over 4.5%. There is much variety in the arsenic levels in mainland copper-based artefacts, with the average level under 2.5%, though certain cases where it rises to 5.5% are known.

5.4.5 COPPER-IRON Figure 5.4.5.

The values for iron in Troadic copper-based artefacts are very scattered. Levels are generally below 1.05%. We should note however that in many cases the iron levels were not recorded in the analyses when published. The smelted copper used in the Troad was probably slagged using a variety of procedures. In the Cyclades, iron levels are lower than the Troad, averaging around 0.3%. This suggests good slagging procedures or the use of a high quality copper. The lowest iron levels in the Aegean are recorded for Crete, where 0.01% is an average, and Greece where the majority of artefacts analysed have no iron. This suggests the use of a high grade copper or very developed slagging procedures.

5.4.6 COPPER-SILVER Figure 5.4.6,

It is not easy to state the relationship between copper and silver for the Troad and the mainland as many measurements for silver are not available. It appears that silver levels are commonly below 0.1% in unalloyed copper-based artefacts in the Troad. On the mainland, a low level of around 0.1%

is silver known from unalloyed copper, but there are two cases recorded of higher silver, at around 0.5%, in unalloyed and alloyed copper. In the Cyclades, silver is present in almost all artefacts in unalloyed and alloyed copper. The average level is around 0.16% though one artefact has 1.7%. In Crete, silver is present in all artefacts up to 0.5%.

5.4.7. COPPER-NICKEL (Figure 5.4.7)

The lowest nickel levels in the Aegean are observed from the Troad and the Cyclades where the levels are around 0.4% and 0.45% respectively. The mainland and Crete have similarly higher nickel levels, at around 0.75% on average. The higher nickel levels on the mainland are often associated with higher arsenic levels.

5.4.8 TIN-ARSENIC (Figure 5.4.8)

Although sixteen measurements are missing from the Troad, a clear picture of the relative use of tin and arsenic is apparent. Tin is the most common alloy element. Arsenic levels are generally low at around 0.81% though the average in higher arsenic-copper alloys is around 6%. Tertiary alloys of tin and arsenic are known. We should note that there is a close relationship between tin and lead levels in several artefacts and it appears that at least one source of tin used in this region was contaminated by lead.²⁰ In the Cyclades, arsenic levels are usually low, even though levels of up to 7% for each have been recorded. Tertiary alloys of arsenic and tin are also known. In Crete, tin and arsenic were kept more distinct though arsenic in low levels is known in some of the higher tin bronzes. On the mainland, the average tin level was around 3% (including recent data on Levkas). Tin levels are either good alloy levels (i.e. around 6% and above) or below 1%. The predominant alloying element was arsenic, where the highest level was near 6% and the average around 1.5%. The highest level of tin ever recorded for the Aegean comes from the mainland. It had 22% tin.

5.4. 9. CONCLUSION

On the mainland, as in the Cyclades and Crete, the main alloy element was arsenic. Tin bronzes are known in every area of the Aegean. Lead-copper alloys and tertiary alloys are known in the mainland industry as in the other Aegean industries. There is as much variety in the range of elements and alloys on the mainland industry as in the rest of the Aegean. The arsenic-nickel relationship is particularly distinctive in the mainland copper working tradition, however. Figure 5.4.9 shows the comparative chemical character of Aegean copper artefacts in the principal component diagrams. This type of analyses replaces the original multi-dimensional data with a representation in only two or three dimensions. It can be regarded as successful if the first two or three components contain more than 70-80% of the total population variance. The principal component analyses for the EBA confirm the more detailed picture obtained in sections 5.4.1 to 5.4.9. They bring out the basically individual character of the four main metal industries of the Aegean.

5.5 THE NEW APPROACH TO PROVENANCING

This section introduces a new approach to provenancing. It attempts to utilise the mass of chemical results available for the Aegean third millennium BC by combining computer programming, metal typology and lead-isotope analyses, where available. It does not purport to be a general panacea for the provenance deadlock, but does offer insights and solutions which have hitherto eluded workers in the field. There are a number of ways in which a combination of the above data sets can support or test observations made for only one set.

5.5.1. MAINLAND GREECE

As a first step, eighty-five chemical results for the Greek mainland

were fed into the computer and dendrograms were obtained for the LN and EBA periods. The clusters in the dendrograms were then studied for their archaeological significance. The results of this section substantiate the conclusions made in 4.7 and in doing so prove the validity of the taxonomic analysis made by the computer. Thus it is worthwhile to apply the programme to the remaining Aegean material.

Of the eighty-five mainland results, sixty-two belong to the second half of the third millenium BC. The majority of LN finds fall into four main clusters (Figure 5.5.1.1). The first cluster represents very pure ^{average} coppers, characterised by low lead, antimony and iron levels. The ^{level} of copper was 98.7% and the artefacts ranged ^{in type} from awls to flat axes. The second LN cluster consists of material predominately from Sitagroi. This cluster has two sets, the first of which has more lead, antimony, arsenic and tin than the second. The third cluster is again of very pure copper (97% and above). No lead isotope results are available for this cluster. Two of the artefacts come from Sitagroi and the third from "Athens". There are no typological parallels between the artefacts in this cluster. In the fourth and final cluster, lead isotope analyses demonstrate that the copper originated from three different sources (the "S/S", Laurion and "Cypriote"). The similarity levels reflect iron content which no doubt represents similar slagging procedures. Two of the samples come from Sitagroi and this shows that similar techniques were used to work copper from two different sources. A further artefact from Sitagroi also belongs to this cluster, which shows that it was made with the same techniques, though no lead-isotope results are available to demonstrate which source it ^{could} belong to.

The dendrograms for the LN show that: the copper sources determined by lead-isotope analysis do not group chemically; the artefacts with higher tin all come from Sitagroi; there is no obvious relationship between

chemical composition and artefact type. The taxonomic analysis produced by the computer agrees with the results obtained in 4.7.

In the succeeding EBA the character of the industry changes. The dendrograms for the EBA alone show eight main clusters (Figure 5.5.1.2). Seven main clusters are observed in the combined LN-EBA dendrogram, (Figure 5.5.1.3).

An EBA awl of unalloyed copper from Mandalo falls into the LN cluster no.1. Lead-isotope results for this awl demonstrate that the copper from which it was made came from the "Cypriote" source. The EBA addition to the LN cluster suggests a continuity of tradition and use of unalloyed copper.

Many EBA artefacts group together with the LN cluster no. 4 when they are computed together. Low levels of arsenic are an important common feature of this group.

All the remaining EBA material forms new clusters. The next main cluster is number five. All the artefacts in this cluster come from Petralona and they also grouped ^{together} in the cartesian diagram (Figure 4.7.). Their similarity in the dendrograms also is consistent with their having come from a single hoard.

Cluster number six includes the high arsenic coppers. The main characteristic of this cluster is higher arsenic and lower nickel contents. The Petromagoula artefacts in this cluster demonstrate a local continuity of tradition from the earliest mainland arsenical copper from nearby Pefkakia.

Cluster seven consists of southern Thessalian artefacts from Petromagoula and Sesklo. The cluster is characterised by high arsenic, low nickel and low antimony. The alloys were deliberate and indicative of the use of a high arsenic alloy agent.

Cluster eight contains material from Sitagroi and southern Thessaly. All artefacts in this cluster were of smelted copper.

Cluster nine has material from Sitagroi, Spata and Sesklo. They all have lead levels which represent deliberate alloys.

Cluster eight and nine demonstrate the similarity between several artefacts from northern Greece and Thessaly.

The computer picked out the major differences and similarities between groups of artefacts and between LN and EBA artefacts.

5.5.2 MAINLAND GREEK AND AEGEAN MATERIAL

The second stage was to see where the mainland material would fall in the "master dendrogram" which contained all the Aegean material for the EBA.

All the chemical analyses for the EBA II-III in the Aegean were computed and the dendrogram which resulted is shown in Figure 5.5.2.1./2. A total of seventeen clusters were obtained. Four of these contained material from only one of the four main industries, one of which was local mainland material. This is significant, because it has been claimed that all mainland material consisted of imports from other areas of the Aegean. Of the thirteen clusters which remain, two represent material from all areas of the Aegean. There are no clusters with exclusively Troadic/Cycladic; Troadic/Cretan; Troadic/Mainland or Cretan/Cycladic material. The mainland and Crete share five clusters and the mainland and the Cyclades share three clusters.

Mainland material is found in twelve clusters (numbers 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 15 and 16). The five clusters where mainland material associates with predominately Cretan material are 2, 3, 5, 8 and 9. The three clusters which have mainland and Cycladic material are numbers 4, 6 and 15. The two clusters which have mainland and pan-Aegean material are numbers 10 and 16.

5.5.2.1 THE MAINLAND AND CRETE

Six clusters contain material from the mainland and predominately

Crete. The Cretan artefacts are from a large number of sites, but the mainland material comes consistently from four sites: Petralona, Sitagroi, Petromagoula and Eutresis. The material from Petralona is homogeneous, being a hoard, but the material from the other three sites are typologically quite distinct. No lead isotope analyses are available for any of the artefacts in these particular clusters. The Cretan material is mainly weapons while the mainland material is mainly tools.

There are no strong grounds for assuming that the artefacts are imported. Tools in copper are rare in Crete and Cretan weapons are quite distinctive. While it is not possible to say that the copper came from a similar source, it is highly likely that the same or similar techniques were used to smelt and work the copper at each of these sites. As the sites are geographically dispersed, perhaps the copper was prepared at some central supply which has not been discovered yet. It is difficult to put much weight on this interpretation, but one cannot ignore the fact that seven clusters repeatedly bring out a significant association in chemical composition between Cretan and mainland material.

5.5.2.2 THE MAINLAND AND THE CYCLADES

Much has been said about the relationship between the mainland and Cycladic metal industries, so it is surprising that only three clusters contain mainland and predominately Cycladic material. Lead isotope results are available for quite a few of the artefacts in these clusters and this makes the following interpretation more reliable.

Let us take cluster 4 where a discrete sub-cluster (228-099) represents an awl from Petromagoula and a spearhead type IIc from Amorgos (Renfrew, 1967, no. 52). The two artefacts are quite dissimilar typologically. Lead-isotope results for the awl show that it belonged to the "S/S" source. Lead-isotope data is not available for this particular blade from Amorgos, though results are available for other spearheads from the site,

(Gale and Stos-Gale, 1982, Fig. 3 top, and Table 3, 15-16). The copper used to make the Amorgos spearheads was derived from three sources - the Laurion, the "Cypriote" source and an as yet unidentified source labelled "A". When plotted on the lead-isotope diagram, a Late Cycladic find from Amorgos falls into the "S/S" source area and it is possible that this source was known in the EC period. There is no technological reason why the composition of these two artefacts should be so alike, and there is no evidence for Cycladic influence on the small tools at Petromagoula, which were probably made locally.

In two sub-clusters of cluster 6, northern Greek material is again found with material from Amorgos. There is an awl from Sitagroi and a blade from Saratse. The Sitagroi awl clusters closely with a flat axe from Amorgos. Lead-isotope results for the Amorgos axe showed that the copper from which it was made came from either the Laurion or a source with an identical lead-isotope ratio. There is no evidence for the use of Laurion copper as far north as Sitagroi, although one copper sample from that site had a lead-isotope ratio close to the Laurion field, even though it qualified for the "S/S" source. The metal industries from Sitagroi and Amorgos are quite different typologically, the latter being much more sophisticated.

In the second sub-cluster, a blade from Saratse groups with a dagger from Amorgos. It is fitting that the composition of these two artefacts is similar as they are of the same basic type - both are blades. The lead-isotope results for this Amorgos blade^{suggest it} was made of Laurion copper. Both artefacts date to the third phase of the EBA. The remainder of the cluster contains material from Amorgos - all daggers, two of which used copper from the as yet unidentified source "A". Obviously the method of production has more effect on the final composition than the source of copper used. One can dismiss the idea that the Saratse find was

necessarily an import. It is curious that no other blades are found in northern Greece in this period, however.

It is interesting to note how the island of Amorgos has material which clusters with three other sites, all from the northern half of Greece.

In cluster number 15, a knife from Sesklo clusters with material from the island of Kastri. The Sesklo knife falls into the "Cypriote" field in the lead-isotope diagram, as does another contemporary knife from Sesklo which has a different chemical composition. The two chisels from Kastri most closely associate with the Sesklo knife. Lead-isotope data showed that they belong to the Troadic "B" group, as defined by Gale ^b et al (1984). If we plot the Sesklo and Kastri finds together on one lead-isotope diagram, we observe that they fall into the same area (Figure 5.5.2.2). These artefacts are therefore made of copper which has the same lead-isotope ratio (if not exactly the same source) and were manufactured following the same techniques.

There is a definite similarity between the metalworking tradition in Amorgos and Syros which need not necessarily be related to the exploitation of similar copper sources. Typologically they do not represent a similar tradition. As noted for Crete and the mainland, perhaps the copper being traded or exchanged in the Aegean at this time was produced from the ore to the metal in certain centres which have not yet been identified, and then distributed. This implies that northern Greece was part of this distribution network in the EBA also.

5.5.2.3 THE MAINLAND AND THE GENERAL AEGEAN CLUSTER

Cluster seven contains artefacts for all four regions of the Aegean. This cluster represents a wide variety of types, from vessels, to jewellery to weapons. There is no connection between composition and type. Lead-isotope data for a spearhead and other artefacts shows that the metal

came from two sources, at least. The artefacts are all made of copper prepared to a similar technique, and as the mainland material is included, this shows that it was as abreast of new techniques as other areas of the Aegean.

Several artefacts from Kastri cluster with material from the Troadic region. Bossert (1967) drew attention to the typological similarities between certain of the samples found there and similar pieces in the Troad. The composition of the Kastri objects, especially their tin and arsenic contents, are uncharacteristic of the Cyclades at this time. Lead-isotope analyses of most of the Kastri finds demonstrated that the copper used was derived from three different copper ore deposits which are in turn different from the copper deposits exploited by other Early Cycladic metalworkers. Both the lead-isotope and the chemical data demonstrate that some of the Kastri artefacts were similar to two groups of artefacts from the Troad, in particular Troy II (see Gale ^bet al. 1984; Gale and Stos-Gale, 1986). The conclusions of Gale ^bet al. 1984 were based on the analysis of copper-based artefacts from the Troad. These views are substantiated by the work of Pernicka et al (1984) who demonstrated, from the analyses of copper ores from north west Anatolia, that Troy used different sources in the EBA.

Here we have a case where lead-isotope analyses support typological observations and demonstrate the potential of the clustering method in picking out significant associations between artefacts.

5.5.3 CONCLUSION

The clusters in the dendrograms are determined more by the resemblance in the production process than in the particular chemical character of the copper source used. Although lead-isotope results provides data on

source location, both multivariate analysis of the chemical results and typological data provides a check on the lead-isotope results and gives important information on the use of similar techniques which is lost in lead isotope, and indeed typological, studies alone. The assessment made of the similarity levels amongst the chemically analysed metal artefacts of the Aegean demonstrates that one is justified in using the computer to "standardise" the chemical results and provide a taxonomic ordering which could not effectively be achieved by any other way.

CHAPTER SIX

THE CONTEXT OF EARLY GREEK METALLURGY

6.1 INTRODUCTION

The aim of this chapter is to study the temporal, spatial and socio-economic context of metals and metalworking during the LN and EBA periods.

6.2 THE DATING OF THE ARTEFACTS

To place metal artefacts in their correct chronological position, the dates for artefacts and material evidence for metalworking were determined by checking their associated assemblage and stratigraphical context. Where such data was unavailable, typological parallels were employed. All the material, listed in Table 1.3.1. is classed in Table 6.2.1 into three groups. Group A have well-defined associations and reliable stratigraphical contexts; Group B were indirectly dated by comparative material and Group C were poorly dated/controversial. Group C material is discussed in Appendix 6.

6.3 THE REGIONAL DISTRIBUTION OF ARTEFACTS IN THE LN AND EBA

Figure 6.3.1 shows the combined geographical distribution of LN and EBA metal finds throughout the mainland.

In the LN period, about the same number of artefacts are known from northern and southern Greece. It had previously been claimed that most LN finds came from northern Greece (Branigan, 1974, 98). No finds are known from the central region in the LN. In the EBA this picture changes. The majority of finds now come from central and southern Greece. Forty-nine locations on the mainland have metal finds in the EBA against thirteen in the LN. There is also a marked increase in the evidence for metal-

working. Although the metalworking sites in the LN only number two, they occur in both northern and southern Greece. The amount of evidence for metalworking in the EBA is much greater, but it is restricted mainly to the southern half of the mainland.

In the first phase of the EBA, metal finds are very rare - much less than the preceeding LN period. They come from Sitagroi in the north, Eutresis, "Euboea", the "Peloponnese" and possibly "Mesolonghi" in southern and central Greece. The Eutresis example is the only clearly dated piece from the EH I. It is worthy of note that the first EB I finds come mainly from the south, in particular the central region which had apparently no LN tradition yet this region goes on to produce some of the major metalworking centres in the succeeding EBA.

From the beginning of the second half of the EBA, there is a dramatic increase in the number of metal finds. The emphasis in distribution is markedly central and southern. Northern Greek finds of this period are more rare and most cannot be dated with much resolution.

6.4 THE RELATIVE DISTRIBUTION OF DIFFERENT METALS

The relative distribution of different metals is shown in Figure 6.4.1.

Copper is the main metal used in each area and in each period. Lead, silver and gold have more restricted temporal and spatial distributions.

Lead is restricted mainly to the south, particularly the south-east where Attic lead sources, known to have been exploited in the EBA, are located (see 3.2.2; 4.4.3). The only finds of lead in the northern half of Greece are pieces of lead wire, one from LN Dimini and one from EBA Petromagoula (cat. nos. 380 and 382). No silver is known in the northern half of Greece. Lead and silver both become more common from the EH II period onwards.

Gold is known from northern and Thessalian sites mainly from LN contexts. Further south, gold finds are relatively rare in the EBA, though they are known in the central region (especially at Levkas).

There is an inverse relationship in the use of gold and silver for jewellery in northern and southern Greece, though the central region uses both and this may be indicative of the boundary between the respective N-S industries. No sources of gold or silver are known in the central region, so all precious metals, as well as copper, were imported. (3.2.2.; 3.2.3). More use is made of gold in northern Greece than of silver in southern Greece.

6.5 THE RELATIVE DISTRIBUTION OF ARTEFACT TYPES

While gold and silver were used for jewellery and lead for pottery repairs and weights, copper was used for the production of all three main artifact types: weapons, tools and jewellery/toilet articles, Fig. 6.5.1.

In northern Greece, the use of copper for weapons is very rare. Copper was used mainly for small tools, although a certain amount is used for jewellery alongside gold.

In Thessaly, copper was not used a great deal for weapons. Tools form the main group of copper artefacts, both numerically and by weight. Copper jewellery was rare, though gold was used.

More weapons are known from central Greece than any other area - the blades from Levkas adding substantially to the overall total. Just about as many tools were made from copper, although it is jewellery and toilet articles which form, numerically, the largest total, despite the number of gold and silver finds in the region. More copper by weight was used for weapons, however.

In the south, weapons are less common than in central Greece, although they total twenty-seven pieces. More tools of copper are known in the south than in any other area of Greece, although numerically the greatest number of copper artefacts are items of jewellery or toilet. In southern Greece less precious metal was used than in the rest of Greece. By weight, most of the copper was used to make tools.

Thus, copper had a distinctly practical use in northern Greece. In southern Greece most copper was put to practical use, though some of it was used for adornment or defence. In central Greece we have the only evidence^{of} ceremonial weapons (some weapons from Levkas, see 47) and copper was used^{for} both practical and ornamental purposes. The scarcity of precious metals in southern Greece supports the view that the Attic silver was probably not exploited until the end of the EBA (see 47). Silver could have been obtained from Siphnos and the distribution of silver finds in southern Greece would support such an area of origin.

6.6 LOCATIONS OF ARTEFACTS

The locations of metal finds is shown in Figure 6.6.1.

In northern Greece, the vast majority of finds come from inland sites. Most of these are on land routes. Material from coastal locations comes from sites to the east of the Thermaïkos Gulf.

In Thessaly, known finds come mainly from coastal sites, or sites just slightly inland. All sites are also on major land routes. Those in southern Thessaly gravitate around a major nodal area which guards an important north-south land route. They are also within easy access to the main water route south, the Evoïkos Gulf.

In Central Greece, the finds in the Ionian Sea, to the west, are coastal as most sites are located on islands. In the east of the central

region metal finds come from sites which were either coastal or associated with the former Copais lake. The main routes in the area were the land routes around the lake or connecting the area with Attica and Corinthia and the sea route along the Evoikos Gulf.

In the south, the vast majority of finds come from coastal sites, but some are located inland on main land routes or nodal areas, such as the pass from Corinthia to the Argolid.

Metals were thus transported by sea and land and it appears that/sites ^{non-coastal} on major land routes had proportionately greater opportunity of obtaining metals than others. Certain routes were obviously richer in metals than others (eg. the Khalkis-Corinthia-Argolid routes).

6.6.1 TYPE OF FINDSPOTS

The data in Fig. 6.6.1.1 show the relative distribution of finds in various locations: site; grave; cave or stray.

In northern Greece the finds come from a few sites, though stray finds are not uncommon. No material comes from graves or caves.

In Thessaly, most of the finds come from sites. None come from graves or caves.

In Central Greece, finds come predominately from sites, though an important number of finds come from large cemeteries, such as Levkas and Manika. A few cave and stray finds are also known.

In southern Greece, finds are found in all types of locations, the majority coming from sites. Most of the finds from graves come from the east of region.

It would appear that the central region and Attica are richer in metals than other areas, as they saw fit to conspicuously consume the metals by burying artefacts with their dead.

Let us now look more closely at the relationship between finds and

locations.

6.6.2 SITES WITH METALS

Here we discuss the types of sites which have the most metals. Many of these are in some way distinctive. "Special feature" sites are defined as those with a special function and accompanying architectural or functional/featural characteristics. The functions could be social, political, economic, defensive or possibly religious. Monumental buildings indicate a developed social role and are no doubt indicative, in most cases, of social stratification. The special feature or special function sites have: 1) central, large buildings; or 2) fortifications; or 3) sites with evidence of metalworking or a substantial number of metal finds, and/or 4) sites with collective or distinctive mass cemeteries which indicate social stratification of the interred. A combination of these features is often found.

6.6.2.1 CENTRAL BUILDINGS (Fig. 6.6.2.1.)

These buildings range from buildings of larger size, within sites or associated with sites (but with no other distinctive feature), to complex, central buildings of distinctive, monumental design, usually megaron or circular in shape.

The rationale for assuming that such buildings and their associated sites were more important or significant than others rest on the determination of the function of these central buildings. Evidence indicates that they were not usually occupied, but had some communal function. No two buildings are identical, but their architectural complexity suggests that they represent social stratification or perhaps territorial demarcation. Despite the increase in internal and external contacts, agriculture still remained the basis of the EBA economy. Settlement location, even though predominately coastal, was directed by the availability of good

arable land. The function of these central buildings is undoubtedly connected to the needs of the agricultural communities which built them. Most of the debate regarding these large buildings centres around their possible function as storage centres.³⁰ Storage implies surplus, which in turn requires redistribution. What surpluses were intended for is obviously central to the debate. There are two possibilities: they were intended to protect against times of shortage or they were produced to supply the export or exchange trade. Estimating the areas they were to serve in times of shortage is difficult, however. Halstead (1981) has also noted that more effective storage would have been to fatten livestock, who could then be transformed into food later. These surpluses, which were organised, could have been for local, inter-regional or external distribution (Renfrew, 1972; Bintliff, 1976; Chadwick, 1976). Many believe that surpluses were for local consumption as they can find no good evidence for exports, (Renfrew; Bintliff; Gamble, 1979). If certain areas of mainland Greece had to obtain copper or other produce from abroad, the question still remains as to what could be used to exchange for it. Bintliff (1976) has pointed out that areas with known copper sources, in the east Aegean and east Mediterranean, produced the same range of subsistence goods as mainland Greece. Lehmans (1977) has noted that a similar problem exists in Mesopotamia, where it is known that most products were imported but there is no evidence of exports.

Just as important as the goal of surpluses is the question of who organised the surpluses. It is difficult to assess the relationship between the LBA palace system and the EH storage system. If storage was a community effort, why is there evidence for social stratification in so many graves. If storage was directed by a ruling group was it permanent or temporary, that is, was the ruling group selected members in a decentralised political

organisation, chosen because of the age grade or association organisation to which they belong (such as the Kipsigis of East Africa where the senior age grades of the warrior and the elder take most of the political decisions, (Prins, 1953) or the Cheyenne Indians which formed military societies to deal with particular problems as they arose (Hoebel, 1960)). Alternatively, we must assume that surpluses were directed by some centralised political body, such as a chieftainship, where a ranked society exists and every member has a position in the hierarchy. In a decentralised system, exchange could take the form of balanced inter-regional reciprocity. In a centralised system, redistribution implies a form of exchange in which goods flow into a central place, such as a market, and are redistributed again. The economy is controlled by the chief and his immediate followers. The Argolid possesses more "proto-palaces" than any other area of Greece during the EHII. Was this area just particularly advanced in the organisation of local foodstuff redistribution or do the redistributive centres tell us something else? It is obvious from the distribution of redistributive centres that not all areas of southern Greece were governed by the same level of political authority. If areas with central buildings were ruled by chiefs, then there is a relationship between the rise of more complex political and social organisation and the distribution of the Mediterranean polyculture (Renfrew, 1972, figure 15.6). It is these areas which also have more evidence of foreign contact in the second half of the EBA (see 6.8). There are still many outstanding problems in the interpretation of their function and their relations with other areas of the mainland which were apparently not organised on the same scale, (eg. Laconia). In the MBA, the central buildings decline but monumental architecture continues in the form of fortifications.

Let us now look at the most important buildings themselves. The circular buildings are known from Tiryns (Kilian, 1982) and Orchomenos (Bulle, 1909). Circular buildings of a smaller scale are characteristic of the Cypriot Neolithic, and are known also from Kythera and later, in the EBA, from Poliochni (Brea, 1964). It is thought that the buildings at Tiryns and Orchomenos were used as regional storage centres for agricultural produce, Bulle (1909); Marinatos (1946, 337); Vermeule (1972). Orchomenos has a very uniform construction. There are no traces of doorways. Evidence suggests that the building went through three separate phases when the former was demolished and the succeeding building placed upon the same spot. It was no doubt covered by a "beehive" superstructure in crude brick. Indeed, the shape of the roof, walls and the absence of doorways argues convincingly in support of Marinatos' view (1946, 337) that this building, together with the **Rundbau** of Tiryns, were granaries. Granaries are filled from the top. Contemporary granaries in Egypt were similar. However, no evidence for grain has been found.

The **Rundbau** of Tiryns is larger in size and more complex in construction. This is the largest EH building known. The double wall of the building provides two concentric "corridors". The remarkable system of buttresses at the base suggests that it had to bear a great weight. The building was tiled. In the limited area that could be excavated there was no evidence bearing on the manner of access to the building. The building would have had two or three storeys approachable by ramp or staircase. It is unlikely that this building was simply a granary, on account of its size. Müller suggested that it was a palace and one of the floors could have been living quarters (Müller, 1930).

The remainder of the large buildings are **megara**. Without detailing the various theories concerning the origin, development and diffusion of the **megaron** in Greece or elsewhere, a brief account of the place of Greek

megara will be given. Rectangular or nearly square buildings are known in Greece from the Early Neolithic at Nea Nikomedia (Rodden, 1964) and later in the Neolithic at Otzaki Magoula and Tsangli (Theocharis, 1973).

Modification of the original, square design might involve the addition of rectangular rooms to one or all sides of the building, resulting in

a simple, long and narrow megaron-like form. In Crete, the structure of the megaron becomes more complex. The regular two- or three-roomed structures appear very early on the Greek mainland, without the central room losing its initial, almost square, form. Later, Neolithic examples are seen at Otzaki Magoula, Sesklo, Velestino and Dimini (Theocharis, 1973; Tsountas, 1908). The Dimini building is made into a megaron in the EBA by the addition of a hall and vestibule. Most Neolithic **megara** are easily distinguished within settlements.

While most EBA houses are **megara**-shaped, it^{is} the large scale **megara** which can be distinguished as central buildings in the settlements to which they belong. Monumental **megara** are confined to southern Greece. Their architectural form, structural details and purpose still remain problematic.

Comparable Aegean material is known from Troy (Blegen, 1961) and Heraion on Samos (Milojčić, 1961).

Figure 6.6.2.1 gives the distribution of such central buildings on mainland Greece along with the distribution of metal finds and the evidence for metalworking.

All central buildings but two (Akovitika and Orchomenos) had metals. Seven had associated evidence of metalworking. Seven other sites with evidence of metalworking were not associated with central buildings (although three of these were associated with fortifications or possible fortifications, see 6.6.2.2).

There are more central buildings per square kilometre in the Argolid,

Copais basin and Messenia than in any other area. Those in central Greece and Attica are on major routes and this is also the case for those in Corinthia and the Argolid.

The central buildings on Aegina and Spetses would have served the needs of their islands and may also have played some role in goods sent by sea. They are both on major sea routes (see Ch 7). It is the region from the Argolid to Copais that has most of the EH II-III metal artefacts and the central buildings date predominately to the same periods.

6.6.2.2 FORTIFICATIONS (Figure 6.6.2.2.)

The fortification of sites was practised from the Early Neolithic. None of the fortifications at mainland sites have been completely cleared and it is not possible to tell how the fortifications as a whole relate to the whole plan of a settlement. However, in most cases it is possible to classify fortifications into basic types- the magoula, ditch or moat, acropolis or stone wall. Supplementary fortifications were usually added to naturally defensible positions.

In northern Greece, most of the early fortifications date to the Neolithic period, particularly the MN and LN. Almost all of the fortifications were located in proximity to the coast or to lakes or rivers. It is difficult to find parallels for ditches, though defended Balkan ditches are perhaps the most suitable. Chourmouziades (1979) observed that it is still the practice in many Thessalian villages to dig a large ditch around the settlement in order to obtain raw material for mud bricks. This could be a probable explanation for the small ditches, but those the size of Servia (north Greece) or Argissa (Thessaly) require another explanation as do the multiple ditches such as are found at Sesklo (Tsountas, 1908), Gremnos (Theocharis, 1973) and Dimini (Tsountas, 1908). Drainage does not appear to be the reason for them as all but two of the ditches were located on elevations where

natural drainage would have occurred. Simple ditches are often dug round settlements in ancient times for religious purposes. It is not apparent that any of the ditches acted as rubbish dumps. Excavations demonstrate that they were generally kept clear during the period of use.

Thus, sites with multiple ditches or with ditches accompanying walls were most likely concerned with their security. Fortifications signify the beginnings^{of} territoriality which accompanies sedentary village life, especially noticeable towards the end of the Neolithic when, in Thessaly at least, population increase led to infilling of available agricultural land.

The basic form of fortification in north Greece, found predominately in Thessaly, was the ditch. These are almost unique to this area. They would have been the easiest to make as the soil was generally good and as such conditions are not found in the southern half of Greece where the land is stony, stone walls became the common type of fortification in the EBA.

Twelve sites are fortified in southern Greece, the earliest being known from Perachora-Vouliagmeni which dates to the later EH I (Fossey, 1969). The majority of defences date to the EH II and in many cases it is difficult to assess whether or not they continue into the EH III period. Most sites were located on naturally defensible positions, mainly near the coast.

The EH I fortification at Perachora is somewhat different from the general type known in the EH II. It was initially a stone wall, possibly circuit, which was superseded by an earth bank with stone revetements on each side (Fossey, 1969). The standard EH II fortification had strong stone walls as the base or foundation, and a superstructure of mudbrick. Stone walls for fortifications are first known in the Cyclades, from LN Emborio (Hood, 1981) if not before (eg. from Saliagos in the MN, Evans and Renfrew, 1968).

Within the area of the southern mainland, similarities between fortifications are noted, in particular between the stone and mud-brick

walls of Askitario (Theocharis, 1954)^a, Raphina (Theocharis, 1954)^b and Manika (Papavasiliou, 1910). Differences are also obvious, such as those between the Lerna (Caskey, 1955) and Aegina (Welter, 1910³⁷; Walter, 1986) fortifications which have quite different plans and wall designs. An entrance system comparable to that at Aegina is not found at Lerna, though a close parallel is known from Troy II (Blegen, 1961). Again the closest parallel to the flagged and stepped approach on Lerna's fortifications is also seen at Troy II.

Though Raphina and Lerna appear similar in overall construction, the rooms at Lerna are obviously an integral part of the fortification system, whereas at Raphina it appears as if the builders merely took advantage of a convenient strong wall for their houses.

There is quite a strong relationship between some of the southern Greek fortifications and those in the Cyclades. Many similarities have been noted between the design and structure of the Lerna and Chalandriani (Bossert, 1967) fortifications, in particular their dry stone walling, bastions and magazines.

French (1968) believes that Lerna, Tiryns and Troy represent the fortified "çiftlik" or farmstead, known in its earliest form at Karataş (Mellink, 1963). Lerna and Troy were more than farmsteads and recent excavations at Tiryns (Kilian, 1982) have shown that the size of the fortifications suggests a grander purpose.

Nine fortifications are associated with important central buildings and seven with metalworking sites. Eleven fortifications had important finds of metals.

Three LN fortifications in Thessaly had metals, but most of the main fortification in the south had metals - except for the earliest fortification at Perachora-Vouliagmeni. No fortifications are known from the Copais region and this must be because the sites were inland and it is here that

we have metalworking sites without fortifications.

Thus, fortifications began in the MN in Greece and become more common in the LN, especially in heavily settled areas, such as Thessaly. The type of fortification changed in the EBA as a result of the physical environment of the south, which did not provide conditions suitable to the digging of ditches. There is evidence that EH fortifications were associated with larger or more important centres. They did not necessarily demarcate territory, but it appears they were constructed to protect coastal sites from threat. As seafaring increased at this time, pirates and raiders must have also increased. Fortifications protected vulnerable settlements.

6.6.2.3. DISTRIBUTION OF METALWORKING SITES ^{a, b.} Figure 6.6.2.3

This section will look at the location, size and type of site which has evidence for metalworking. The data is summarised in Table 6.6.2.3. From this it is clear that Copais, the Argolid and Attica have the most evidence for metalworking. The nearest neighbour distance between these sites is shortest between the Attic and Argolid centres.

There is no apparent relationship between central buildings and the evidence for metalworkingⁱⁿ the Copais region, although there is a clear relationship between the number of metal artefacts and central buildings. Copais was certainly a nodal area and one which obtained metals through trade or exchange as it is very poor in resources.

In Corinthia/the Argolid, there is not a great deal of evidence for metalworking though it was practised at four sites. As none of the reported slags have been analysed, it is not possible to confirm whether or not they were the products of melting or smelting (see 4.2) No metallurgical furnaces have been discovered as yet in the area.

In Attica we have much evidence of metalworking, both in copper and lead. Most of the sites are in the eastern half of the peninsula. Thorikos

and the Laurion were exploited for lead and the Laurion for copper also from the middle of the third millenium BC. The earliest evidence for metalworking in southern Greece comes at the end of the Neolithic at Kephala on Kea (Coleman, 1977).

Finds at Kea consist of two fragments of possible knives and four tools (Coleman, 1977, 3-4). Slags from Kephala have been analysed, but there is some disagreement over the results. Conophagos (1977) concluded that smelting was being practiced in the LN, though he does not stipulate on what grounds he bases his conclusions. Further analyses of the same samples by Tylecote and Cooke (1977) agreed with Conophagos' conclusion regarding smelting, but maintained that the metallurgical processes which produced the slags were more advanced than would be expected at such an early date, without actually detailing in what respects they were more advanced. It is thus possible that the Kephala slags are not LN and that the range of techniques at Kephala did not vary from those at Sitagroi in the same period. One piece (no.7.147, Coleman, 1977, 108) was analysed and found to be almost pure copper and this in itself may be characteristic of the level of metalworking in LN Kephala.

The earliest evidence for metalworking comes from northern Greece and dates to the beginning of the LN. Metalworking continues throughout the LN and into the beginning of the third millenium BC at Sitagroi. Slags and small artefacts are known from Sitagroi levels II (5200-4800BC) and III (earlier than 4700-c.3300BC). Preliminary analyses of slags by Slater (1972) do not confirm smelting (see 4.6); and the clearly established techniques with which we are dealing involve hammering (of native copper), casting of re-melted copper and annealing techniques.

In east Attica in the EH II and at Aegina we have much new evidence for metalworking which includes a possible metallurgical furnace from Aegina and material from Rouf (Petritaki, 1986) and Koropi (Kakavoyiannis, 1985).

The metallurgical kiln (at Tiryns) may have been used in the EH II-III period (Walter, 1986). Recent finds, as yet unpublished, indicate that Manika may have had metallurgical kilns and an area for separating the copper ore from accompanying minerals. The site is certainly richer in metals /^{than} has hitherto been believed²².

Although the area of most intense metalworking, Attica and west central Euboea, is well-served by fortifications, Raphina is the only site in that area with a central place. There is no evidence that any site, except perhaps Manika, has a monopoly over mineral deposits (see 6.9.1.3.). Thus the areas with the most evidence for metalwork and metal artefacts are those with the least evidence for reliable mineral sources. This suggests that these sites had the added function of controlling the supply of copper imported from outside the regions.

6.7 GRAVE TYPES

Several finds of metal were made in various graves throughout the mainland. Most finds from graves came from the southern half of Greece, however.

Figure 6.7.1 and 6.7.2 show the distribution of different types of graves which have metal artefacts amongst their offerings. The aim of this section is to determine whether or not there is any relationship between grave type and the metals associated with them.

The pithos mode of burial was considered to have started in Crete in the Early Minoan period. It is the most common form of burial in EH Greece, though this picture is due to the numerous examples from Levkas (Dörpfeld, 1927). Geographically, this method is the most widely distributed.

Rock cut tombs are a feature of the later EBA and only two cemeteries are known (Manika, Papavasiliou, 1910; Sampson, 1985; 1986; and Zygouries, Blegen (1928)).

The first built graves in the Aegean are known from LN Kephala on Kea (Coleman, 1977). Roughly built graves using slabs developed into cist graves which are considered typical of the Cyclades in the third millenium BC. The first mainland cist grave was found in the Athenian Agora (Shear, 1936). Until the cist graves at Syvres^{on Levkas} (Andreou, 1975) and Strephi in Elis (Koumouzelis, 1979) were brought to light, this grave type had a distribution which was concentrated in south east Greece.

Intramural graves are known in the LN and EBA. Much evidence for this mode of burial has been lost as the buildings which contained them were buried under tells or succeeding buildings.

Cemeteries, defined as places for mass burial distinct from living quarters, begin in the LN. It is more common for cemeteries to be set outside the settlement in the EBA however. This accounts for the small number of cemeteries known in the EBA. In the case of the Nidri cemetery on Levkas, the site cannot be located at all (see 8.6).

The number of metal finds from the different types of graves appear to be almost equal, when we qualify the rich data from the Levkas graves. No particular type of grave consistently yielded more or richer metals than others. Some trends, however, can be detected.

Rock-cut graves had proportionately higher silver than other types of graves. The Manika graves have much evidence of contact with north-west Anatolia. ²³

The pithos graves have overwhelmingly more weapons than other grave types, as the finds from Nidri show.

Cist graves have proportionately more Cycladic artefacts in their associated grave goods than any other grave type.

Silver occurs in all grave types; gold is much rarer. It is known only from Levkas and Zygouries.

Thus there is a wide variety of burial customs within southern Greece. No one type is regionally distinct. No clear pattern emerges from the multiplicity of burial customs, except that there is a preference for communal burials. Communal burials are first known in Crete in the EM I and are common in the mainland and Cyclades in the EBA II.

Despite the lack of apparent patterning in grave type distribution, burial practices are not mixed, each region or settlement keeping to one type.

The earliest cremations are known from Levkas, but we have no evidence for human or animal sacrifices at this time.

There is evidence that some metal artefacts were made specially for the graves. Some blades from Nidri, Levkas (see 4.7) were not strengthened by arsenic or tin and were thus of ceremonial, not practical, use.

The obvious distinction of certain graves within some cemeteries through rich grave goods strongly suggests marked social ranking. This ranking may, in some areas at least, have been based on military strength. The Nidri graves number thirty three, twelve of which were rich in metals. Seven of the graves produced mainly weapons and are believed to be male graves; five others produced mainly jewellery and are believed to be female graves. At Manika, great wealth distinguished certain members of society in the cemetery. Whether wealth, military power or both represent an elevated status for certain members of society, the possession of metals was an obvious symbol of that status. The question remains as to what conditions led to the development of the social elites.

6.8 THE EVIDENCE FOR FOREIGN CONTACT IN THE LN AND EBA

A thorough search was made of all the excavation reports for mention of foreign elements in the ^{EBA}assemblages associated with metals or evidence for metalworking. The data is presented briefly in Table 6.8.1. and this is complimented by Tables 7.1.1. and 7.1.2 in the following chapter.

It is difficult to assess directly the significance of similarities or imports in pottery to those of metallurgy. They can only be taken as evidence of contact between different parts of the Aegean. The evidence for such inter-Aegean contacts is greater for southern Greece and for those areas which would have been involved in the contact network permitted by the sea currents (see Ch 7).

Cycladic influence is the most notable, this region being geographically closest to southern mainland Greece. Troadic and west Anatolian influence appears to come in during the EH II and last until the EH III. Cretan influence is minimal - probably being directed via the Cycladic islands. The data given above shows that the mainland took an active part in the exchange network which operated in the Aegean during the second half of the third millenium BC, but its pottery repertoire, as well as its metal repertoire, remained distinct, despite the borrowing and exchange of ideas and artefacts at this time.

6.9 THE RELATIONSHIP BETWEEN THE DISTRIBUTION OF METAL RESOURCES, METAL ARTEFACTS AND METALWORKING SITES

This section looks at the distribution of metal sources, artefacts and the evidence for metal working or extraction, in the hope of discerning possible areas of early exploitation and distribution. Metalworking sites have already been discussed in 6.6.2.3.

One would expect to find that the distribution of artefacts shows a clear "fall-off" around sources and would presume that metalworking sites would have a direct relationship with sources as the transfer of metallic ores would have been laborious. We have the advantage of several chemical and lead-isotope results to help suggest possible sources which were exploited in the LN and EBA.

6.9.1. COPPERS AND BRONZES

Here we give the distribution of copper and bronze artefacts and shows their relationship to copper sources and the evidence for copper metalworking. The distribution is shown in detail for each region of Greece in Maps 6.9.11(A-E). We will look at each region separately.

6.9.1.1 NORTHERN GREECE

In northern Greece there are three groups of metal finds located around the three sites of Sitagroi, Petralona and Vardarophtsa, respectively. Altogether fifty-one copper/bronze artefacts are known from these three groups, nine of which belong to the LN and forty-two of which belong to the EBA.

(1) The Sitagroi Group

The three sites in this group are Sitagroi, Dikili Tash and Dimitra. The number of artefacts which belong to the LN total eight and those which belong to the EBA total twelve. Evidence of metalworking comes from Sitagroi and Dikili Tash (see 6.6.2.3.).

The closest sources of copper are numbers 13, 14, 15, 18 and possibly 19 (Figure 3.2.1). All these sources are within a radius of about 20-30 kilometres and all have obvious oxide copper, mainly malachite and azurite on the surface. The nearby mixed sulphide sources contain some copper also (especially galena copper sources no. 38, 53 and 54, even though no galena was used in the north of Greece in the LN or EBA.) Copper source no. 15 is high on Pangaion mountain, cut off from the river valley behind it by steep mountain ridges. This source may not have been as accessible as the others. No. 19 has chalcopyrite as well as oxide copper and this is scattered on the surface and is obvious from open trenches in the ground.

There is evidence that no. 54 was exploited in Antiquity for lead and silver and that Pangaion was a source of gold from early Classical times (see 3.2.3). There is no direct evidence for the exploitation of any copper source at this time, however.

The sites in this area had potential sources of accessible copper of the type used in the LN/EBA right on their doorstep. Many of the finds in this group date to the LN. It is in this period that many suggest northern Greece was in the Balkan sphere of metallurgy (Branigan, 1974; Chernykh, 1978). However, the evidence for possible smelting and use of tin at Sitagroi suggests that the metallurgy practiced had a certain local character as well. Lead-isotope analyses demonstrated that Sitagroi used more than one copper source. Similar analyses of Balkan ores, especially Rudna Glava should perhaps shed some light on at least one of the sources used by Sitagroi and perhaps the whole group, though it is quite likely that some if not all of the copper used was obtained locally. (see 4.5)

(2) The Petralona Group

There are four sites in this group, Petralona, Gona, Kritsana and Saratse. They are all located near the Thermaikos Gulf.

The copper finds from the group all date to the EBA and number twenty-six. Although the chronological evidence for Kritsana and Saratse is not clear, the finds probably date to the end of the EBA. The Gona find dates to the beginning of the EBA and the Petralona hoard is apparently later EBA in date (see 6.2).

There is no evidence for early copper working in this group, though slags from gold working are known from Saratse which testify that metallurgy was practiced at these sites in the EBA. There is no direct evidence for metalworking in Antiquity, except for reported gold panning in the Gallikos river, near Saratse.

Neither copper sources nor mixed sulphide deposits containing copper are known in the immediate vicinity of this group. The closest deposits of copper are those in east Chalkidiki, numbers 26 and 27. No. 26 is a sulphide copper deposit, with oxide copper associated and no. 27 is Skouries, a rich copper deposit in Greece, exploited in Antiquity and today. Malachite, azurite and even chalcopyrite are to be found scattered on the surface. It is possible that source no. 19 could also have been used. The richest mixed sulphide deposits also lie in east Chalkidiki, and numbers 74 to 82 are well endowed with copper. The copper here is associated with galena, and often arsenic. The Petralona hoard had a high percentage of arsenic (47) which may be indicative of local source exploitation.

As the distribution of the Petralona group is predominately coastal, it is possible that the east Chalkidiki copper was transported by sea. Alternatively, Balkan copper could have been imported via the Vardar /Axios valley. The fact that the finds from Petralona itself came from a hoard suggests the importation or exchange of artefacts rather than raw copper. This may be substantiated by the lack of evidence for copper working in this small region. No new analyses are available yet for any of the artefacts in this group.

(3) The Vardarophtsa Group

There are three sites in this group, Vardarophtsa, Vardina and Mandalo. They are all located along or near the Vardar/Axios river, Mandalo being located further to the south west. All these sites were once closer to the sea as the Thermaikos Gulf has silted since prehistoric times (Eumorphopoulos, 1964).

Four copper artefacts are known from the sites, all of which date to the EBA, probably the second half. Evidence of copper working is known from Mandalo (6.6.2.3). There is no direct evidence for metalworking or extraction in Antiquity or even in more recent times, apart from slag deposits near sources 22 to 25.

The closest copper sources are at an average of 30-50 kilometres from the sites. They are all quite accessible and have malachite, azurite and chalcopyrite. Copper sources 22 to 25 to the east and 28 and 29 to the west of the group are the closest. A set of mixed sulphide ores (nos. 71 to 73) which contain copper are located farther up the Vardar valley. They may have been known if transhumance was practiced by the sites.

As the Vardar-Morava valleys are the main access routes north for west Macedonia, it is possible that some copper, either in the form of artefacts or metal was reaching these sites from Yugoslavia, though the slags from Mandalo suggest that local copper could have been used. Lead-isotope results for the copper from Mandalo showed that this site used a different copper source from the sources used by Sitagroi. If one of these sources was Balkan, we still have to identify the remaining three.

The evidence for northern Greece shows that at least four different copper sources were exploited. Ai Bunar and Rudna Glava were exploited at this time. If copper was imported from one or both of these sources, one would expect that all the copper used by each site would be of one or

two types, which is not the case. This fact, combined with the evidence for possible smelting in at least two sites, strongly suggests the use of local copper sources.

6.9.1.2. THESSALY

There is only one cluster of finds from Thessaly and these are in the south of the region. All the sites with metals, apart from Rachmani, cluster to within a 50 kilometre radius of one another. They are: Sesklo, Dimini, Pevkakia and Petromagoula. Over twenty-five copper/bronze finds are known from LN and EBA contexts, though over ten of these could be EBA I/II/early MB I. Nine LN artefacts are known from three sites - Sesklo, Dimini and Pevkakia and fourteen artefacts from the EBA sites of Dimini and Petromagoula.

Evidence for copper/bronze metalworking comes from Sesklo alone (see 6.6.2.3.). In Antiquity, there was much activity in the mines of the Orthys mountain range. There is evidence for the exploitation of eight copper sources in Fthiotidha, the immediate western neighbour of southern Thessaly.

The closest sources to southern Thessaly are sources numbers 40, 41, 42 and 43. All of these have been visited personally as part of this work^{2,4}. They are all rich in chalcopyrite and all have obvious surface appearances of malachite or azurite. The most accessible are numbers 40-43. Important copper lodes occur in the mixed sulphide deposits numbers 87, 88 and 89. These lodes have obvious chunks of galena and copper in the mineral matrix. It would have been easy to separate the metal crystals from the quartz.

The single find from Rachmani could have been made from copper coming from the nearby copper deposit no. 39.

Fthiotidha is one of the richest areas in Greece for copper. The nickel contents in the coppers from Petromagoula may have been the result of using copper from Limogardion or other sites in the region which have

copper and nickel in close association (see 3.2.1). Lead-isotope results suggest that one source was used with a similar Pb-isotope ratio to the Laurion, and also showed that other copper sources were used by this group of Thessalian sites (see 4.7)

6.9.1.3 CENTRAL GREECE

There are two main clusters of finds in the central region of Greece. These are the thirty-two finds from Levkas, in particular the "R" graves at Nidri, as well as the finds from Syvres and Pelikata, with the second being the group of ninety finds from several sites in the southern Copais/Khalkis region (i.e. Lithares, Eutresis, Thebes, Lefkandi and Manika).

All of the finds date to the EBA except a stray find from "Euboea" (cat. no. 263) and one from "Mesolonghi" (cat. no. 160).

Over sixty artefacts of copper/bronze and silver, comprising weapons, tools and jewellery have very recently been recovered in new excavations

at Manika (1985-1986, Sampson²²). These finds show that the central region had two of the largest collections of copper/bronze finds, both from graves contexts. New evidence for metalworking has been found at Manika and metalworking is implied from the originality of some finds from Nidri, Levkas. There is no direct evidence for ore extraction in this region in Antiquity, the nearest sources being those in Fthiotidha. As no sources are known in the central region, the copper was imported. This substantiates the evidence for a trade in copper during the EBA.

The closest copper sources to Levkas are in the distant mountains of Epirus on the mainland, numbers 34 to 37. After these come those in Fthiotidha. The island of Levkas itself has three main geological zones, one of which is the type shown in Figure 3.2, that is the geological deposits which are known to bear copper. It is possible that copper sources may have

gone undetected on Levkas. Geological surveying has been very limited on the island. Levkas was supplied by sea and, like Manika, managed to secure a steady supply of copper throughout the EH II/EH III period.

In central Greece, the distribution of artefacts concentrates predominately along the shores of the one-time Copais Lake. This area acted as an entrepot between north-south seaward and east-west landward trade and communications. The east Boeotia/Khalkis connection links Euboea with central Greece, and through the land passes, with the Peloponnese. Attica is more easily reached by sea. Thus via the Evoikos Gulf, Attica (and its sources) is in touch with Central Greece, Thessaly and Euboea. It seems that Manika and Khalkis functioned as a port or ports in the tidal gulf and that this enabled them to secure a supply of copper. It is also probable that their function as an entrepot developed because there was once no sea passage between Euboea and the mainland (see 8.5). All metals and other goods would then have been transported overland for a short distance.

Manika and other sites in west central Euboea show that the directions of foreign contact and perhaps trade, was with the mainland, the Cyclades and Anatolia (see 6.8), and so we cannot be absolutely sure that the area obtained its supply of copper solely from any direction. On current evidence it is possible that it was supplied from several areas.

As we have no firm evidence of contacts between Italy, northern Greece and the Ionian islands, we should assume that southern Greek sources supplied the Ionian industries. This supply probably arrived via the Corinthian Gulf or the western coast of Greece. Pottery distributions indicate that both these routes were used in the EH II (Howell, 1982). Cycladic sauceboats and painted wares are known from Teichos Dymaion (on the Corinthian Gulf) and from Ithaka (off the coast of the west Peloponnese). Moreover, the distribution of northern Minyan ware extends from Levkas/Epirus along

the Corinthian Gulf and down to Euboea. It is thus most probable that the copper in Levkas came from a south-easterly direction. Lead-isotope analyses substantiate this view (see 4.5). The number of finds and volume of metal implies a steady supply. This is confirmed by the fact that most of these goods came from the "R" graves on Levkas. This form of conspicuous consumption is only possible when the supply is secure. Overall, this implies a well-organised system of procurement. If the alternative dating of the Nidri assemblage is accepted (see 6.2) this industry extended into the MH period; the island therefore succeeded in securing copper despite the upheavals and discontinuities of the EH II-III period (Caskey, 1972). The areas which we presume served the island with copper were affected, however. The question is, how did Levkas manage to secure a good supply of copper throughout the EH II-MH period?

Other finds in the region are scattered. They are known from Aghia Marina (Phokis), Delphi and Levadheia. They are not near any copper sources but are all on land routes.

In Central Greece, we have a great deal of evidence for metalwork, but no real indication that local or nearby sources were exploited. Our only safe conclusion is that the sites in this region imported their copper and thus trade in copper during the LN was already a well-established practice.

6.9.1.4 ATTICA AND SOUTH WEST GREECE

In Attica/South West Greece there are ten sites which have a total of twenty-seven finds. The sites are: Athens, Aegina, Aghios Kosmas, Rouf, Koropi, Marathon, Askitaro, Raphina, Kitsos and Kephala (Kea). Eight of the finds come from LN contexts and nineteen from EH contexts.

The evidence for metalworking is known from one LN site (Kephala, Kea) and seven EH sites (Raphina, Askitaro, Aegina, Rouf, Koropi, Laurion and Thorikos, see 6.6.2.3). The last four are predominately for lead/silver

working. The evidence that Laurion was exploited for copper as well as lead and perhaps silver is indirect and comes from the lead-isotope results of EH artefacts. The four mixed sulphide sources, predominately galena and ironpyrite, have significant amount of sulphide copper. Sources 102, 103, 104 and 105, all mixed sulphide ores, also contain arsenic, copper and galena. Source 103 (Tsakir Villia) once produced 25 Kg/t of silver and 104 was also exploited in Antiquity, mainly for silver.

Mixed sulphide ore with associated copper is known from ten locations in southern Euboea, around the village of Kalianou. Copper, lead, silver and gold are known and there is evidence of exploitation of lead ores in Antiquity. Theocharis (1955) suggested that Kalianou supplied Raphina with its copper. Lead isotope analyses have shown that this was not so. (see 4.5).

There is a great deal of evidence for metalworking in this area, even though not all of it is for copper working. Copper sources have been confirmed in this area despite the scepticism of Muhly (1983). As local lead sources were exploited, it is thus highly possible that the copper sources were also worked.

6.9.1.5 THE PELOPONNESE

In the Peloponnese there are three clusters of finds, of which one far outstrips the others. These are (1) Corinth/Argolid group: (2) the southern Messenia group and (3) the Lepreion/Elis group. The first is by far the most important.

(1) The Corinth/Argolid Group

There are eight sites with copper/bronze artefacts in this group. They are: Corinth, Korakou, Berbati, Lerna, Tiryns, Asine and Spetses.

A dagger pommel from EH Argos suggests a further example. One hundred and five copper/bronze artefacts are known from these eight sites - the second greatest number for any region in Greece. One artefact alone belongs to the LN and 104 to the EH. The evidence for metalworking is known from Lerna, Tiryns, Corinth and Spetses (see 6.6.2.3).

The only immediate copper source is no. 54, with sources nos. 52 and 53 in the Ermioni peninsula following. Source no. 52 is sulphide copper and source 53 has three locations rich in copper. The finds from Spetses may indicate the route by which some copper was imported, if indeed it was. Copper and lead could also have come from Attica. Lead-isotope analyses of some copper / lead from Lerna and lead from Tiryns gave an isotopic ratio similar to that for the Laurion (see 4.5).

This area has a great deal of evidence for metalwork, central buildings, fortifications and high population. The communities in Corinth/Argolid appear to have been socially, if not politically, more advanced than other areas of the Peloponnese. It is highly possible that they directed some part of their subsistence produce into the acquisition of copper.

(2) The Southern Messenian Group

The finds from this area do not form such a cohesive group as in Corinthia/Argolid. Over five finds from three sites are all EBA in date. There is evidence for metalworking at all three sites: Malthi, Nichoria and Voïdokilia (see 6.6.2.3).

The closest copper sources are those on the Messenia/Laconia border, particularly numbers 118 and 119, which contain copper, lead, silver arsenic and gold. Given the coastal distribution of finds and the lack of evidence for exploitation of the Laconian sources in this period, it is most probable that the copper used was obtained from supplies on their way by sea to Levkas.

(3) The Lepraio/Elis Group

The finds from the three sites in this group do not form a regional group, but they are all located along the north west coast of the Peloponnese. The sites are Teichos Dymaion, Strephi (Elis) and Lepraion (Olympia). Nine finds alone are known from the entire area. There is no evidence for metalwork and no immediate source. It is highly possible that the copper was obtained from the same source as that used by the Ionian islanders. All of the finds are mainly coastal.

Although the copper sources in Laconia are rich, very few copper finds are known from the region. The finds are three from LN Alepotrypa and one find from Aghios Stephanos. The Alepotrypa finds have parallels along the northern Adriatic coast (see Ch. 2.) but the exact date of the Aghios Stephanos find is circumspect.

Only one stray find from the "Peloponnese" (cat. no.163) is known from a LN/EH I context. Several finds from Lerna were classed as "LN/EHII" by Banks (1967), but these are probably all EH II. There seems little evidence that copper working reached the Peloponnese until the middle of the third millenium. B.C.

In conclusion, we can say that more finds come from areas which do not have copper sources than from those which do. The picture emerging from this study is that the distribution of metal artefacts is more closely related to sites with evidence of metalworking or those in central nodal areas rather than those close to the sources themselves. The larger centres, especially those with evidence for metalworking, appear to have had some kind of control or monopoly over copper supplies.

The locations of settlements was predominately for agricultural and subsistence needs. This situation did not change even in the LBA. Sources on the mainland were no doubt known and exploited and then trans-

ported to sites. We cannot be sure how much refining took place first near the sources. It has not been possible to date the vast amounts of slags associated with most of the sources used in Antiquity and that is why an attempt is now being made to date slags at these sites by the thermoluminescence method. (Liritzis and McGeehan Liritzis, 1986).

6.9.2 SILVER AND LEAD

Here we give the distribution of silver and lead artefacts in relation to the sources of silver and lead known. These are shown in some detail in the regional figs. 6.9.2.1(A-E). As the distribution of finds is more limited than for copper, it is not necessary to do such an in-depth regional study.

6.9.2.1 Northern Greece

The earliest finds of lead come from southern Thessaly in the LN. This lead could have been imported though lead itself is plentiful in nuggets and associated with copper nuggets in quartz from two locations to the south east of the region, nos. 88 and 89. At site 87 lead, in the form of galena, is known. No litharge is known from the sites and lead-isotope data suggests that Laurion lead could have been used. The wire from Petromagoula and the axe from Sesklo were probably made of imported lead.

6.9.2.2 Central Greece

Quite a different picture is seen in central Greece. Although no lead or litharge is known, we have evidence for rather a lot of silver. Silver artefacts are known from later EH contexts in three sites: Levkas, Manika and Lithares. The most immediate source is no 93, which has galena. There is no evidence for the exploitation of this source even in Antiquity. The next sources are in southern Thessaly (nos. 87 to 89)

and in southern Attica (the Laurion group). Analyses of some of the silver artefacts from Levkas suggest that the Laurion group provided silver to the Levkas industries (see 4.5) The material from Lithares and Manika²⁵ has not yet been analysed.

6.9.2.3. Attica

In Attica, we have many finds of both silver and lead, though lead finds are more numerous. Litharge is known and the earliest direct evidence for the exploitation of a galena source comes from the Laurion and Thorikos. Both these sources were exploited in Antiquity and the Laurion source was exploited right up to the 1980's. It was from the Laurion that Themistocles gained enough wealth to build his "wooden walls", the new fleet with which the Athenians defeated the Persians at the Battle of Salamis in 480 BC. Lead was worked at Rouf, Koropi, Raphina, Laurion and Thorikos. Lead-isotope results show that Laurion lead was transported to Aegina, Lerna and Tiryns on the mainland. Silver from the region reached Levkas also.

6.9.2.4. Peloponnese

In the Peloponnese there are two groups of silver/lead finds and they are distinct. The first group comes from the Argolid and consists of lead artefacts from Lerna and Tiryns and silver artefacts from Zygouries. Silver is not known from Lerna until the MH. There is no immediate source and lead was imported from the Laurion. Litharge is however known from Tiryns and Zygouries. Silver used in the Argolid could be either from the Laurion or from Siphnos. (see 4.3)

The second group is perhaps not actually a group, but rather consists of two sets of finds, one which dates to the LN and the other to the EBA. Silver is first found in an apparent LN context at Alepotrypa cave in the Mani (see 6.2). This is the earliest silver known from the Aegean. The

form of jewellery made from it is known in the Balkans and the Aegean from the and LN (see Ch.2.).

A lead artefact from Asea is possibly LN and could represent the earliest find of lead in the Aegean (Holmberg, 1944) There are no nearby lead or galena sources, but the contemporary finds of silver from Alepotrypa demonstrate that some cupellation was being carried out in the Peloponnese during the LN.

Further finds are known from Malthi and Voïdokilia. The Messenian sources are in the east of the region and the sites with lead are located near the west coast. They could have obtained lead from local source or "siphoned" it off from material on its way to Levkas. No lead is known from Levkas, however.

The distribution of silver is restricted, occurring only in two sites in the Peloponnese,— one in the Ionian islands, one in Attica and two from Copais/Khal/kis region. It is always used for jewellery or ornament. Lead, on the other hand, is used for pottery repairing and weights and is more widely distributed.

On present evidence, there seems to be no evidence outside of Attica or the north Cyclades that silver was cupelled from argentiferous lead ores. Even though silver is quite rare in Attica itself, there is no reason to assume that silver or silver artefacts were imports from outside Greece or north Cyclades.

The relationship between lead/silver working and artefacts is tied closely with Attica and there appears to be some fall off in the distribution of lead and silver artefacts from Attica/north west Cyclades. The wider distribution of finds in southern Greece and the Peloponnese most likely represents the sea route between the southern Peloponnese and Attica.

6.9.3 GOLD

Figure 6.9.3 shows the distribution of gold artefacts in relation to the known sources of gold.

6.9.3.1 NORTHERN GREECE

Most of the Greek sources of gold lie in north Greece and it is not surprising to find that most early finds of gold are located in this region. Indeed, gold slags are reported from Saratse and Vardarophtsa in the EBA. These slags are the only evidence for the processing of gold in the period under consideration.

While all the finds of gold, from Sitagroi, Dimitra, Saratse and Dikili Tash could easily have been made from native gold, the gold slags do suggest a more technical knowledge of gold-working (see 6.6.2.3). These slags have not been analysed as they could not be located in the museums. The abundance of gold, in secondary alluvial deposits, in the Gallikos river near Saratse is an obvious source of good quality gold. Gold was also known from Mount Pangaion, near the eastern sites. Between the four sites which have gold artefacts lie eight deposits of gold, two of which are close to sulphide copper deposits which also contain gold.

6.9.3.2 THESSALY

Tsountas (1908) was the first to note the many finds of gold in Thessaly. One find dates to the LN, but none are actually known from the EBA. Tsountas suggests that a local Thessalian source may have been used. The closest source is number 10, in Fthiotidha; no gold is known to be associated with the copper of the Orthys range. Often gold is associated with arsenic and the amount of gold can often be substantial. This is the case with arsenic source no. 1 (see 3. 2.5.). Although no analyses of the gold contained in the southern Thessalian arsenic sources are available, it is possible that the two were associated and that the

gold used in southern Thessaly was of local origin. One cannot exclude the availability of native gold.

6.9.3.3 CENTRAL AND SOUTHERN GREECE

The remainder of gold finds in Greece come from the later EBA in central Greece and from Zygouries, a site which appears to have had close contacts with central Greece. The character of these later finds is markedly different from the relatively primitive items of jewellery known from the northern half of Greece, mainly from LN contexts. Sources immediately available to central Greece, were numbers 10 to 12. There is no evidence that any of these sources were exploited, thus the sources which served southern Greece in the EBA are as elusive as those which served Mycenae in the LBA.

Aristotle and Strabo refer to the exploitation of gold from Vermion and Pieria. Herodotus and Strabo refer to the exploitation of Mount Pangaion and of a source near Krinidion in the Phillipon area. Strabo speaks of the wonderful Skaptin Ilin deposit, located in the Eleftheron Gulf and of various sites in the Rodopi and Gallikos regions.

There seems to be a direct correlation between the majority of the gold artefacts, the evidence for gold working and the greatest number of gold sources in northern Greece. The gold found in central Greece is of an entirely different character and represents a more advanced tradition, stylistically, from the more primitive "northern" gold artefacts. It is possible that the north supplied the south with gold even though the amount being exchanged was minimal.

6.9.4 ARSENIC, ANTIMONY AND NICKEL

The importance of these metals depends on which copper source they were associated with. The distribution of these metallic minerals are discussed in association with the analytical results in section 4.6; 4.7.

6.9.5. TIN

All evidence suggests that the tin used in the later EBA in Greece was imported, though it is possible that some stannite may be associated with sfalerite in the mixed sulphide deposits in northern Greece.

Only the distribution of tin bronze finds in mainland Greece can perhaps tell us something about the possible sources used. Tin sources themselves are discussed in Chapter 3.

The earliest find of tin-bronze in continental Greece comes from Sitagroi Phase IV (latter half of the fourth millenium BC) and also Phase Va (Slater, 1972). Evans (1986) and Sherratt (1986) have evaluated the contacts which this site had with its neighbours in the fourth and third millenia BC. In terms of its pottery assemblage, Sitagroi had strong ties with the Kodjadermen, Bubanj-Hum, Gumelnitsa culture complexes of the early fourth millenium BC. The pottery assemblage of the Phase IV settlement changes markedly from the preceding phase, producing material with typological links with central southern Europe, notably the southern Carpathian basin. Sherratt actually emphasizes the Morava/Vardar link, and attributed Sitagroi Va elements to the Kostolac (late Baden) culture in the Carpathian basin, including its satellite in northern Yugoslavia. It is interesting that tin-bronze was used at Sitagroi before alloying with arsenic was practiced.

Finds of tin-bronze from EBA contexts were discovered at two sites located in the lower Vardar valley. The Vardarophtsa and Saratse finds, originally analysed by Heurtley (1939) cannot now be located for re-analysis, and data on the chronology of the sites cannot place the date of the finds with any more resolution than EBA, most probably the middle or later phases.

The assemblage at Steno^(Nidri) on Levkas (Dörpfeld, 1927) revealed two artefacts of tin-bronze. This assemblage has been variously dated (see 6.2).

Contemporary finds at the two EH II/III sites of Aghios Kosmas (Mylonas, 1959) and Manika (Sampson, 1985) show tin bronze was also used in southern Greece. We can conclude that tin was obtained in both north and south Greece in the EBA.

Copper and bronze artefacts do not represent a fall off from source, except perhaps in northern Greece (around the sites of Sitagroi and Vardarophtsa) and in southern Thessaly. The association of lead finds with the southern Attic sources is quite clear, but there is no direct proof that the silver finds came from the Laurion - they may have come from the northern Cycladic islands. There is an anti-correlation between the distribution of gold and silver artefacts.

6.10 THE RELATIONSHIP BETWEEN MINERAL RESOURCES, METALWORK AND THE EVIDENCE FOR SETTLEMENT

This section will compare the material given in 6.9 with the evidence for settlement in the LN and EBA, summarised in 8.2. The evidence will be reviewed chronologically.

6.10.1 THE LATE NEOLITHIC SETTLEMENT

The evidence for LN settlement is given in 8.2

6.10.1.1 SETTLEMENT, COPPER SOURCES AND METALWORK

It is important to note that many settlements are in close proximity to potentially important copper^{sources}. In particular, sources 12, 13, 14 and 15 in northern Greece, which are all situated on low-lying ground and near to the coast. The LN sites of Sitagroi and Dikili Tash are nearby. Malachite appears as a surface outcrop or scatter at each of the above sources.

In Thessaly, sources 39, 40, 42 and 43 are thought to be important. Having personally visited sources 40 to 48, it is fair to say that these sources were the most obvious. Others were quite high up in Orthys mountain, though a few were close to highland plains which would no doubt have been used for summer transhumance. Sources no. 39 and 40 are close to a lake and all other sources were right beside streams which run rapidly in winter. Although these sources were sulphide copper, a notable amount of oxide copper (mainly malachite and azurite) are still apparent today - despite the fact that they were all "stripped clean" by a mining company ~~at~~ the beginning of this century. Fortunately, they left enough debris to make it possible to estimate the amount of work and size of deposits. Sources 41, 44, 45, 46, 47, 48, and 49 are on higher ground, but they are still close to good soils and still within a 50 kilometre radius of the southern Thessalian sites.

The concentration of sources in Laconia cannot be related to settlement pattern in the LN as there is inadequate data from which to draw conclusions.

Although settlement survey in LN Attica has been piecemeal, it is fair to say that several settlements are close to potential copper sources and that the finds from Kephala, Kea prove that copper was known and worked, (at the very end of the Neolithic, Coleman, 1977).

Coincidentally, the general formation of metamorphic rocks which bears the majority of copper ores degrades well and weathers to produce soils which correlate well with those soils which Bintliff (1977, 100-103) identifies as good ^{for} agriculture. These would have been sought after by Neolithic farmers and it is on these soils that the main centres of population lie, in both the LN and EBA. It is thus inherently likely that early settlement should occur in zones adjacent to **potential** copper sources. It is the extent and distribution of settlement in each

period which plays an important role.

6.10.1. 2 SETTLEMENT, LEAD/SILVER SOURCES AND METALWORK

The finds of lead and silver are very restricted in the LN. The most reliable data on settlement distribution is from Thessaly where there are so few known lead/silver deposits or finds.

In northern Greece there are many lead and silver deposits and it seems that LN settlement was close to the sources located in lower lying ground. However, lead is not known from any northern site and there is no reason to suppose that these sources were exploited.

In Attica, the LN sites would have been very close to lead/silver sources, because all southern Attica is one large lead deposit. No lead is known from a LN context. Surprisingly, copper was used before lead in Attica.

It is in Laconia, which is very rich in galena sources that we have silver finds from the only known LN site in the area of southern Laconia - Alepotrypa. The finds from this site are somewhat problematic, however (see 6.2).

6.10.1.3 SETTLEMENT, GOLD SOURCES AND METALWORK

The only sources of gold which are close to LN settlements are those in Macedonia. Our data on settlements in northern Greece is not complete. It is possible that gold was used in the MN, if the gold artefacts from Dimitra are truly of this date (see 6.2). Certainly, only rudimentary use of gold as made in northern Greece during the LN.

Southern Thessaly was quite densely occupied in the LN and it in this region where we find gold used also. Tsountas first recognised the importance of the early use of gold in this area (Tsountas, 1908) though more use the metal is made in northern Greece. Gold objects are not found further south until the later EBA.

6.10.2 THE EARLY BRONZE AGE SETTLEMENT

The evidence for EBA settlement is given in 8.2

6.10.2.1 SETTLEMENT, COPPER SOURCES AND METALWORK

Branigan (1974) reported that there were no known EH/EB I copper artefacts known from the Greek mainland. A few artefacts designated "Late Neolithic", but of uncertain context, could be EB I or early EBA II, (eg. the axes from Levadheia, Gona, Athens and Mesolonghi, cat. nos. 229, 376, 11 and 154a). However, this limited evidence for artefacts and the absence of evidence for actual metalworking at the beginning of the eponymous Early Bronze Age period demonstrates a recession in metallurgical activity. The LN, of course, spanned a longer period of time, but the shorter EB I does not, in itself, account for the lack of finds. Towards the end of the LN the number of metal finds appear to increase and we then have our earliest evidence for metalworking in the south at Kephala, Kea, though the evidence for metalworking dates to the beginning of the LN in the north at Sitagroi (see 6.6.2.3). The LN artefacts in the north, southern Thessaly and Attica are close to good soils and one would expect that local sources ^{if used} would continue to be exploited in the succeeding EBA I. This does not seem to have been the case, even though denser settlement in the EH / EB I brings settlement close to potential sources and there is an increase in the evidence for metalworking. This Greek development may parallel a similar recession in the Balkan industries at this time (Todorova, 1978, Table 2).

The expansion of settlement in southern Greece certainly brings settlement close to sources, especially in Laconia and Attica, but the areas of greatest population increase and spread (Copais/Khalkis, and Corinthia/Argolid) are those which have no, or few, copper sources. The increase in population created an increase in demand for metal

products in those areas which were, in all other respects, the most technologically advanced in Greece. The areas of high EH II settlement, except Laconia, were the first to adopt both Neolithic technology and to adopt or develop the domestication of the olive and the vine (Renfrew, 1972). They were thus the first to be able to support and encourage specialisation and metalworking as a specialised occupation. The distribution of central building and rich graveyards in this period supports the idea that stratification, based on the control of agricultural wealth, was established. Regional centres are most common where there was dense population, and good soil. Initially metal artefacts may simply have been prestige items of little practical value, but with the introduction of alloying and the development of weaponry, metal became, as Renfrew has already suggested, an indispensable commodity (Renfrew, 1972). What seems curious is that main sites are not located near sources. Branigan (1974) suggested that settlements would be located near sources in view of the difficulty of transporting the metal from the source to the settlement. Following this idea, it would appear that most of the EH II metalwork was imported. If we look for a fall off in distribution from larger centres instead of from sources we see that one exists. It is only in Attica that larger centres are absent and this may be because of the ready availability of metals.

Northern Greece wanes as a centre or focus of metalworking, though metalworking was still practiced in the EBA. This may be due as much to the geographical position of the area as to its ability to sustain cultural progress (Ch.7). The Thessalian finds suggest that this area, at least, was part of the southern Helladic cultures, perhaps indirectly. Contact would have been easy via the Evöikos Gulf. It is difficult to say at this point what role the rich copper (and galena) deposits near these settlements had to play in their incorporation.

6.10.2.2 SETTLEMENT LEAD/SILVER SOURCES AND METALWORK

The development of silver and lead working is synchronous with the spread of settlement in the EH II. It is accompanied by an increase in the evidence for cultural contact, particularly with the Cycladic islands, (see Ch 7). It is known that both lead and silver sources were exploited from the EC II in Siphnos also (Gale and Stos Gale, 1981).

The distribution of silver is more limited than that of lead. The silver finds cluster around the south Attic/north west Cycladic source epicentre and are found only rarely the farther one moves from this area. Silver is found in the graves at Levkas, Manika, Tsepi and Zygouries.

Lead is more widely distributed (see 6.4.) More lead is found in areas of high settlement than in areas of low settlement. Its distribution carefully follows trade routes.

6.10.2.3 SETTLEMENT, GOLD SOURCES AND METALWORK

Less is known of the changes in settlement patterns in the third millenium BC in Thessaly and northern Greece and it is thus not possible to fairly assess the effects of change upon the proximity to gold sources. The exploitation of gold still continues, as the later EBA evidence for gold working demonstrates. Little gold is found in the rest of northern Greece. In central Greece the gold jewellery was more advanced but the sites which have gold jewellery of this type are ^{also} advanced. They traded to obtain their gold.

6.10. 3. CONCLUSION

Several potential copper sources are contiguous to good agricultural soils sought by LN and EBA settlers. The increase in settlement number and distribution enhances the possibility that these sources could have been known and exploited. There is no direct evidence for the exploitation of

local copper sources in the LN, though there is an increasing body of evidence to suggest that the Laurion, at least, may have been exploited in the mid-third millennium BC. At least two other sources were used by the sites in the northern half of Greece.

The "S/S" and "Cypriote" sources are probably located on the Greek mainland, but these have not yet been located geographically. There is a continuity in tradition in the exploitation of at least three sources from the LN to the EBA periods. There seems to be a direct relationship between the distribution of gold sources and gold artefacts in northern Greece and between the distribution of silver/lead sources and artefacts in southern Greece.

CHAPTER SEVEN

SEAFARING, CRAFT AND CULTURAL CONTACT IN THE AEGEAN DURING THE THIRD MILLENIUM B C

7.1 INTRODUCTION

The aim of this chapter is to reconstruct the most probable sea routes between the Greek mainland and other areas of the Aegean in the third millennium BC. An attempt is also made to show that these routes were indeed frequented in the third millennium BC and that they correlate with the distribution of sites which possess architectural features or artefactual evidence for advanced social or technological achievements. Imports or exchanged items are easily recognisable due to regional differences evident in the Early Bronze Assemblages of the Aegean. When one plots the respective distribution of certain local types throughout the Aegean the result is a complicated network of cross-cultural links which Renfrew (1972) has likened to an "international spirit." Table 7.1.1 and 7.1.2 give some examples of the exchange network. It is clear from this that the southern and north-western Aegean had particularly marked evidence for exchange and external contact while northern Greece and Thessaly were not involved.

From the fragmentary evidence available, it is possible to reconstruct the types and variety of craft used in the Aegean during the third millennium B.C.

7.2 SEA ROUTES IN THE AEGEAN DURING THE THIRD MILLENIUM BC

The data for sea currents and wind strengths used in this study was derived from the publications of the Hydrographic Service of the Greek

Navy (NGGS, 1976). Greater details on particular routes can be obtained from local sailing guides. The present data is quite relevant to our interpretation of the situation in the third millenium BC, because the consensus of opinion on eustatic sea stability is that there has been little or no change between the present sea level in the Aegean and that of the third millenium BC, so sea currents will be essentially the same, (Loy, 1967; Dufaure, 1970; Kraft, 1972; Fleming **et al**, 1983 and Inman, 1983). Paepe and de Meyers (1983) have shown that the present climate is similar to that of the third millenium BC so the wind data is reliable. Local coastal change will no doubt have occurred through erosion and deposition caused by climatic changes in the intervening period, and more seriously, as the result of tectonic instability (see also Ch.8).

The effects of winds on surface water can counteract sub-surface sea currents quite dramatically and would have affected pre-sail craft plying the Aegean. Greater control of the winds' directional pull would have been gained by using a sail. Longer, quicker and more hazardous journeys could then be tackled.

The Aegean is notorious for extreme seasonal and local diversity which certainly influenced the effectiveness and timing of early sea journeys. Shorter distances must have been preferred and this is no doubt why "island hopping" via the Cyclades began.

Wind and sea currents in the waters surrounding Greece vary seasonally, summer and winter, but not every area is equally affected by these alterations. The overall trends in wind changes may be summarised as follows :

During winter: northern winds predominate, due to a high pressure belt in the Aegean. These winds are intense when the winds from the south abate. Cyclones over the northern Aegean are attributed to

interaction of northern and southern winds of significant intensity.

During summer: southern winds increase and northern winds abate; thereafter good weather from the southern direction lasts all summer, except when the *meltemia*, or Etesian winds, strike, creating storms in the central and northern areas of the Cyclades. These winds strike the central areas of the Aegean from a north and north-westerly direction and the Ionian Sea from a north-west direction. Marinatos (1963, 162) noted, "at definite periods of the year, navigation in definite directions is not very difficult."

7.2.1 INTERACTION OF SEA CURRENTS AND WINDS IN THE DETERMINATION OF SEA ROUTES

The direction of sea currents are indicated in Figure 7.2.1 (winter) and 7.2.2 (summer). They incorporate the effects of wind direction, data for which is given in Table 7.2.1. This gives the most probable average seasonal variation in the direction of the surface waters. Thus they indicate the most viable routes. Henceforth, the term sea currents includes the wind data.

The Aegean is divided into six areas in order to discuss the best sea routes. These are: (a) Levkas/Ionian Sea. (b) Southern Mainland Greece and Crete; (c) Thessaly; (d) Troy and the Troad; (e) Argolid, Attica and the Cyclades, and (f) Inter-Cyclades.

(a) Levkas/Ionian Islands

There are no apparent changes in the sea currents from winter to summer in the waters of the west Peloponnese and Ionian Sea. Currents flow upwards along the coast, permitting access on either side of the Ionian islands. Difficulties would have been encountered returning southwards, as there is a danger of being swept into Italian-bound waters. Tides

produce some confusion at the mouth of the Corinthian Gulf and in the Levkas Strait, where surface waters are influenced more by the wind and that is why the direction of sea currents here is north-south. These anomalies would have produced difficulties for both pre-sail vessels and early sailing boats. Similarly, in the Amvrakikos Gulf (Preveza, near Levkas), tides at the mouth of the gulf alternate four times per day. North and south winds help the strength of the output or input of the respective gulf currents.

The **meltemia** in the Ionian Sea blow in a north-westerly direction.

This region, in particular the island of Levkas, with its famous "R" graves at Nidri (Dörpfeld, 1927), had many contacts with the southern Peloponnese, the Cyclades and, to a lesser extent, the Troad. The material assemblage, in particular the pottery and metalwork, show clear and sustained links outside the region, all of which would have been possible only by sea. There is, as yet, only very limited evidence for contacts between this region and the north Adriatic or Italy.

(b) **Southern Mainland Greece and Crete**

There are differences here between winter and summer sea currents. During the summer, access is easier from Messenia and Laconia to southern Crete, but there are dangers of being swept into the Libyan Sea. It is difficult to enter the waters to the north of Crete, as currents between Laconia and Messenia wash away from Crete. Between the Argolid and Crete a downward washing of currents along southern Laconia and towards the southern Cretan coast occurs, though there is some pull to the west also. The easiest access to the north Cretan coast is via the Cycladic islands. As winds in the southern and mid-central Aegean blow predominately southwards, sailing is facilitated by southerly bound currents. This is not the case during the **meltemia**.

In winter, similar problems would have been encountered by those wishing to sail south from Messenia or Laconia to Crete. The south-bound currents now favour accessibility from the Argolid and Attica, where there is a more direct downward wash to the north Cretan coast. There are no conflicting currents along the north Cretan coast in winter, so landing would not have been as hazardous as in summer.

Throughout the year, landing areas for vessels coming from the Greek mainland direction are favoured in south-central Crete or in the north-central Cretan shore.

Clear evidence for contact between the southern Greek mainland and Crete is limited. In the later third millenium BC, the Minoans colonised Kythera, and there are indications that the Cretans may have obtained some metal from the Attic sources, known to be exploited in the third millenium BC (Gale and Stos-Gale, 1981; McGeehan Liritzis and Gale, 1988). It is most likely that contact between the Greek mainland and Crete was indirect for most of the third millenium BC, being conducted via the Cycladic islands.

(c) Thessaly

In both summer and winter the tides in the Evripou Gulf run north and south at six hourly intervals. These tides are accentuated in intensity when the north winds blow. The alternating tides facilitate contact between southern Thessaly, Euboea, Boeotia and Attica. From the east Thessalian shore, along the east coast of Euboea, downward washing currents in summer lead to the Cyclades and south. It is difficult to sail east in the winter due to conflicting currents, though it may have been possible in the summer. Winds are predominately southwards, but periodically they change to blow south-westerly.

There would have been obstacles to sailing north from ^{the} Volos region, in summer and winter, unless very close to the coast, where the effects

of the predominately downward currents may not have been so strong.

There is only limited evidence for cultural contact between Thessaly as a whole and the south Aegean. However, the communities of southern Thessaly exchanged pottery with some parts of central Greece (French, 1974), and it is possible that they may also have been involved in the metalwork exchange of the second half of the third millenium BC.

(d) Troy and the Troad

In summer, the tides around Troy (north west Anatolia) and the Troad are strongly influenced by the south-west currents originating from the Bosphorus. Southward currents are located to the west of Lemnos, while currents east of Lemnos are directed northwards towards Thasos or European Turkey. Return currents from the north via European Turkey to Hellespont are possible, though not directly to the coast near Troy. There are problems in returning westwards, as this is only possible via Thrace and thereafter southwards along the coast to Thessaly. Mid-Aegean conflicting currents prohibit trans-Aegean crossings directly from Troy. The difficulty is accentuated by the lack of protection from ^{the} open sea as there are so few small islands in the northern half of the Aegean. Travel south along the east Aegean coast (even though currents are northwards) and then across the mid-Aegean to the west is possible by following the coast until Samos and crossing west from there.

In winter, northward currents are not so strong, but they are directed towards the northern shores of the Aegean, near Thrace. It is easier to return south of Lemnos as the circulating tides aid a return to Troy from mid-sea in the north Aegean. Currents southward from the mid-sea are pronounced, sweeping down into the Cycladic zone. Access west through the same route as in summer is possible. This emphasises the Cyclades as the preferable crossing point in the Aegean.

The archaeological evidence for contacts between the Troad and other areas of the Aegean is most marked in the later EBA. One could almost presume that the Troadic communities had direct contact or trade stops with the island of Chalandriani on Syros and several east central mainland sites, for example, Lefkandi and Manika in Euboea. This contact is marked by similarities in metalwork, pottery and architectural style.

(e) Argolid, Attica and the Cyclades

Summer currents favour crossings from Attica to the Argolid, but a return trip would not have been so easy, except if via the coastal waters. Little access to the Cyclades in summer is possible due to opposing currents in the opposite direction.

In winter, access between Attica and the Argolid is favoured with an easy return more probable due to the currents. Access from Attica to the Cyclades would have been facilitated by the currents sweeping into the north Cyclades (that is, Syros, Kea and Delos) and via these islands into the other more southerly Cycladic islands.

The methods and know-how of Neolithic agriculture first came to southern Greece via the Cycladic islands and the contacts between these two regions grew more strongly after the third millenium BC when the majority of the Cycladic islands were first settled (Cherry, 1981; see 7.3). The similarity in certain pottery, metal and architectural designs indicates strong cultural contact and this was no doubt strengthened by the late third millenium BC exploitation of lead and perhaps silver from both the Lavrion and the north-west Cycladic islands, in particular Siphnos. (see 4.4).

(f) Inter-Cyclades

In summer, currents are predominately westwards and south-westwards

in the southern Cyclades. Currents off Euboea tend towards the east and southeast and by-pass the east coast of the southern Cycladic group of islands. Currents flowing southwards are on the west side of the group (Siphnos and Melos), with the south east and south west pulling in the area between the Cyclades and Crete. Westward sweeping currents in the north west Cyclades pull towards Attica and the Argolid. The route to Anatolia and the east Aegean is most feasible via the north Cycladic islands and Samos.

In winter, there are strong currents west around Syros, Delos and Kea, as well as southward sweeping currents around and between Paros, Melos and west of Naxos. Upward sweeping tides west of the Cycladic group of islands would have aided return or circular journeys. Circular currents east of the Cycladic group of islands and off the Carian coast would have helped return journeys also. Circular currents sweep upwards and westwards towards the Argolid and northwards towards Attica. Thus, even amongst the islands themselves, there were certain routes more feasible than others, depending on the season.

Concluding this section, we may summarise as follows. Seasonal changes in sea currents and wind direction caused local diversity and played a major role in determining both the timing and the direction of sea voyages. Departure and return journeys may well have taken separate routes.

The Cycladic islands were important mid-way stops for both north-south and east-west Aegean navigation. Broken journeys reduce the risk and protect against danger. The most predictable journeys would have been those where seasonal variations were at a minimum.

Having established that certain routes would theoretically have been

more feasible than others, it must now be shown that these routes were indeed frequented and that the patterns these routes form can be meaningfully related to the evidence for cultural contact.

7.3 CORRELATIONS BETWEEN SEA ROUTES AND CULTURAL PHENOMENA

Bintliff first reconstructed the traditional movement of Greek fishermen in southern Greece in their pursuit of seasonal migrations of various types of fish (Bintliff, 1977, 130). He suggested that the communities engaged in this fishing network had correspondingly more participation in the cultural exchange process of the Bronze Age.²⁶ His map of the fishing runs is reproduced in Figure 7.3.1.

If we compare Figures 7.2.1, 7.2.2 and 7.3.1, for the south Aegean, we see that they correlate well. None of the routes obey cultural boundaries and their complicated network no doubt encouraged or indeed provided the means for interaction in the Aegean at this time. Moreover, many of the most viable sea and contact routes had the added advantage of being supplied with fish in season. As we will see below, the relationship between water routes and fishing is substantiated by the fish ensigns, or *occuli*, on the ship representations on the Cycladic ceramics known as "frying pans" (Figure 7.3.3.).

Further proof can be given to show that these routes were frequented on a regular basis. The distribution of "special feature" sites (6.6.2.1-6.7), and of artefacts exchanged in the third millennium BC is shown in Figure 6.8.1 and Figure 7.3.2, respectively. Figure 7.3.4 reproduces Renfrew's Figure 20.5 (1972). A comparison of these maps shows that there is a direct correlation between the sea routes, fishing routes, artefact distribution and the distribution of "special feature" sites. Further, the area of exchange of metal types in the Aegean is closely related to

these routes(see relevant figures in Ch. 2).

The reason why there is more evidence for cultural contact and sea-going in the third millenium BC is that rising population densities on the mainland^{and} on the east and west Aegean forced colonisation of secondary, marginal environments, (Cherry, 1981, 53). Cherry maintains that the poorer environments had lower probabilities of maintaining themselves indefinitely without recourse to subsistence items from beyond the islands. Fishing would have always been important to the occupants of the Cyclades. Renfrew (1972, 358) believes that piracy in the southern Aegean explains the differences in the prehistoric Aegean growth patterns. Piracy, fishing and carrying would no doubt also have been "trades" practiced by the early Cycladic islanders over and above marginal farming. Twenty-one of the twenty-nine islands were colonised (more purposefully than passively) in the third millenium BC, (Cherry, 1981, Table 1). The inter-island routes would have provided more sustained contacts between the east and west (notably north-west) Aegean. Figure. 7.3.4.

A change in settlement pattern is noticed in the Greek mainland during the third millenium BC. Settlement was predominately eastern and coastal: the main centres of population being Copais/Khalkis Attic and Corinth/Argolid regions in the second half of the third millenium BC (see 8.2). It is obvious from this distribution that the sea was important to the settlements of the time, even though, as the growth of fortifications indicates, it became increasingly dangerous to locate near to the coast (see 6. 6.2.2.).

To demonstrate further that there is a sound relationship between the development of an effective means of^{sea} transport and an increase in cultural activity, we need only look at the distribution of what are considered "special feature" sites or architectural evidence for advanced social or

technological achievements. When these are compared with the sea routes and fishing runs (Figure 7.3.2), it is quite obvious that the relationship to the ^{sea}/routes is integral. Sites on the sea routes were easily in contact with the extended Aegean and so both benefitted from, and contributed to, the "international spirit" of the time. Conversely, areas outside the network of contact were at a distinct disadvantage and this no doubt explains why only the southern and north west Aegean experienced a marked increase in exchange and contact. By this reasoning, sea routes determined, rather than were determined by, the location of these "special feature" sites. It seems that before the sailing ship permitted greater control over the tides and winds, these tides and winds controlled the direction of contact. This implies that it was not necessarily the case that most of Thessaly and northern Greece lacked any basic resources which southern Greece possessed, but rather that their inability to partake in the cross-cultural activities of the third millennium BC was due to sea routes.

7.4 AEGEAN SHIPPING IN THE THIRD MILLENIUM BC

Let us now try to piece together what evidence the archaeological record has left us for the types of craft used in the third millennium BC. There are still four unresolved questions regarding the type of craft used and their development. These are: (1) what was the general design of the boat - in particular the design of the prow and stern?; (2) were the boats dugouts or plank-built?; (3) what sizes were the craft?, and (4) was the sail used, and when did it start?

The evidence for the craft is derived from three sources: (a) representations of contemporary craft; (b) boat models, and (c) reported remains of the boats themselves. We will look at each of these in turn and try to compare the evidence with data for craft from other regions of the

south east Mediterranean and beyond.

7.4.1 REPRESENTATIONS OF CONTEMPORARY CRAFT

A series of around a dozen ships engraved on Early Cycladic frying pan pots was first published by Tsountas (1899). These have been supplemented by similar representations found on rocks in some of the Cycladic islands and this type of ship was also in use on the coasts of the mainland as the incised sherd from Orchomenos demonstrates (Kunze, 1934, pl. xxxix, 3).

A controversy has arisen regarding the form of these vessels. Archaeologists cannot agree which end of these representations was the prow, or fore-end, and which was the stern, or rear-end. Tsountas (1899), Evans (1921, 240) and Hutchinson (1962, 92) were in favour of a "high prow-low stern theory and therefore understood the projection at the low end of these vessels to represent a fixed rudder. Adherents to the opposite "low prow-high stern" theory (Marinatos, 1933, 182 and Renfrew, 1972) interpret this projection as a ram, cutwater or keel projection. Sherratt (1982, 13) produced new data in the form of three boat models in lead from Amorgos and stated that these seem to supply the answer as they, "clearly indicate that the raised end was the prow, and that the vessel had a low, square stern." Certainly this is true for the three particular examples illustrated, but when one considers contemporary Egyptian representations (Figure 7.4.1), the higher end is most often the stern and is usually accompanied by a steering oar. Therefore, the new data does not solve the controversy once and for all. Other ethnographic parallels in Oceania and India support the popularity of the low prow-high stern on early wooden sea-going vessels (Hornell, 1946; Johnston, 1981).²⁷ There seems no good reason to exclude either possibility. It is becoming increasingly apparent that more than one type of craft was in use during the

third millenium BC in the Aegean.

7.4.2 BOAT MODELS

There are seven third millenium BC models in lead which hail from two Cycladic islands - four from Naxos (Renfrew, 1967, pl. 3) and three from Amorgos (Sherratt, 1982, 13), Figure 7.4.2.1. Two clay models are known from Crete, Figure 7.4.2.1. One dates to the Late Neolithic/beginning of the EM period, (Mochlos), and the other dates to the middle of the Early Minoan period. As noted above, the recent discussion of three boat models from Amorgos (Sherratt, 1982) helps very much in the interpretation of the actual structure of this kind of craft. Sherratt contends that the Amorgos craft were built on a dugout base with minimal superstructure and that the models demonstrate clearly that the high part of the ship was the prow. Hutchinson (1962, 91) suggests that the longboats, which are very similar to the boat models were basically dugouts, with a pointed prow and stern added separately. Here we see some agreement. As the boat models are three dimensional, they permit us to say more about their structure. They are flat bottomed; the bottom usually comprising slightly more than half of the boats length. Both ends rise at a low angle from the bottom. One end terminates in a flat, transome-like fashion, while the other end forms a point (Johnston, 1981). The sides are low, which suggests that the main body of the craft, at least, was manufactured from a dugout of a tree. The sharp angles between the sides and the bottom suggests that they were dugouts of an advanced type. The plane at the base of the boats is smaller than at the top suggests that the tree trunk, if it was used, was hollowed inside and shaped on the outside. This type of craft could represent an intermediary step between the monoxylous craft and the planked boat - producing a much more seaworthy vessel.

One way of distinguishing a dugout from a plank-built boat, which has a broader plane and a curved hull, would be to measure the length to width²⁸ ratios of the various types of boat types. Typical ratios could be identified and deviation from the average width could be calculated. This method is only applicable to models, of course. The wider the boat and the more variation from the average width suggests it ~~would~~ ^{be} probably/plank built, as the dugout would necessarily be close to a standard, narrow rectangle.

Various archaeologists have tried to estimate the approximate length of the larger craft, that is, from advanced dugouts onwards, Marinatos (1933), Hutchinson (1962) and Renfrew (1967; 1972). If one accepts that these craft were essentially dugouts, then the total length would not exceed a full-grown tree plus the superstructure at the front and the rear. The superstructure could be estimated relative to the average length of the tree. Hutchinson (1962) suggested the use of Cypress trees. It is known that the Egyptians most probably obtained their ship-building wood from the Levant, through the port of Byblos, and the most likely type of wood was Cypress (Lucas, 1962). Marinatos (1933, 191) hoped to estimate the length of the longboats represented on the "frying pans" by counting the number of oar markings and multiplying the distance by approximately 1.65 metres (called **interscalmum** and used as the standard distance between oars in Classical Greek ship-building). The figures he arrived at were so great that he concluded the markings to be purely token representations. Renfrew (1972, 357) noted that there are some representations which mark the number of oars more carefully. He estimated (using **interscalmum**) the average size of these boats to be around 20 metres if the strokes were oars, less if they represented paddles. Johnston (1981) estimated the length of the "frying pan" boats which had between twelve and twenty-six

oars or paddles. He suggested that the craft were between fifteen and thirty metres in length. The consensus of opinion, then, favours an average length of twenty metres for the extended dugouts represented on the "frying pans".

7.4.3 REPORTED REMAINS OF BOATS

Two or three "wrecks" have been reported or rumoured, but they have never been published. One possible find was made by the Greek Department of Underwater Antiquities (Papathanassopoulos, 1976). A preliminary note on the find was published, giving the location of the "boat", just off the Greek mainland in the Dhokos Gulf. Early Helladic sherds dating to the second half of the third millenium BC were located a few metres offshore and under water. The excavator suggested that these sherds got there when the boat carrying them was wrecked. No tangible evidence for a boat was recorded and it is possible that these sherds came to be found under water as a result of some topical submergence of the shore. No concrete evidence has been given and the claim that an Early Helladic wreck has been found is premature and unconvincing.

7.5 THE USE OF THE SAIL IN THE AEGEAN IN THE THIRD MILLENIUM BC

A sail affords greater control of the ship, enables greater speed and longer, more difficult journeys to be undertaken. With the sail, it is possible to tackle the open sea.

The sail requires structural alterations to the craft: a mast, a yardarm and at least elementary rigging. A steering rudder would have been necessary, but no doubt it was developed on pre-sail craft.

On present evidence, the origin of the sail does not seem to have been indigenous to the Aegean; it was most probably Egyptian (Hutchinson,

1962; Johnston, 1981; Sherratt, 1982). The earliest reference to a sailing ship comes from Egyptian Second Dynasty records of ships on the Byblos run, (Hutchinson, 1962, 93). The first known constructed ship, capable of sailing the open seas also comes from Egypt in the Third Dynasty (c. 2750 - 2600 BC).

In the Aegean, the earliest evidence for the use of the sail comes from Early Minoan III, the last centuries of the third millennium BC. Engraving on seals and gems from several sites which date to the beginning of the Middle Minoan period are similar to those from the preceding EM III period, Figure 7.5.1. The masts are clearly shown and the craft have curved hulls which suggests that they were plank-built. According to Hutchinson (1962, 94) the rigging in many of these is typically Egyptian. In these engravings, the prow is high and the stern is low, usually with a projecting keel.

The craft on the seals and gems represent an advanced type of vessel, one which Hutchinson (1962) believes ^{to} demonstrate a certain continuity from the longboats on the "frying pans". What is clear is that there is some development in the type of craft in the Aegean during the third millennium BC. To what extent this development, particularly the adoption of the sail, can be contributed to contact with the Egyptians is not easy to say. Certainly the Minoans had more contact with the Egyptians than any other area of the Aegean during the third millennium BC.

The earliest evidence for contact between Crete and Egypt dates to the end of the Neolithic in the Aegean (equivalent of the Predynastic/First Intermediate periods in Egypt). Stone bowls and vases, thought to be of Egyptian origin are found in Crete (Evans, 1921-1925, II, 16; Penniman, 1952; Warren, 1965, nos. 5 and 13). In the succeeding Early Minoan I period (equivalent to the Second Dynasty) ivory is used for seals and amulets and ivory was imported to Crete from Egypt and the Levant (Renfrew,

1972). The amount of ivory increases in the remaining Early Minoan periods and scarab beetles, distinctively diagnostic of contact with Egypt, are found in the later third millenium BC of Crete also. It is thus highly likely that Egyptians influenced Cretan shipping. After all, Crete could only be reached from Egypt by an open sea crossing. Hutchinson (1962, 95) said that the outward journey from Egypt to Crete would have been via the Levantine coast; the return journeys would have taken advantage of the southward circular winds in the Libyan and south Mediterranean Seas. The question is, was the sailing ship introduced to the Aegean from Egypt via Crete or did Aegean sailors develop the sail independently? There are several pieces of evidence which could suggest that the change from the typical, elementary dugout, to the curved hull, plank-built sailing ship may have taken place in the Aegean. Egyptian influence cannot be excluded altogether, however. The Thera fresco of the mid-second millenium BC demonstrates that quite a variety of craft, large and small, were then known. There is no reason to presume that a variety of craft was not also known in the preceeding millenium BC.

The Pelikati representation (figure 7.5.2) shows the image found on an Early Bronze Age potsherd from the island of Ithaka in the Ionian Sea (Heurtley, 1935). The excavator discussed his find as follows. "... sherd with a roughly incised ship (?) and what seems letters or numbers above; on other side roughly scratched marks," and, "(the sherds) ... seem to be Early Helladic and though they were found in unstratified fill, there is nothing but EH with them. Nor were they found on the surface ... (the sherd with the incised "ship") ... being 0.5 metres ... below it. ... I do not believe they are modern forgeries, and there is nothing left by to suppose that the scratchings were made at the time to which the sherds belong ..."

An attempt is made here to try and interpret the engravings and to distinguish the structure of the base, the stern/prow features and the mast/rigging.

The hull is curved, not angular, as the Cycladic longboats. The craft was most likely plank-built. If line (a) represents the lower part of the hull, it is incomplete. Line (b) goes almost to the end, but not quite. These two lines do seem to represent the hull. There are a series of vertical lines (c, d, e) which may rather crudely represent rigging on a somewhat similar manner to that seen on Middle Minoan gems. Hutchinson has already considered this rigging to be similar to Egyptian. Line (e) passes straight down and across the hull and then beyond. It is difficult to assess what it represents. It would possibly be a later scratch. Line (f) intersects line (g) and gives an impression of a "T-shaped" mast. The three vertical lines (c, d and possibly e) are attached to it, as rigging would be. Possibly line (f) may be a single forestay and lines (c), (d) and (e) the numerous backstays. A similar system is used on Egyptian craft.

Line (h) could represent a shelter structure first seen in the Aegean on the Phylakopi representation (figure 7.5.3^a) but more common on Middle Minoan gems and also on the main craft in the Thera fresco. It was common in Egypt and Mesopotamia from pre-Dynastic times.

Line (i) at the front of the craft may represent a bowsprit.

If this representation is not a ship, it is difficult to surmise what it is meant to be. The lines do not appear to be completely random. If it is accepted as a ship, it is of the sailing variety, plank-built and being EH in date it could be contemporary with the earliest Cretan representations. Sailing to and from Ithaka would almost/certainly require a sailing boat and we know from the evidence at Levkas that this route was

frequented throughout the EH II-III periods.

Representations of boats on two sherds from Phylakopi, Melos are important to this discussion. One, dating to the Phylakopi I (late EC III) culture is shown in figure 7.5.3^a (Renfrew, 1972, pl. 18). Only one end of the craft is shown on the sherd. It represents a steering oar and although the other end of the vessel is missing, it supports the low-prow theory. Most of all, it supports the view that in the Aegean, both low-prow and high prow craft were known, the latter may well be a local Aegean type. Just as important is the curved line of the prow which suggests that the craft was plank-built. It has an oar clearly marked and other markings seem to be either a cabin or a poop (the latter is not seen in the Aegean until the Middle Bronze Age). Alternatively, this structure could represent a supportive structure for a mast.

The second sherd from Phylakopi (figure 7.5.3)^b most likely dates to the Phylakopi I culture (Renfrew, 1972). It is a sailing ship with a clearly defined mast. The mast can be paralleled with those on the Middle Minoan gems and seals. The steering oar at the rear is plainly obvious and is again Egyptian in type. Oars are marked also. Most interesting is the angularity of the hull. It differs from the previous Phylakopi representation in that it does not seem to represent a curved hull, and therefore a plank-built boat. This may be because it is represented as sitting on the water, when the exact shape of the hull would be hidden. Alternatively, it could represent early efforts to use a sail on the longboat. Because of the structure of the longboat, it would be best to put the sail at the stern and weigh down the prow artificially. This representation supports the idea that the sail developed in the Aegean also.

7.6 CONCLUSION

As shipping seems to have been so important in this period, it is striking that there is so little evidence for it. It is quite possible that much evidence has been overlooked. For example, Koumouzelis (1979, 117- 180) noted that several "weaving" shuttles were boat-shaped. Another example is known from Asea, though it was classed as a lamp. Also, the enigmatic Phaistos disc (figure 7.6.1), a unique inscribed object of terra-cotta, dating to about 1600 BC, but as yet undeciphered, bears representations of what appear to be ships (Figure 7.6.2). They have not yet been interpreted as such, but they do have a basic form similar to the long-boat, the bar at the top of the stern may be taken to represent a yardarm - in which case these representations are of plank-built vessels. They can be compared to Egyptian and Near Eastern parallels (Fig. 7.6.3). Their positions on the Phaistos disc follows no particular pattern to help their interpretation, except that they often occur on initial and terminal sequences. This may represent a journey's beginning and end.

The evidence from the above sources suggests clearly that there was a variety of craft in the third millenium BC of the Aegean. These ranged from simple dugouts, to dugouts with a superstructure (longboats) to sailing ships. Both high and low prow craft are known. No doubt different types and sizes of craft were used for different purposes and types of journeys. Egyptian influence in the development of the sail seems clear - for Crete at least, though local development in the Aegean cannot be ruled out. These craft encouraged trade and contact in the Aegean and carried with their cargoes or crews influences and knowledge which encouraged cultural change.

CHAPTER EIGHT

GEOMORPHOLOGICAL CHANGES OF SOUTHERN GREEK COASTLINES AND THE EFFECTS ON THIRD MILLENIUM BC SETTLEMENT DISTRIBUTION AND HARBOUR LOCATIONS

8.1 INTRODUCTION

The aim of this section is to briefly discuss the ways in which the coastlines of mainland Greece can and have changed since the third millennium BC and to assess the effects of coastal change on previous settlement and harbour locations.

Although the present eustatic sea level and climate are similar to that of the third millennium BC, marked local variation along certain stretches of the mainland's coast has occurred, because of fluctuations in sea level during the intervening millennia. As coastal features change, the relationship between the location of settlements and harbours to the former shoreline is obscured. The results of transgression and regression of the sea are a disassociation of settlement or harbour from the shoreline, either by submergence or grounding. Apart from world wide sea level changes, transgression and regression of the sea are caused by local sea level changes, climatic change, rheological response to altered physical conditions and local tectonic activity.

The main fluctuations and variations in world sea level and Greek climate have been documented in previous studies. "Palaeological" studies conducted on the coasts of the Greek mainland which refer to the period 4,000 to 2,000 years BC are listed in Table 8.1.1. Their regional distribution is shown in Figure 8.1.1 where the three areas first discussed here are also shown (Corinthia, Central Euboea and the Ionian coast).

The ultimate goal of many investigators has been to relate historic/archaeological periods to climatic-geomorphic or man-made changes. The

coastal deltaic regions have been most carefully studied as they shed most light on the nature of geomorphic and possible climatic changes over the past 5,000 years. Analyses of vertical sediment sequences can produce a three-dimensional model of the coastal environment, and comparison of these models provides data on the variety of regional change.

8.2 SETTLEMENT PATTERNS IN LATE NEOLITHIC AND EARLY BRONZE AGE GREECE

8.2.1 LATE NEOLITHIC SETTLEMENT

Late Neolithic settlements are known predominately from eastern Greece, usually within 20-30 kms. of the coast and in river valleys or on low-lying ground. However, this apparent distribution is a minimal one, and suffers from several distorting factors. The greatest concentration of known LN settlements is found in Thessaly, and other areas appear sparsely covered in comparison. This is due partly to the intensity of research^{on,} and excavation of the conspicuous tell-sites in Thessaly at this period, which over-emphasises the contrast with other areas of mainland Greece. Figure 8.2.1 gives the current general picture of LN settlement coverage.

Bintliff (1976)²⁹ has drawn attention to the inadequacies of the main archaeological site-surveys carried out in Greece. These particularly affect LN settlement numbers in areas other than Thessaly. For southern Greece, for example, research has usually concentrated on the Bronze Age and neglected the LN. Many LN settlements are overlain by Bronze Age occupation levels and many others are likely to have been masked by subsequent geomorphological changes. In northern Greece, settlement surveys have been least intense. Thus, the comparative differences between settlement numbers for Thessaly and other areas of Greece, especially southern Greece in the LN may not be in reality quite as marked as the data

from site surveys would have us believe.

8.2.2 EARLY BRONZE AGE SETTLEMENT

Little is actually known of the EBA I material assemblage. The culture follows on from the Late/Final Neolithic and was first identified by Blegen (1921) and Goldman (1931). A good review of the evidence of the period is given by Phelps (1975, Appendix A).

Settlement numbers for this period are almost certainly underestimated in relation to other phases of the Bronze Age, and this is because of biases against the detection of EH settlements. Some, at least, of the undivided EH settlements shown in Figures 8.2.2 , a, b and c in some of the otherwise "empty" areas are probably EH I, and thus the apparent lack of EH I sites is rather artificial.

The distribution of EH I settlements appears to be more restricted than that of LN. The two main LN settlement clusters around Thessaly and the head of the Argos Gulf seem to differ from the EH I concentrations of north Argolid/Corinthia, east Boeotia/east central Greece/Khalkis and Thessaly. Though the number of clusters increase, settlement is generally less evenly distributed, although dense clusters of sites in some areas, may, to an extent, be the result of differential surveys.

In the EBA II, there is a dramatic rise in settlement numbers. In general the settlement pattern is very similar to that of the previous period, though expansion is evident in the infilling of areas already occupied as well as in the founding of new settlements in areas which had hitherto been sparsely occupied, if at all. The artificial lack of EH I sites should be borne in mind as well as the fact that only site surveys can calibrate the coarse picture of general finds. Thus, the "newly occupied" nature of some areas (eg. Pyrgos) needs to be confirmed by survey data. The main reason for the comparative ease in recognising

EH II settlements is that much is known of the EH II material assemblage, in particular its distinctive pottery shapes and, to a lesser extent, its distinctive architecture. In the EH I and EH III periods, pottery attribution is more difficult, as archaeologists rely heavily on the pottery's decorative pattern or colour for typological distinction. The acuteness of this problem is felt more in western Greece, which has a wetter climate and soils which are deleterious to the preservation of surface texture and paint. This is reflected in the recorded settlement pattern.

The Argolid/Corinthia and Attic areas have been most intensely surveyed for this period, and the results from these areas are thus most reliable. The dramatic decline in the settlement figures in Thessaly is perhaps the most noticeable change in the EBA II. The number of known sites in Macedonia increase for this period however. It is difficult to correlate Thessalian and northern Greek events and trends with Helladic cultures which differ basically. From the middle of the third millennium BC, the participation of the northern half of Greece in the overall cultural developments is much less marked, the emphasis of developments lying firmly in the hands of the south, particularly south east mainland Greece. The main concentrations of growth in the south are Corinthia/Argolid, Attica, Messenia/Laconia and east Boeotia/west central Euboea.

In the EH III there appears to be a dramatic shrinkage in the number and areal distribution of settlements compared with the EH II period. There is some difficulty in identifying EH III pottery, which is affected by poor preservation. A further complication which we have to deal with is the confusion produced by EH II-EH III variant cultures. (see Introduction).

Existing settlement figures will change with future surveys, yet it is fair to say that there is undoubtedly a reduction in the total number of settlements for the whole of mainland Greece during the period. Given the

problems of identifying the pottery, one possible indicator of whether a site was EH II or EH III is the presence of obsidian. EH II sites apparently have obsidian, while EH III sites are more likely not to have, (Howell, pers. comm. 1982). However, the dangers of circularity in this argument are obvious.

The EH III settlement pattern represents a shrinkage of the EH II pattern with emphasis on east mainland Greece. There is a slight change in site reference, detectable at this stage with a movement from strictly coastal locations to locations slightly inland (and upland). Such locations are characteristic of the Middle Helladic settlement preferences. Settlement decreases in Macedonia, but numbers appear to remain stable in Thessaly, with the main arc of population and settlement in the broad belt from the Argolid/Corinthia to east Boeotia/west central Euboea. Surprisingly, Attica is not included, unlike in the EH II. Apart from one site in Laconia there is a striking absence of settlements in the southern Peloponnese. This may be due to a difficulty in distinguishing EH II from EH III sites, or possibly EH II cultures persisted in these areas into the EH III cultural phase.

8.3 GEOMORPHOLOGICAL FACTORS AFFECTING GREEK COASTLINES

The majority of EBA settlement was coastal and so settlement numbers could be much affected by dramatic changes in coastlines. The factors which have altered the appearance and the extent of coastlines in southern mainland Greece since the third millenium BC are: sea level change; rheological response and tectonic activity.

8.3.1 SEA LEVEL CHANGES

The cyclic fluctuations of world climate are known by temperature

curves interpreted from changing oxygen-16/18 contents of deep sea cores (Shackleton and Opdyke, 1973). Glacial interstadials (periods of increased temperature) cause large volumes of water from melting glaciers to produce a general world-wide "eustatic" sea level rise. Eustatic sea level changes were originally thought to be essentially uniform and monotonic, but this has now been shown not to be so, (Inman, 1983). Several schools of thought now exist regarding the nature of eustatic sea level change. Loy (1967), Bloom (1967), Kraft (1972) and Van Andel et al (1980) all agree that it is not possible to apply the average sea level rise curve after 4,000 years BC, because of a flattening of the curve (Figure 8.3.1.1) and the extreme discrepancies between the proposed later Holocene sea level histories renders the attempt futile. Loy (1967) emphasises the point for Greece in particular when he says, "there have been too many variations in rates of denudation, alluviation and coastal movement in both time and place to allow the strict application of alleged world-wide sea level fluctuations to any place in Greece. Each problem must be solved, if it is to be solved, locally with local evidence." Thus, sea level studies are presently at a state when one must consider only the local setting and the implications of various theories of sea level rise. However, the following general remarks can tentatively be made. Sea level in the Aegean was on the rise in the Late/Final Neolithic to the beginning of the Early Bronze Age (that is, late fourth millenium BC to early third millenium BC). It varied between -2 metres to -16 metres below present in this period. Both the global and Aegean curves show a significant rise again in the Late Roman period with adverse effects on Greek coastlines.

8.3.2 RHEOLOGICAL RESPONSE AND CLIMATIC CHANGE

Gravity forces a river's flow down to sea level. If the land is flat,

for example a plain, the river's road to the sea will be long and winding and the deposition of fluvial sediments will often cause deltaic formations or silting-up when the river reaches the coast. When sea level falls the river will cut a valley. The depth of the valley will depend on local geology. When sea level rises, the valley or flood plain of the river becomes a bay and the river will deposit its load on the inland edge of the bay. As the bay recedes, with a subsequent fall in sea level, the former flood plain becomes covered with a layer of alluvium. This often covers settlements and harbours on the original coastline.

Climate and local geology are important in determining the yield of sediment brought to the coast by river action. The important contribution of these two factors alone for local sea level variation can often be dramatic. The effects of sediment build-up on the coastal plains are well known, though researchers in the field of coastal change do not agree as to what is always responsible for the increase in alluvial deposition. Opinions vary between human activity, climatic change and eustatic sea level fluctuation. Bintliff (1977, 35) presents the opposing views and argues quite convincingly that the climatic factor was the most important. So far, little consideration has been given to the contribution of tectonic instability.³⁰

Perhaps the most significant revelation of late has been that alluvial depositions which have occurred in the centuries after the third millennium BC have caused radical changes in gulf coastlines in Greece and other areas of the Mediterranean. Vita-Finzi (1969) and Bintliff (1977, 87-110) claimed that there were two such major alluviations, termed "Younger" and "Older" Fill respectively. Recent work demonstrates that there were up to seven alluviations³¹. We can term the alluviations "post third millennium BC sedimentation" (PMS) for the purposes of this thesis. Sedimentation has graded to a sea level

a little different from the present one. As a result the sea has regressed at the heads of many of the gulfs. Figure 8.3.2.1. shows the areas of Greece which are now covered by deposition. In these areas, settlements and harbours have been lost and the recording of settlement numbers and harbours will not represent the actual totals in these areas.

Researchers in the field of climatic change in the Greek past do not agree about the occurrence and character of climatic changes from the third millenium BC. Bintliff (1977, 59) summarised and discussed the views. More recent work by Paepe and de Meyers (1983) provides new data. Their study attempts to establish a river flood and lake level fluctuation curve based on the stratigraphic evidence of river and lake deposits from Attica in southern Greece. The overall aim of this project is to eventually make a comparison with sea level curves and climatic fluctuations in the peri-glacial area. The work is still in a preliminary stage, but some of the results are of relevance here. Table 8.3.2.1 outlines the basic climatic fluctuations in the period concerned; these fluctuations have a direct correlation with soil formation. Figure 8.3.2.2 shows the data in Table 8.3.2.1.

This new data seems to substantiate Bintliff's view that climate played a major role in sedimentation build-up and coastal change.²⁹

Work on the effects of climate (erosion and deposition) has been carried out in areas neighbouring Greece and similar results have been obtained. In Anatolia, Butzer (1958) and Eisma (1964) have shown that climatic change and erosional processes developed along similar lines to the Greek events. Bell (1970; 1971) has analysed Egyptian data for flood levels of the Nile. He showed that there were even marked climatic fluctuations within and just after the third millenium BC. These short term fluctuations are also known from the Near East (Butzer, 1957;1958), Mesopotamia and even the Indus (Lamb, 1977).

8.3.3 TECTONIC ACTIVITY

Tectonic theory assumes that the earth's crust is sub-divided into a number of large plates and that the plates are in motion relative to one another. Some plates are oceanic and some are largely continental in character; both ride on a viscous asthenosphere in the upper mantle of the earth (Gass et al, 1975).

The moving plates have an effect on relative sea level. Coasts on the collision side on continents are mountainous and subject to tectonic uplift.

Greece is one of the most seismically active countries in the world. Most of the largest earthquakes in Greece occur along well-defined belts that coincide with plate boundaries (Drakopoulos and Makropoulos, 1983). The convergence rate of the subduction zone in the Aegean is estimated to increase from 2cm/year in the west to 5cm/year in the east: there is north-south spreading in the Aegean and this is the reason for the very high seismicity rate in the circum-Aegean area. The neo-tectonic map of Greece is shown in Figure 8.3.3.1^{a,b}. It shows that many major and innumerable minor faults exist which might have the potential for damaging earthquakes. No singular tectonic movement would alter all the coastlines simultaneously or uniformly. Local tectonics would have caused local coastal deformation. The overall pattern of strong earthquakes in ancient times follows the distribution of strong earthquakes in modern times. One can compare data on the number and strength of earthquakes from early historical times with those of today (Galanopoulos, 1977; 1981; Comninakis and Papazachos, 1982). Table 8.3.3.1 lists the known major earthquakes in the past up to 1800 AD. Figure 8.3.3.1 already includes earthquake data dating from 1800 AD onwards. A clear relationship in the distribution of major earthquakes is apparent. Thus, we can conclude that areas of high tectonic activity today were also prone to damaging earthquakes in the

intervening millenia since the third millenium BC. The coastal regions in these areas have been subject to the most change.

The work of Mercier (1979) and Jackson et al (1982) show that it is possible to make some general conclusions regarding the current trends of tectonic activity in Greece. In four well-defined aseismic blocks tectonic activity is less frequent. These are (a) Attico/Cycladic block; (b) Ptolemais Basin block; (c) North East (Thrace) block, and (d) an extended area in the sea around $35^{\circ}\text{N}/21^{\circ}\text{E}$. All other areas are seismically active.

It is argued here that both tectonic activity and climatic change contributed equally to the overall change in the coastlines of Greece. Tectonic change had more localised effects and climatic change produced greater effects in areas with soft rocks and numerous rivers.

From 8.1.1 it will be clear that not all areas of southern Greece have received as much attention from geomorphological investigations. Preliminary investigations of coastal change in Corinthia and the Corinthian Gulf, west central Euboea and the shores of the Ionian Sea are given here to complement the work already done in other areas. An attempt will be made to show the main areas of change in southern Greece.

8.4 CORINTHIA AND THE CORINTHIAN GULF

There are several important Early Helladic sites in Corinthia. The region is strategically placed for both land and sea routes. A thorough study of geomorphological changes has not yet been conducted. Figure 8.4.1. shows the distribution of Early Helladic II sites in Corinthia. Few sites of this date are known from the shores of the entire gulf and even though no full-scale survey has been carried out around the shores, the curious lack of sites has not been satisfactorily explained.

8.4.1 GEOMORPHOLOGICAL CHANGE

Although no direct study of the geomorphological changes of the Gulf of Corinth itself has been conducted, there is much relevant, comparable data from several locations along the gulf. This will be supplemented by new data on sediment build-up in Corinthia itself.

Pausanias reported that the ancient city of Helice sank into the Corinthian Gulf in 373 BC (Pausanias, book vii/24/3-7). Schwarcz and Tziavos (1979) obtained vertical sediment sequences for the area and concluded that the coast here had slumped twice downwards at different times in the past, the last major slump being around 4,000bc (that is, in the middle of the third millennium BC). They postulate that a series of recurring slumps occurred just off the present shore. This suggests that the city of Helice was located farther north into the gulf than the present shoreline.

Across the gulf and to the north are three other sites which also testify to a change in sea level. The altered coast is obvious from the undulous silts on the shore, at different levels just outside Antirion (Figure 8.4.1.1). The sea appears to have stood once at about thirty metres from the present shore. The Venetian castle, built in 1689, was once further inland. This suggests a transgression of the sea since the 17th century, even though a series of regressions and transgressions occurred in the subsequent centuries.

Just a few kilometres along the northern coast of the Corinthian Gulf, at Naupactus, we have an entirely different situation. Leake (1814) confirms Thucydides testimony that the now lost city of Oineon once existed and that it had a port and harbour. The most possible location now stands some three kilometres from the sea, (Liritzis et al 1983). It was apparently buried by deposition brought down by the river Daphnus (or Mornos) which had the effect of "grounding" the city, Figure 8.4.1.2.

Such a different geomorphological history for these neighbouring areas suggests that local tectonics played some role in relative sea level fluctuations.

In Itea, Phokis, an Early Helladic site has recently been discovered, (D. Skorda, pers. comm). This site was occupied until the Late Helladic. Now the EH settlement is under the water table and is over 150 metres from the sea. It was usual for EH sites to locate on the coast. Alluvium now covers the site. This is deposition from the transgression of the sea combined with sediments brought down by the River Pleistos. The fact that the site is now under water suggests that there has also been a land slip in the area. The region suffers from strong earthquakes, the most famous of which uncovered Ancient Delphi at the end of the last century.

The region immediately around Corinth has been subject to numerous severe earthquakes this century. It is one of the most seismically active regions in a highly unstable tectonic belt which stretches the length of the Corinthian Gulf. Mercier (1979) and Jackson et al (1982) believe that Corinthia's coast is rising and has been doing so for the past fifty years. Tselentis and Makropoulos (1986) used the seismic moment values and fault plane solutions for large earthquakes which occurred in the Gulf over the last twenty-five years to calculate the average rate of deformation in the area. The results show a north-south and east-west extension together with a downward movement of the northern side of the Gulf relevant to the south at about one millimetre per year (Figure 8.4.1.3). Marked tectonic activity in the Gulf since Classical times is testified from the coastal changes at the sites studied above. Others are mentioned in Table 8.3.3.1.

Based on the methods explained by Bintliff (1977), for translating geological maps into local soil maps of five basic soil types, it was possible to estimate the extent of "Younger Fill" which had built-up along

the coast of Corinthia as a result of the weathering of softer rocks during the Late Roman and Early Medieval periods, Figure 8.4.1.3. The distribuion of "Younger Fill" is not as extensive as at other gulf heads. Isodepth maps do not indicate a sharp decline of the coast, so unlike the Lelantine Plain, deltas did not form because of the steep off-shore morphology. The classic conditions exist for the formation of "Younger Fill", but there seems to be some discrepancy as its distribution "runs short" as the piedmont meets the coastal plain. Only very limited extents of "Younger Fill" are observed along the coast. It seems that part of the shore has slumped and been covered with water while agriculture and the spread of modern settlement has obscured the stretches of "Younger Fill" across the coastal plain.

Further, when one calculates nearest neighbour distances between the EH II sites on the plain, it appears that some sites are yet to be uncovered. These are marked on Figure 8.4.1. Previous harbours have now been obscured.

This data, then, demonstrates the unstable character of the shoreline of the Corinthian Gulf and, in particular, of Corinthia itself. Cyclical transgression and regression of the sea, caused by tectonic change, climatic change and the effects of world eustatic change altered the third millenium BC coasts beyond recognition and as a result many sites along the shores of the Gulf have been lost.

8.5 WEST CENTRAL EUBOEIA

Most of the third millenium BC sites in Euboea are concentrated in west central Euboea. This location is not fortuitous as the best soils are located there and the region was an entrepot for both landward and seaward trade and contact. Figure 8.5.1 shows the distribution of EH II settlements.

Previous work on geomorphological change comprise the preliminary work of Kraft (1972) on the Lelantine Plain. Lehmann (1939), Phillipson (1959) and Sackett et al (1961) have described and discussed the geomorphology and geology of the area. Figure 8.5.2.

According to Kraft (1972), the Lelantine Plain has been gathering sedimentation for some time, but the delta fan has not built-up because the Euboean Gulf, being very deep and tidal now, has moved much eroded material away.

There is no build-up of sediment on the coastal Lelantine plain but across the gulf in Attica sediment build-up is noted (Figure 8.5.1). The Marathon Plain is enigmatic, as, according to Kraft (1972) it represents a pattern of development different to that of the Lelantine Plain, in particular its arcuate beach showing evidence of strong littoral drift. It may be possible to explain this littoral drift if Euboea had not always been an island and the drift represents the sediment build-up as at the head of a gulf. If there had not been a waterway between Khalkis and the mainland in the third millennium BC, one would expect a build-up of alluvium, just as at the head of any other gulf. The evidence for alluvium to the north of Khalkis will have been lost by the rise of local sea level which accompanied tectonic downfaulting. There is some "Younger Fill" in patches along the shore between Eretria and Khalkis. Much of the harbour which belonged to Classical Eretria is now under water, (Fig. 8.5.3.). Several stretches of the west shore of the the north Euboean gulf are covered by water because the land has slipped into the sea. At Manika, EH II graves are now under water and a part of the town stretches out to about 100 metres from the coast. Several of the newly excavated tombs from the cemetery at Manika lie from one to two metres under the present-day water table (Sampson, 1986). If Euboea had not been joined to the mainland, a build-up of alluvium at the head of the gulf would have

provided some of the land on which Manika was built. This land subsided as the result of tectonic activity and that is why there is little evidence for "Younger Fill" in later periods.

Data by Drakopoulos and Makropoulos (1983) shows that the seismic activity which has occurred over the past century and a half in Euboea has had the following characteristics: all along the west coast of Euboea earthquakes have caused westward subsidence into the gulf. Some rearrangement of the gulf floor, probably a caving-in, is producing this result. Contrary to this, the east coast of Euboea is subsiding in an eastward direction, into the Aegean. This is producing stress on the island, right down its mountainous backbone.

Fossilised beaches, beach rock, has been noted at Manika, the coast between Eretria and Vasiliko, Porto Rafti (Avlaki), Zoumberi and Raphina in Attica. These former beaches are at an 20° to 30° angle to the present beaches. Unfortunately they have not yet been dated, even though such beaches have previously been dated (Radtke et al, 1982).

Another indication of sea level change are the marsh lands on both sides of the Euboean Gulf. Expanses of marsh at Livashi in Euboea and Marathon in Attica have no doubt developed since the third millenium BC and have a direct relationship with the swamping of the Manika graves. This indicates that the tectonic activity affected quite a wide area.

At Thermopylae, further north, the narrow passage of land which the Greeks defended against the Persians in 480 BC is now a broad plain. Climatic factors and tectonic activity has caused this dramatic alteration in local geomorphology. This part of the Euboean Gulf changed since Classical times, and Eretria and Manika has changed before that.

Euboea and its immediate westerly neighbours on the mainland are in a seismic origin zone. Earthquakes are generally shallow here and as a result the effects on the surface are profound. As the floor of the

gulf is altering, the effects on Euboean shorelines can be marked and often locally restricted. The difference between the joint effects of climatic and tectonic factors has been so varied. More evidence is now needed to show whether or not the water passage between Euboea and the mainland was open or not in the third millenium BC. If Euboea was joined to the mainland in this period, it goes a long way to explaining the rise of important settlements in the immediate vicinity.

8.6 IONIAN SEA

A brief note is made here on the possible changes in geomorphology along the east coast of the Ionian Sea. No detailed geomorphological work has yet been published for this area, Figure 8.6.1. The reason for selecting the area is that the enigmatic "R" graves at Nidri on Levkas do not have a site nearby which was as wealthy or as developed as the graves testify.

The island of Levkas, the straits between this and other islands in the Ionian Sea and the mainland lie directly on a tectonic fault line, Figure 8.3.3.1. There is evidence of subsidence in the area, even though Kraft (1972) in his preliminary study suggested that much of Levkas was covered with Quaternary alluvium.

A recent rescue excavation by the Greek Department of Underwater Antiquities brought to light a partially submerged Early Bronze Age site on the Astakos Gulf. Half the site is underwater, but foundations can still be made out. Though it was a large site, the finds so far recorded do not match a centre of importance similar to the Nidri graves. The finds leads one to believe that along the coast of the mainland or on the island of Levkas itself lies buried, or partially under water, the site which belongs to the Nidri cemetery. Dörpfeld scoured the island in

search of the home of Odysseus. However, recent rescue excavations near Nidri on Levkas, which are being carried out due to expanded settlement on the island, has uncovered foundations of prehistoric settlements. No further details are available at present. The Nidri graves are at present about three metres below ground level and the accompanying site may also lie buried at the same level.

Undoubtedly an important factor in coastal change in the area was tectonic change.

8.7 CONCLUSION

Although sea routes *per se* would not have been dramatically changed by coastal change, settlement numbers during the EH and related harbour location would have been. Climate has already been accepted as a major determinant of sedimentation build-up, but not enough stress has been given to the contribution of local tectonic change to variations in sea level histories in various regions of the mainland.

Figure 8.7.1 shows the areas where settlements and their associated harbours have been lost, through "grounding" or submergence. The more sites which lie undiscovered the less representative are the figures for metal types per area. Although new finds may not change the overall picture, they could add significant data on the character and context of metalworking in the LN and EBA of Greece during the third millennium BC

CONCLUSION

The number of artefacts included in this study was twice as large as in any previous attempt. This increase justifies taking a fresh look at the range of metal types for the mainland: and through them, the range of technological skills demonstrated, the variety of metals used and the evidence for external and internal relations.

The results of the thorough typological study presented in Chapter 2 was to demonstrate that the Early Bronze Age repertoire of metal types owed much to the preceeding Late Neolithic. Whilst the mainland had several types in common with the Cyclades, the Troad, Crete and the Balkans, local types, (many with LN precedents) do exist and many of these survived the EBA itself.

There were three common elements between the repertoire of the Cyclades and that of the mainland. These were: weapon type W 3, chisel type Ch 2 and hook type H 1. Contrary to the view of French (1968), the Cycladic industry did not have a greater number of artefacts than the mainland and there are in fact fewer similarities between the metal industries of the Cyclades and the mainland than previously thought.

Common elements between the repertoires of the Troad/Anatolia and the mainland are: weapons W2, possibly W 4, Knife K2 (an important introduction but not the only one), Axe A2c, A 3a (the advanced forms), Awl Aw 1b, Pin P2a, 2b, 2c and 2f (and possibly 2d and 2e). North west Anatolian influence came mainly in the later EBA, and is especially marked in pins and some blades. The ultimate origin of these blade types is inner Anatolia and

Mesopotamia.

Common elements between Crete and the mainland industries are: knife K1, tweezer T 1, the Thyreatis beads and possibly the Lithares blade. Influence is more marked in the later EBA and is noted in articles of toilet and, to a lesser extent, blades.

Common elements between the Balkans and the mainland are seen in: axe A1, A2 and A 3b as well as in pins P2g. All have bone or stone prototypes and it is mainly LN types which we find translated into early copper forms. This translation could easily have taken place independently on the mainland.

Several types are common to three or more regions of the Aegean (that is the Troad, the Cyclades, Crete and the mainland). These are: weapons W1 and W4, as possibly W 6 and W7: axe type A 3d: chisel type Ch 1: awl type Aw 1: pin type P 1, tweezers type T 1 (except the Cycalides), needles, beads types B1, B2 and B3 (except the Cyclades) and B4 (again, except the Cycalides) and rings types R1 and R 5. Little significance can be placed on the similarity of such simple types as simple pins, awls, rings and beads. They are all basically early translations from bone prototypes. Weapons were introduced and used in the four regions of the Aegean at the same time.

Helladic (i.e. mainland) types which denote a healthy, innovative local industry are: weapons type W 5, W 7, group 8; knives type K2; axes types A1a, A2, A2a, A2b, A3b; chisels type Ch 1; awls types Aw 1 and Aw 2; pins type P2d and P2f; tweezers types T1a and 1b; rings types R2 and R3 and needles. The mainland was innovative in weapon- and tool-making as well as in jewellery and in articles of toilet.

The typological study demonstrated that the mainland of

Greece had as much to contribute to the typological repertoire of the Aegean as it had to gain from it. It was in no way backward or underdeveloped and cannot be categorised as lacking in imagination.

The result of Chapter three was to show that adequate sources of all metals (except tin) used in the LN and EBA industries were accessible and available to LN and EBA metallurgists. Tin sources were also available, through trade and exchange. Certain potential copper sources were contiguous to the good agricultural soils sought by LN and EBA settlers. Any increase in settlement numbers and distribution would have enhanced the possibility that these sources could have been known and exploited. No direct evidence of exploitation of a local copper source in the LN is available and the distribution of finds or settlements in this period do not apparently cluster around any particular source. Indirect evidence for source exploitation through lead isotope analyses, strongly suggests that two and perhaps three sources of copper were used by LN communities and that these were located on the Greek mainland. The pattern of procurement does not seem to have been so simple with sites in northern Greece, using a number of sources, but the organisation for obtaining the metals does not seem to have been complex. There is, at least, little archaeological evidence to suggest it was so. Certainly some sites with evidence for metalworking (such as Sitagroi) were close to good sources. It is equally likely that some copper entered Greece in the LN in the form of imported artefacts (eg. axes from Bulgaria).

The first direct evidence for source exploitation is observed in the EB II when there was a rapid development in

metallurgical activity, accompanied by an apparent growth in settlement numbers and an expansion in transport facilities (shipping). There is a relationship between the pace of metallurgical activity and the extent of settlement, and many settlements existed adjacent to potential sources of copper before these were actually used. There is still no evidence that local metallurgies gravitated towards any particular rich local source. Indeed, the fact that no major copper source was systematically exploited in the EBA is curious.

In western Anatolia during the third millennium BC, local sources of copper, silver, and lead were used - often several sources being exploited by the same site. The growth of evidence for metalworking and source exploitation in Greece from at least the beginning of the third millennium BC supports a similar practice. The lead isotope work in Chapter four demonstrated that the "S/S", Laurion and "Cypriote" sources were exploited from the LN and that their use by EBA industries confirms a continuity of tradition between the two periods, despite the apparent lull in metallurgical activity in the EH I.

Chapter four provided evidence for the technological level reached by the LN and EBA industries. Melting, casting, polishing, grinding and annealing were all known in the LN (the latter three being lithic techniques applied to the new medium of copper). However, it is now apparent that smelting, from oxide copper ores, alloying with arsenic and tin were known early. Alloys with tin appear from EBA times onwards. These alloys are rare and may have been the result of contact with the industries in north-west Anatolia or north, up the Vardar/Morava valley, to Yugoslavia. Tin could have been imported from either area, but the chronological

evidence suggests it more likely to have come, initially, from a northern direction. There is now evidence for alloying with lead in the EBA also.

The evidence presented in this thesis calls for a reconsideration of the role of LN Greek metalworking. The name "Chalcolithic" should now replace the terms Late or Final Neolithic. This change would not, however, apply to Crete or the Cyclades in the same period. The accumulated evidence demonstrates that the LN/FN industries were not simply on a par with other Aegean industries, but positively in advance of contemporary Cretan and Cycladic industries. During the Chalcolithic, the development of the Greek mainland industries is indigenous, even though peripheral to the Balkan centres of innovation. The progress of mainland metallurgy was no doubt stimulated through Balkan contact, but the independent stance of mainland industries is brought out in their adaptation of Balkan forms. In the EBA, mainland metallurgy comes into its own right. There is arguably strong evidence for external influence, especially from the East (for example the use of the use of the two-piece mould; granulation and filigree techniques in goldworking (Higgins, 1980). Notwithstanding this evidence, almost all the basic techniques used in the EBA were present in the Chalcolithic.

The expansion of metalworking in the EBA is a characteristic feature of the period and one that must be explained. No EB I metals are known and this fall off in metallurgical activity is paralleled in the Balkans. As so little is known about the EB I period in the mainland, it is possible that the LN persisted in many areas. The period labelled EB I represents the end of the Chalcolithic. There is a lull in metallurgical activity between the Chalcolithic and the growth of EBA metalworking which does not start until the EB II.

The character of the EB II and EB III industries is different from ~~that~~ of the Chalcolithic. This is because the mainland industries were encouraged to develop along new lines as a result of reduced contact with the Balkans and increased contact with the Cyclades brought about by the occupation of the Cycladic islands with the result of drawing the Helladic and western Asiatic industries into contact. The exploitation of more local sources also influenced the development of the industry. Southern Thessaly became part of the southern Greek sphere, thereby creating a dichotomy in the Greek industries between the north and the south. Even though the EB II and EB III industries advanced at a faster pace, the basic metallurgical techniques were inherited from the Chalcolithic and the industries maintained their contact with the same copper sources as well as advancing to exploit others, including lead and silver sources. The new metalworking techniques mastered in the EBA relate more to the fashioning of artefacts rather than the mastering of basic techniques.

The study of the context of metals and metalworking in Chapter six brought out the importance of metal as a status symbols and the monopoly of copper sources by larger and important sites. These sites were not primarily located near copper sources, however. Agriculture was still the main occupation of the mainland population, but there was ^{a growth in} craft specialisation in many industries (pottery, architecture, boat building) as well as in metallurgy.

Southern Greece became the focus for cultural change and the most productive area of Greece in the field of metallurgy. It benefitted from its advantageous position in the Aegean. Most

fishing and sea routes served the southern mainland and coincided with centres of large population. Greece played a strong part in intercultural exchange and through the exchange network contributed much to the overall character of the Aegean Early Bronze Age culture.

FUTURE WORK

The following are some of the projects with which I will be involved.

- 1) Having already obtained the permits from the Greek Institute of Mining and Mineral Exploration, with whom I will be collaborating, a programme of smelting copper and chemical and lead isotope analysis of all the copper sources in the Greek mainland will proceed. The aims of the project are to determine the minor and trace element ranges in and within each load; to smelt the copper; obtain a lead isotope determination for the deposit and assess the possibility that the source was exploited in the past.
- 2) As samples were not always permitted from LN and EBA material in the Greek museums, a portable XRF will be used to obtain a chemical analysis for the remaining LN/EBA material in the National Museum of Athens, with a possible extension to other museums. This project is a small part of a larger project led by Dr Y Liritzis (Ministry of Culture, Greece) and Dr R E Jones (Fitch Laboratory, British School of Athens).
- 3) An attempt will be made to date the numerous slag deposits in Greece. A preliminary report has already been made (Liritzis and McGeehan Liritzis, 1986). The thermoluminescence method will be applied to inclusions in the burnt clay matrix. Dr Y Liritzis and Dr A Papastamataki will lead the project. The aim is to assess the date or archaeometallurgical activities at several sources - particularly the earliest use of the source.
- 4) The geomorphology of the Ionian area will be studied using new seismic data. The aim will be to describe clearly the effects of sea level change in the area - especially in relation to the fate of the site which built the famous "R" graves at Nidri Levkas.

FOOTNOTES

- | NUMBER | P | FOOTNOTE |
|--------|-----|--|
| 1 | 31 | <p>The data on the Petralona hoard is scant as this material is being studied by Dr D Grammenos of Thessaloniki Museum and the author was not permitted to examine the material in any great detail.</p> <p>The drawings are all slightly distorted as they were redrawn from a photograph: the only source available.</p> |
| 2 | 101 | <p>Malachite is bright green; cuprite is dark red; azurite is blue; olivenite is green and chrysocolla is golden. The actual process which produces these effects is described in Gale and Stos-Gale, (1981).</p> |
| 3 | 105 | <p>Much of the data presented in this section resulted from collaboration with J Taylor, Oxford University. This joint work is to be published in 1987 in the Oxford Journal of Archaeology (see McGeehan-Liritzis and Taylor, 1987).</p> |
| 4 | 109 | <p>personal communication to J Taylor, see note 1 above</p> |
| 5 | 115 | <p>The arguments for and against the use of chemical analyses as an aid to provenancing have been presented in Gale and Stos-Gale, (1982)</p> |
| 6 | 115 | <p>The separation of the molten, reduced copper from the associated gangue in the ore involves liquid/solid separation on a small scale. These do not separate easily of themselves. To achieve good separation it is necessary to reduce the melting point of the gangue mixture with a flux to produce a single slag which would give a liquid/liquid separation. The incorporation of iron oxide as a flux for the gangue</p> |

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would have developed fusible slags with melting points usually below the temperature attained in the furnace ($\sim 1400^{\circ}\text{C}$). Often the temperature levels developed in this process can be estimated from the mineral constituents of solidified slag and from the separation of iron in associated copper deposits, (Charles, 1979; 1980). Therefore, fluxes are often responsible for introducing foreign elements into the copper. These range from iron, tin and arsenic. High levels of iron in coppers can be indicative of poor slagging procedures.

7 116 See notes on future work in Epilogue.

8 120 No mention is made by Gale et al (1984)^b of how they obtained this amount of arsenic from the copper. No doubt it was by modern techniques.

9 130 Many thanks to Dr Craddock for providing me with this data prior to the final publication of this work

10 143 In a few cases recorded by Gale and Stos-Gale (1984)^b the tin levels obtained from the re-analysis are more than a general few percent higher. For example, artefact no. 11810 from Troy for which Esin (1969) records 0.00% tin, Gale and Stos Gale (1984)^b record 13.30% tin, and no explanation for such marked changes is given.

11 156 The copper samples from Raphina will soon be analysed.

12 157 The term "Cypriote" is used because this particular copper source(s) has a lead-isotope composition very similar to that known to characterise copper ores

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in Cyprus. The location of this source or set of sources has not been geographically determined, but it is highly likely that it or they are located on the Greek mainland.

13 166 These samples were submitted for analysed in 1984 and results are expected soon. (Dr N H Gale)

14 169 Junghans et al (1968) devised five main composition groups for the Old World. The basic elemental characteristics of each of these is:

E₀₀: As=tr; Sb=tr; Ni=tr; Ag usually tr; Bi=0.002%
 C6: As=0.2-1.5%; Sb=0.08-0.6%; Ag=0.04-0.16%; Ni=0.04-0.5%; Bi=0.02-0.12%
 CIB: As=tr; Sb=0.16-0.64%; Ag=0.12-1.2%; Ni=tr; Bi=0.008-0.025%
 EOI: As=0.4-2.5%; Sb=tr; Ag=0.01-0.25%; Ni=tr; Bi=tr
 EOIA: As=0.13-2.5%; Sb=tr; Ag=-; Ni=<0.02%; Bi=0.008%

15 171 I am grateful to Professor R F Tylecote for supplying me with samples of copper waste and copper nodules from Rudna G va in 1982. These samples were submitted to Dr N H Gale in 1982 and results are expected.

16 189 The newly excavated finds of copper and silver from Manika (1985-1986 excavations by Dr A Sampson) will be sampled for chemical and lead-isotope analyses in June, 1987 and results should be available by the end of the year. These results and a typological study will be published in a joint article with V McGeehan-Liritzis and A Sampson.

- 17 192 Copper samples from Teichos Dymaion were submitted for chemical and lead-isotope analyses to Dr N H Gale in early 1983. Results are awaited.
- 18 195 Principal component analysis reduces the characteristics of the chemical data to two dimensions. It is another effective way of showing the similarities and contrast between the chemical compositions of various metallurgical industries.
- 19 196 Several chemical results, eg. those from Levkas, became available after the computer work was done (in 1983-4) These results were assessed along with the computer results.
- 20 198 An alternative interpretation may be that these were made from smelted copper sulphide.
- 21 223 See footnote no. 15.
- 22 224 A preliminary study of the newly excavated material from Manika, kindly permitted by Dr A Sampson, indicates strongly the influence of the Troadic metalworking tradition.
- 23 228 See footnote no. 1 in section 4.6.4.
- 24 231 A field expedition to the copper sources of southern Thessaly and Fthiotidha successfully demonstrated that copper oxide sources were available easily on the surface in a number of loads. See notes on future work in Epilogue.
- 25 239 For Manika see footnote 16 above.
- 26 259 There have been several criticisms of the "Transmerance" hypothesis summarised in Bintliff's work (1977). Gamble (1979) argued that the virtual absence of fishbones at some sites, such as Phylakopi, for example, rules out the suggestion of Bintliff that fishing was important in site location. One must

also bear in mind the problems of preservation or differential exposure. Then again, no olives were recovered from Phylakopi, yet no arguments has been put forward against the "Polyculture" theory advanced by Renfrew (1972 (see footnote 30 below). The second criticist argues that ethnoarchaeology assumes modern conditions to be applicable to the past. Since transhumance, and modern/recent fishing reflect for example historically-particular manifestations and not universal features of Mediterranean life since early prehistoric times, the relevance of recent economic practices is very doubtful. Ethno-history offers good models of practices in the same or similar landscapes, especially when one can disentangle recent market and other pressures on these ethno-historic phenomena. Similar practices may have operated in prehistory and ancient times. Bintliff, personal communication, still holds strongly that in spite of recent criticisms of his theory, the data on Aegean transmerence in the last century or so offers a model of how fishermen can improve catches by moving about and following the natural congregation times and places of the fish and such routes do explain the distribution of obsidian, the location and type of the Saliago culture sites, etc.

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Anatolia, for example from EBA II Dorak,
(Mellaart, 1966)

- 28 264 The length to width ratios can be estimated effectively from the scaled drawings of the craft. For example that given by Renfrew, (1972, figure 17.7). The length of the craft to its widest section was 12:1. This was most likely a dugout. A wider craft would have a ratio greater than that of a normal tree trunk.
- 29 272 Bintliff's (1976) conclusions regarding site surveys have been challenged by Dickinson (1982). It should be stressed that LN sites are mainly tells in northern and central Greece, but not in southern Greece. It should also be stressed that little survey work has been conducted in inland/upland regions. Howell (1962) found several early sites in Arcadia and the ongoing Argolid Exploration Project (an interdisciplinary investigation of the interaction between settlement and landscape) directed by M H Jameson, has discovered several sites of EBA date in just such locations. It has been demonstrated by Pope and Van Andel (1984) that changes in the environment, in particular soil erosion, were due as much to anthropogenic activities as to climatic change and this resulted in the loss of good land which

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may in turn have contributed to the reduction in sites of the EH III period. Soil erosion as a result of agricultural practices in the EBA may have been extensive.

All maps are drawn from data collected by Hope Simpson and Dickinson (1976) except for data for west Macedonia (French 1972) and LN settlement in Thessaly (Theocharis, 1973).

- 30 277 The influential thesis of Renfrew (1972), that the EBA settlement of southern Greece was made possible by the introduction of the domesticated olive tree and the grape vine has recently been criticised, (Runnels and Hansen, 1986). They have demonstrated that there is little support for Renfrew's theory of the impact of olive production. The implications of this conclusion for Renfrew's thesis are important. Runnels and Hansen suggest that the first of Renfrew's two models for Aegean cultural change (Subsistence/Redistribution) now finds less support as it depended on the introduction of the Mediterranean polyculture to trigger population growth. Population growth and settlement increase occurred without the olive and Runnels and Hansen suggest that Renfrew's second model (Craft/Specialisation), which links the emergence of stratified society to the development of bronze metallurgy and trade, to be more plausible.

NUMBER	P	FOOTNOTE
31	277	<p>The subject has been dominated by the view of Vita-Finzi (1969), and vigorously supported by Bintliff (1977). that there were only two late Quaternary alluviations - the Younger and the Older Fills. Both were attributed by Vita-Finzi to climatic causes. This model, proposed for the entire Mediterranean, has been widely accepted, notwithstanding some criticism and contrary evidence (Eisma, 1964, Butzer, 1969, Kraft et al, 1975, Davidson, 1980, Paepe et al, 1980). Anthropogenic factors were shown to be important also and a series of seven depositional phases in the late Quaternary now seems more realistic, in the light of the most recent work on the subject (Pope and Van Andel, 1984). The depositions are restricted in distribution by their alluvial character. Aggradation is, however, noted inland also.</p>

ABBREVIATION USED IN TEXT

AAA	Athens Annals of Archaeology
AD	Archaeologikon Deltion
AE	Archaeologikis Ephemeris
AJA	American Journal of Archaeology
AR	Archaeological Reports of the BSA
AS	Anatolian Studies
BCH	Bulletin de Corrépondence Héliénique
BMB	Bulletin du Musée Beruit
BSA	Annals of the British School at Athens
CAH	Cambridge Ancient History
GNBP	Godichnik na Narodniya Bibliotek v Plovdiv
GNM	Godichnik na Narodniya Nuzei, Sofia
IAK	Izvestiya Archeologitscheskoi Komessii
IEJ	Israel Exploration Journal
JAS	Journal of Archaeological Science
JBHM	Jahrbuch des Bernischen Historischen Museums in Bern
JEA	Journal of Egyptian Archaeology
JFA	Journal of Field Archaeology
JHS	Journal of Hellenic Studies
JNES	Journal of Near Eastern Studies
OAK	Otchet Arkheologitscheskoi Komessii
PPS	Proceedings of the Prehistoric Society
PZ	Prähistorische Zeitschrift
WMBH	Wissenschaftliche Mitteilungen aus Bosnien und der Herzegowina
WPZ	Wiener Prähistorische Zeitschrift.

Ag	silver	R	razor
an.	analysis number	"S/S"	Sitagroi/Sesklo source
As	arsenic	Sb	antimony
Au	gold	t	type
Aw	awl	T	tweezers
Ax	axe	Tab	tables
Ay	Aghios or Aghia	Ud	unidentified to type
B	bead	Upbd	unpublished
BC/BP	Before Christ/Before Present	W	weapons
cat.no.	catalogue number		
cent.	central		
cm.	centimetre		
Ch.	chisel		
Cu	copper		† full length not preserved
Diam.	diameter		* corroded metal sample
EH	Early Helladic		
Fig.	figure		
L	length		
L/MaxW	length to maximum width ratio		
LN	Late Neolithic		
Mus	museum		
NA	not available/applicable		
Pb	lead		

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