Arch /Syria, MiddE /Obsid, Chara, Trace, Major, InNAA

AN ANALYTICAL STUDY OF OBSIDIAN FROM TELL ABU HUREYRA, SYRIA

Neutron activation analysis of obsidian from
an early Neolithic site in Syria,
examining changes in obsidian source exploitation
through time

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PREFACE

The obsidian from Tell Abu Hureyra, a Neolithic site in Syria, is analysed by neutron activation analysis to determine the trace element characterization necessary to identify the geological sources exploited by the people of Abu Hureyra, and any possible changes in the exploitation through time. One hundred pieces of obsidian were analysed from one trench dug at the site, with all three cultural phases represented. The results of the analysis show five chemically distinct obsidian groups, representing at least five geological sources, with change in the exploitation of three of the sources within the time of occupation of the site.

The work reported here is the first stage of an extensive programme of analysis directed towards an understanding of the occurrence of obsidian at specific sites occupied during the period from the eighth to the fifth millenium BC. The final aim is to increase our understanding of prehistoric trade.

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CHAPTER 1

INTRODUCTION

Obsidian is a naturally occurring volcanic glass found in areas of recent volcanic activity where acid rocks are found. Its high silica content is apparent from Table 1 where the major elemental composition of two types of obsidian are shown. It is a hard, though brittle material which fractures conchoidally, allowing an experienced knapper to predict the direction of breakage. A very sharp edge can be produced that is particularly suitable for cutting tools. Obsidian is especially important to prehistorians because it survives in archaeological sites, and is suitable for trace element analysis.

Obsidian analysis has been based on the hypothesis that the elemental composition is uniform throughout a single flow of obsidian, but different from any other single flow. Gordus, et al (1968) show this hypothesis to be valid. They analysed 1000 pieces of obsidian from single obsidian flows in distinct volcanic regions in North America by Neutron Activation Analysis to test the hypothesis. They found that in elements such as Mn, Sc, La, Rb, Sm, Ba, and Zr, samples from a single flow showed a less than 40 per cent variation, while samples from different flows show ranges of 1000 per cent or more.

Source identification is important archaeologically when considering questions of prehistoric trade and the spread of ideas. If the source can be identified conclusively, then the minimum distance it must have travelled can be determined,

TABLE 1

AVERAGE COMPOSITION OF TWO KINDS OF OBSIDIAN

OXIDE	PERALKALINE	NON-PER.	ELEMENT	PER.	NON-PER.
SiO_2	68.85%	74.72%	Si	32.18%	34.90%
Al_2O_3	10.53	13.23	Al	5.57	7.00
Fe_2O_3 FeO	7.84	1.88	Fe	5.87	1.36
MgO	0.54	0.29	Mg	0.33	0.17
CaO	0.73	1.07	Ca	0.52	0.76
Na_2O	5.89	4.19	Na	4.37	3.11
K_2O	4.27	4.08	K	3.54	3.4
H_2O^+	1.05	0.63	H_2O^+	1.05	0.63

and hypotheses about the possible directions of trade routes can be developed. The presence of obsidian from the same source in more than one site is evidence that some kind of contact, though it may have been indirect, existed. Similarity of ideas as represented by architectural styles, similar tool types, etc., could be a result of parallel invention, but the presence of obsidian from the same source on different sites is evidence for some kind of contact that is independant of the possible similarities of human thought processes. The presence of obsidian at sites distant from the sources helps establish the trade routes necessary, not only for the spread of obsidian, but for the movement of other kinds of goods, especially ideas (Dixon, et al 1968).

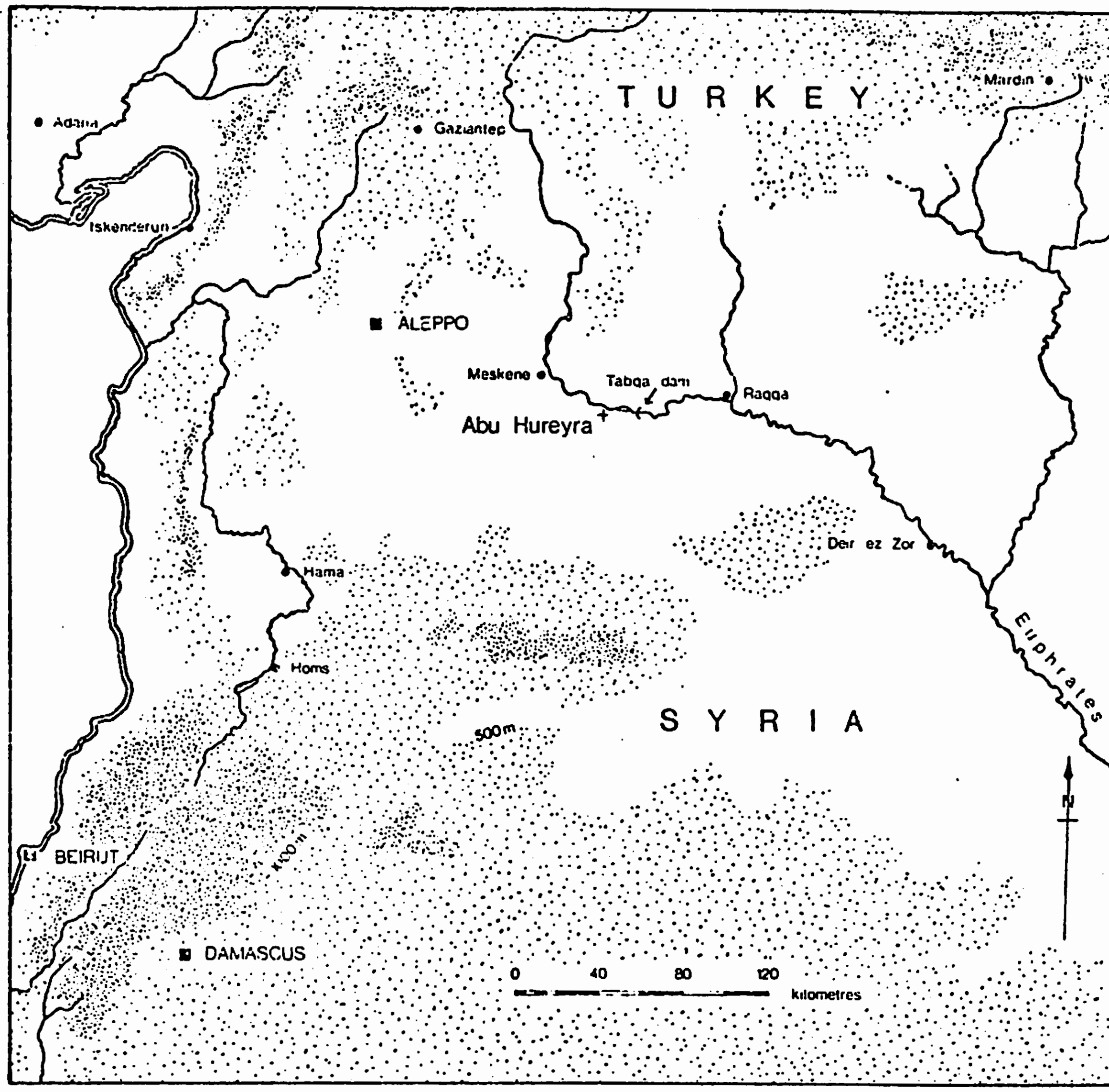
Archaeological obsidian has been analysed for source identifaction in different parts of the world, using different analytical techniques. A great deal of work has been done in North America (Frison, et al 1968; Bowman, et al 1973; Griffin, et al 1969; Nelson, et al 1975), Central America (Cobean, et al 1971; Hammond 1972), The Mediterranean and the Aegean (Cann and Renfrew 1964; Renfrew, et al 1965; Aspinall 1972; Williams 1975), the Near East (Renfrew, et al 1966,1968; Wright 1969; Pearson pers. comm.), and New Zealand (Ward 1974). Much of this work has been done by Neutron Activation Analysis (Frison, et al; Bowman, et al; Griffin, et al; Hammond; Wright; Williams; Pearson) and some by Optical Emission Spectrometry (Cann and Renfrew; Renfrew, et al). Nelson, et al (1975) have recently used energy-dispersive X-ray fluorescence on north-west coast obsidian in North America, as has Ward (1974) for New Zealand obsidians. Cobean, et al (1971) used X-ray emission spectroscopy and NAA on obsidian from southern Mexico. These different methods of analysis cause problems when trying to compare the results. It is impossible to compare the results of the analysis of Near Eastern and Mediterranean obsidians by OES directly to the results obtained by NAA because the two methods are not sensitive to the same elements. The energy-dispersive X-ray fluorescence used by Nelson, et al (1975) is very quick, and gives good contrast for the sources, but it does not result in any absolute figures, merely the relative intensities of the peaks, making inter laboratory comparisons difficult, even if the same technique is used.

Two elements difficult to determine accurately by NAA, barium and zirconium, are used by Renfrew, et al to identify different obsidian groups representing different sources. Different applications of NAA can also produce different results that make it difficult to compare results. Wright (1969) uses NAA for his analyses, but he depends heavily on the Na/Mn ratio for separation of obsidian sources, a ratio that cannot be determined by the Bradford laboratory procedure because the half-life of Mn is too short. NAA was chosen for this analysis because it is a well established method of trace element analysis, suitable for archaeological materials (Perlman and Asaro 1969), particularly obsidian because it is not altered at all chemically when utilized for archaeological artifacts (Bowman, et al 1973). It does not require any destruction of the sample, a fact which is important when desiring to analyse rare or unique samples, as obsidian from sites with a very small absolute amount of obsidian. Optical emission spectrometry as used by Renfrew, et al

1964,1966,1968) is a destructive method of analysis and the chances of error are greater. They discovered an internal variation of 100 per cent in the same obsidian group. This could lead to difficulties when analysing samples from similar obsidian flows.

There are three ways of approaching the problem of utilization of obsidian from different sources. One way is to investigate the sources thoroughly, work which still needs to be done. Secondly, a small number of samples from many sites within a large region can be analysed to determine general patterns of exploitation as has been done by Renfrew, et al, and Wright for the Near East. Thirdly, individual sites can be analysed in depth to determine the specific pattern of source exploitation for one site and the changes through time. The analysis of the obsidian from Abu Hureyra is the first stage of a program of analysis of the third type. The obsidian from Tell Aswad and Ghoraife, two sites in the Damascus region of Syria, will also be examined extensively in the future by the Bradford laboratory. Abu Hureyra was chosen for analysis because the standard method of excavation included sieving all the excavated material to ensure a consistent sample and greater recovery rate.

Abu Hureyra is located in the Euphrates river valley in Syria, near Aleppo (Figure 1). The obsidian sources that might have been exploited by the people at Abu Hureyra are all in Anatolia. Two sources in the Aegean, Melos and Giali, which are conceivably near enough to have been exploited during the Neolithic in the Near East, do not seem to have exploited at any of the Neolithic sites where the obsidian has been analysed. The Anatolian sources that could have been



LOCATION OF ABU HUREYRA IN SYRIA

FIGURE 1

utilized by the inhabitants of Abu Hureyra are located in two major source areas; central southern Anatolia, and eastern Anatolia and Armenia (Figure 2).

Renfrew, _et al_ have developed a system of obsidian groups based on the barium and zirconium contents of the obsidian analysed. This was necessary for two reasons: (1) Many obsidian sources are still not exactly located; and (2) the spread within a group defined by OES was broad enough that obsidian from more than one source could fit into one group. NAA seems to provide a tighter grouping, distinguishing differences within what would have been called one group by Renfrew, _et al_, but it is still useful to think in terms of obsidian groups rather than obsidian sources, however. Then one is not saying that obsidian of a particular group comes from a particular source, but rather that a particular source could contribute to a particular group. This distinction is important as long as there are still geological sources not accurately located, and the possibility that obsidian with the same trace element characterization could come from different obsidian sources still exists.

The groups identified by Renfrew, _et al_ for the Near East are called: 1e-f, 2b, 1h, and 4f located in central Anatolia; and 4c, 1g, 1e-f, and 3a in eastern Anatolia.

The central Anatolian sources are located in the region formerly known as Cappodocia, west of Kayseri, in central Anatolia. Five sources are known, two of which do not seem to have been used during prehistoric times (Renfrew, _et al_ 1966)

The Acigöl-Topada source is located approximately eight km east of Acigöl-Topada, eleven km southwest of Nevşehir, on the Aksaray road. Obsidian from this source

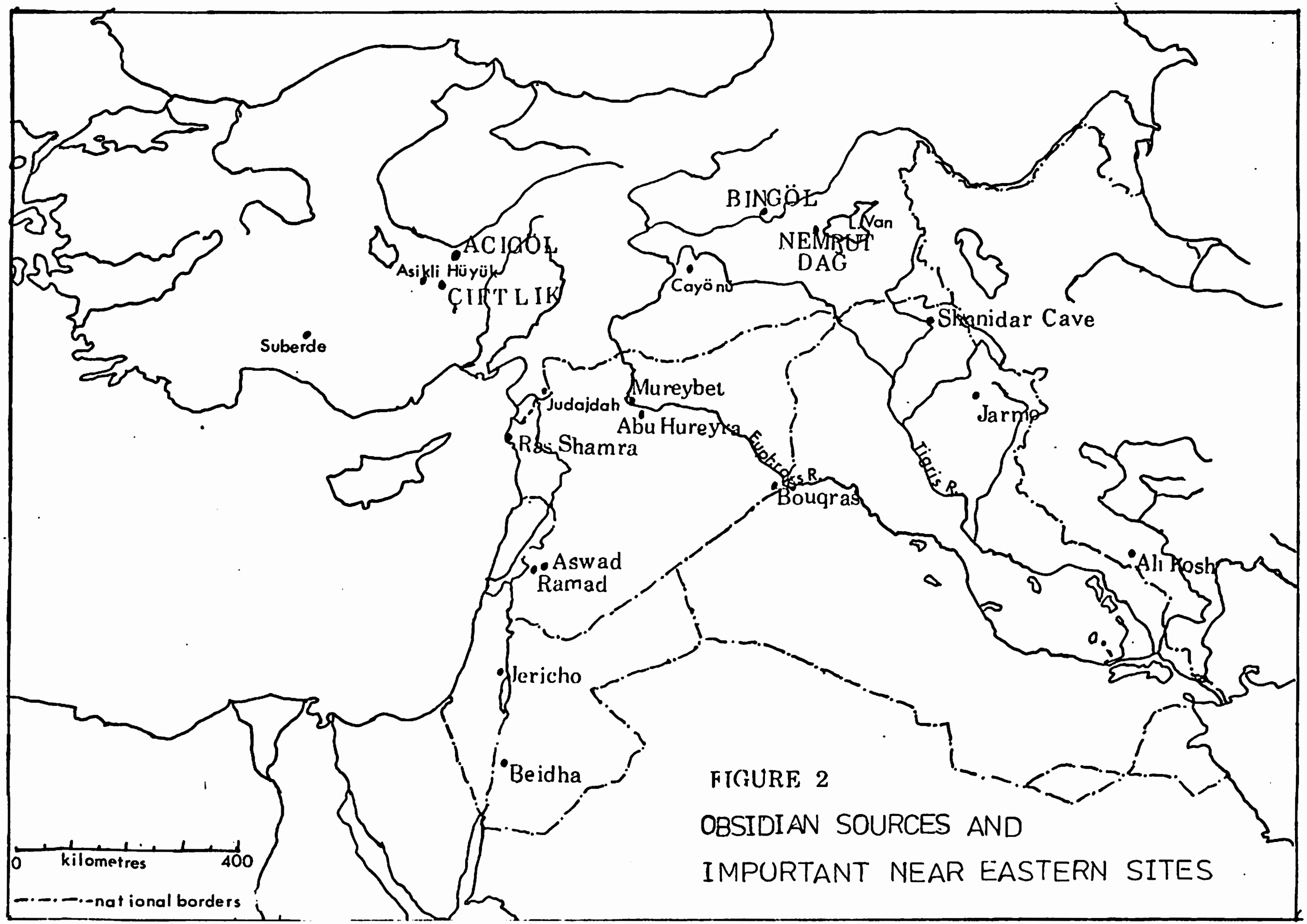


FIGURE 2

OBSIDIAN SOURCES AND IMPORTANT NEAR EASTERN SITES has been classified as group le-f by Renfrew, et al. Wright (1969) has investigated five obsidian localities in this area east of Acigöl, and calls the Acigöl-Topada source localities 2 and 3. Localities 1, 4, and 5 are in the same region. The obsidian from localities 1 and 4 has not yet been tested.

Çiftlik is located about 40 km northwest of Niğde, on the road to Nevşehir, and 43 km southwest of Acigöl. Obsidian of group 2b is from this source (Renfrew, et al 1966).

Karakapu is located south of Hasan Dağ, northwest of Bor, in central Anatolia. Obsidian group lh is found at this source. No artifacts of this group have been found in prehistoric sites, so the assumption is that it was not exploited during prehistoric times.

Small pieces of unworked obsidian were picked up 40 km west northwest of Nevşehir at Kulaklikepez, and also at Karinyarik Kepez, 12 km west northwest of Nevşehir, resulting in obsidian group 4f, but as with the obsidian from Karakapu, no artifacts analysed have been of this group, so it is concluded that the source of this group was not utilized in prehistoric times.

Wright (1969) identifies one additional source, locality 6, located on the east slope of the Korkuyu ridge of the Göllü Dağ mass, about 30 km south of Acigöl.

The sources in eastern Anatolia and Armenia are much less well known than those in central Anatolia. One of the important groups, lg, has not yet been located geographically, but since its distribution is very similar to that of group 4c from Nemrut Dağ, Renfrew, et al (1966), with agreement from Wright (1969), think that it is most likely to be close to that source.

Nemrut Dağ is located at the west end of Lake Van. Obsidian group 4c is found at this source. The obsidian is peralkaline obsidian, typically green or with a greenish tinge in transmitted light. Wright (1969) has identified at least two separate flows on the Nemrut Dağ, A and B. Nemrut Dağ B is the source for Renfrew's group 4c.

Bingöl is another source of peralkaline obsidian, located between Muş and Elaziğ, 100 km west of Lake Van and 50 km east of Bingöl. This obsidian is also classified as group 4c by Renfrew, et al, but it can be separated by the manganese content determined by some forms of NAA (Wright 1969).

Sources for group le-f are present in the Kars district, and in the Erevan region, but the precise locations are not known. It is not possible to distinguish this obsidian from that of Acigöl (Renfrew, et al 1966).

There is a source near Bayezid that may be the source for obsidian group 3a. The exact location is unknown. No samples from this group have been found in archaeological sites of the early Neolithic in Syria or the Levant.

Some hypotheses about the exploitation of obsidian and the obsidian trade in the Near East generally have been developed on the basis of the analysis of a few samples from many sites in the Near East by Renfrew, et al (1966;1968) and Wright (1969).

The Near East south of the Tarus mountains is generally divided into two regions of obsidian source exploitation. These regions are western Syria and the Levant, and the areas east of the Syrian desert, including northern Mesopotamia and Iran. Obsidian was used in Paleolithic times whenever it was available, and at times it was transported some distance. Obsidian from Lake Van was brought to Shanidar Cave in the Zagros mountains 400 km away during the Upper Paleolithic, 30,000 years ago (Renfrew, et al 1966), while at about the same time obsidian from Çiftlik was being transported to the caves in the Antalya region across the Tarus some 350 km away. During the Mesolithic, obsidian trade was not very important. In the Zagros sites minimal amounts of obsidian were found in Mesolithic levels, and it is absent from the Antalya caves. No obsidian has been found in Syria or the Levant in any Paleolithic or Mesolithic occupation site.

During the early Neolithic, obsidian exploitation became established in the Near East. Obsidian from Çiftlik appears in small amounts in Palestine in the late eighth millenium BC at the sites of Jericho and Nahal Oren during the PPNA (Wright 1969). The earliest appearance of obsidian in Syria is probably during the early eighth millenium BC at the sites of Aswad and Mureybet.

The general pattern of exploitation continued to be primarily divided into two regions during the seventh and sixth millenia, so the central Anatolian sources were exploited by the peoples of the Levant and Syria, while the eastern Anatolian sources were exploited by the peoples of northern Mesopotamia and Iran east of the Syrian desert. At this time, though, small amounts of eastern Anatolian obsidian was reaching the Levant. No obsidian from central Anatolian sources has been found in the region east of the Syrian desert. The location of Abu Hureyra is such that either source area could have been exploited by the inhabitants.

Abu Hureyra was an important site occupied during what is known as the Mesolithic and the Neolithic in the Near East. The Mesolithic or Middle Stone Age is defined as a time of settling down and adapting to new environments provided in the immediate post-Pliestocene period. The Neolithic or New Stone Age as a stage of development is much more difficult to define. When the term was first used by Sir John Lubbuck in 1865 (Singh 1974), it was simply defined by the appearance of polished stone tools. As the term has been used, however, the economic implications are much more important than is the presence or absence of any particular type of artifact. The actual meaning of the term is still unclear. Various attempts have been made to clarify the definition of the Neolithic, including suggestions that the term should not be used at all (Braidwood 1960; Wright 1971). None of the proposed alternatives have been considered to be completely satisfactory by archaeologists, so the term Neolithic is still used, but some definition is required to identify the particular aspects of the Neolithic in question. Phase divisions are very important in defining the Neolithic sequence in the Near East. At one time it was thought that pottery was necessary for a site to be called Neolithic, but the economic stage including the presence of agriculture and domestic animals occurred long before the appearance of pottery. This led to a division between the aceramic or Pre-Pottery Neolithic and the ceramic or Pottery Neolithic. Jericho, in Jordan (Kenyon) has been classified as the type site for the aceramic phase in Syria and the Levant, especially the Pre-Pottery Neolithic B (PPNB) occupation. Referring to a level at a site as PPNB does not necessarily mean contemporaneous occupation, but it does imply certain similarities in the archaeological assemblages. Moore (in press) does not classify any of the occupation at Abu Hureyra as PPNB, but he does compare Abu Hureyra to sites with levels that have been classified PPNB, such as Bouqras, Ramad, and Mureybet (Perrot 1968).

Abu Hureyra is a site with a long continuous Neolithic occupation, with aceramic and ceramic Neolithic phases. It is a well stratified site, so the pattern of obsidian usage can be well correlated to the stratigraphic sequence. Obsidian occurs regularly from the bottom of the Neolithic occupation. It was selected for extensive study of the obsidian for several reasons. The location of the site is such that either source area would be within a reasonable distance, approximately 450 km, so if trade routes were working from both directions, Abu Hureyra would be in a good position to receive obsidian from both source areas. Secondly, if there was any change in the exploitation of the obsidian sources, the pattern could be correlated to the stratigraphy. Thirdly, the presence of obsidian throughout the sequence in fairly consistent proportions and increasing during the occupation of the site, indicates that obsidian was being brought into the site regularly throughout the occupation of the site, so that changes in exploitation patterns should appear in the archaeological record at about the same time as any actual changes were taking place.

Since Abu Hureyra is the first site to have the obsidian extensively analysed, it will not be possible to draw any definite conclusions about the archaeological significance for the region as a whole. Abu Hureyra can be correlated to other Near Eastern sites through the archaeological assemblages.

CHAPTER 2

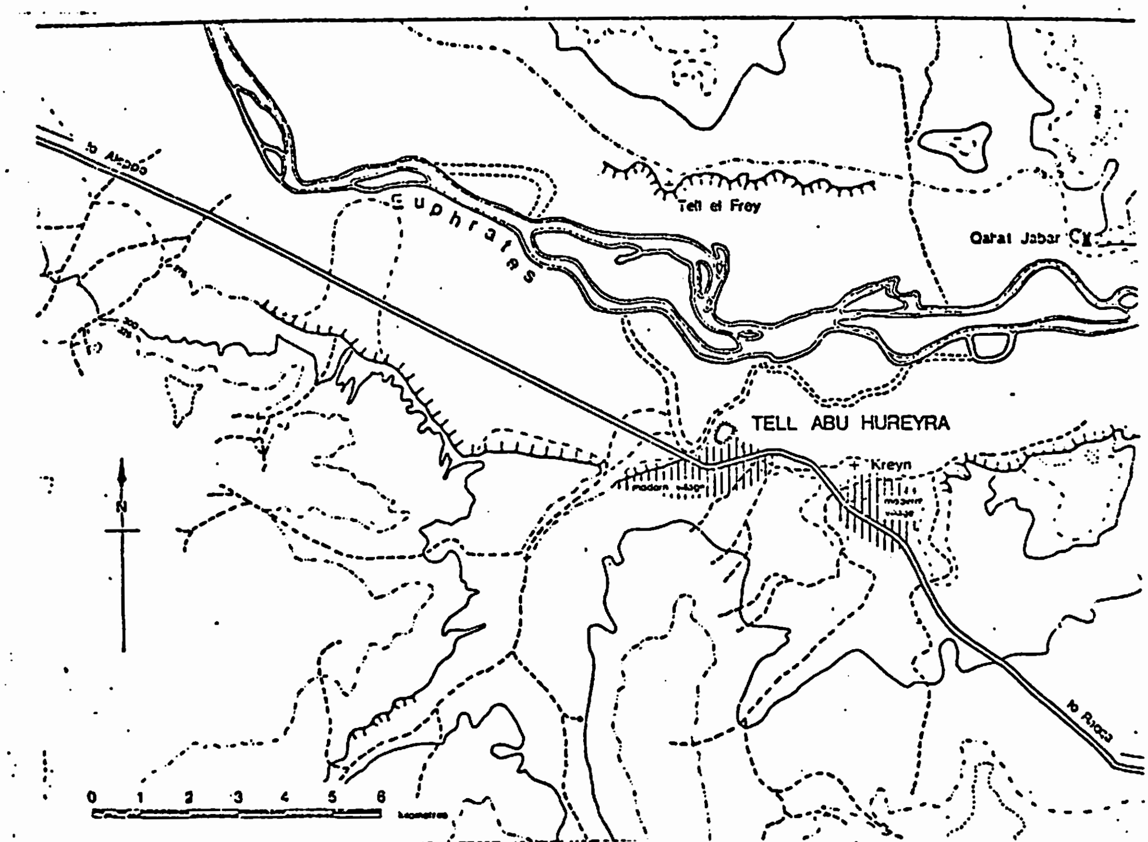
THE ARCHAEOLOGICAL EVIDENCE FROM TELL ABU HUREYRA

Abu Hureyra, a village on the Euphrates river near Aleppo in Syria, is now covered by water as a result of the Teqba Dam. An archaeological survey was carried out in the region, and the site of Abu Hureyra was recognized as one worthy of excavation. The excavations were carried out over two seasons in 1972 and 1973 under the direction of Mr. Andrew Moore. The evidence from the seven trenches excavated shows that the site was continuously occupied for a very long period in the Neolithic. Prior to this in one part of the site there was a Mesolithic occupation. There was a gap between the two occupations, but once it was reoccupied it was continuously occupied until the final abandonment during the Ceramic Neolithic. The site is unusual in that there was no further occupation on the site, and even the modern village did not extend to the tell site, though there are some intrusive burials in the upper layers.

SITE LOCATION

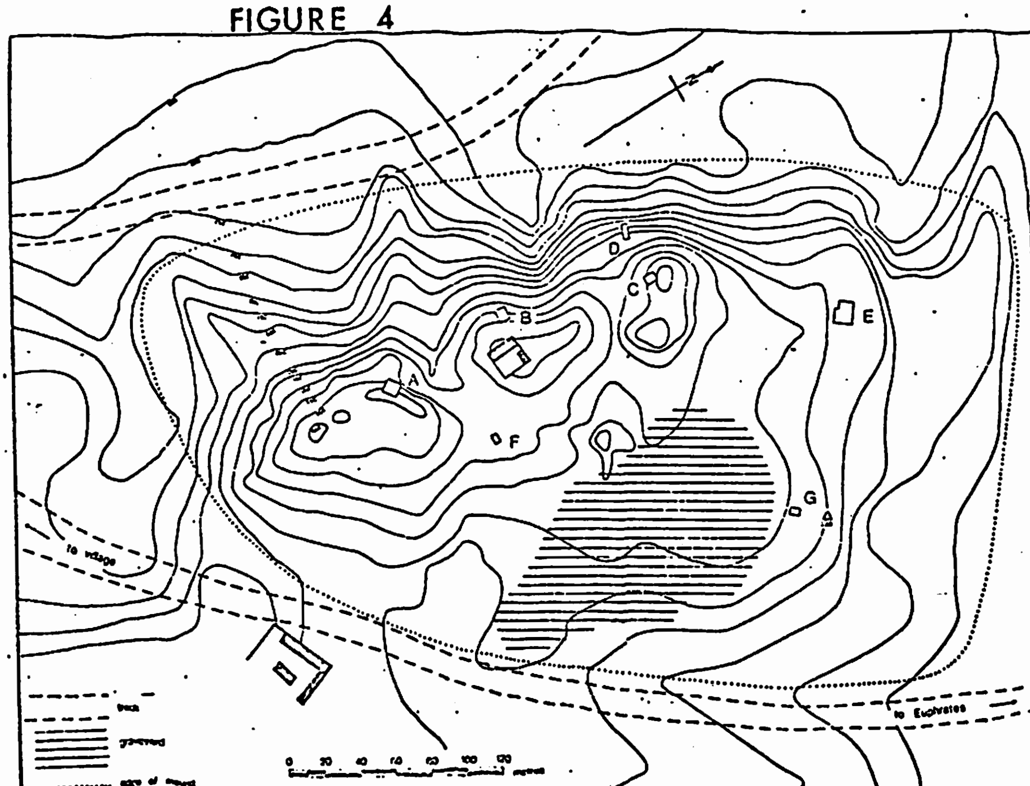
The village of Abu Hureyra is located about 130 km east of Aleppo and 35 km downstream from Meskene on the right side of the Euphrates valley. The prehistoric tell is on the first major river terrace jutting out over the flood plain of the river, with coordinates $35^{\circ}52'$N $38^{\circ}24'$E. The location enabled the inhabitants to exploit several different environments (Figure 3). The site is 480 metres long from north to south and 290 metres wide from east to west (Figure 4). The Euphrates at the time of excavation flowed approximately one

FIGURE 3



EUPHRATES VALLEY LOCATION OF ABU HUREYRA

FIGURE 4



CONTOUR MAP OF TELL ABU HUREYRA

kilometre away from the site, but during the Neolithic occupation it probably flowed nearer to the mound, thus supplying most of the water, as it does today for the modern village.

THE MESOLITHIC SETTLEMENT

The Mesolithic settlement covered a small part of the mound, but the layers were levelled by the Neolithic inhabitants, indicating a gap of some time between occupations. There is no evidence for any continuous settlement from the Mesolithic to the Neolithic as there is at Mureybet (Cauvin 1972), Beidha (Kirkbride), and Jericho (Kenyon). Structures such as pits, floors, hearths, and postholes suggest that there was a semi-permanent settlement during the Mesolithic for a long period of time. No obsidian was found in the Mesolithic layers.

THE NEOLITHIC SETTLEMENT

After a long gap, the site was reoccupied during the Neolithic and continuously occupied, apparently by the same cultural group until its final abandonment. The earliest houses of the Earlier Aceramic were found to the south of the deserted Mesolithic settlement. In trench C, where there are eleven major building levels, the house is built on the same plan throughout the sequence, possibly indicating continuous occupation by the same family. The earliest houses are in trench B, built on the natural sub-soil 8 metres below the surface of the mound.

CULTURAL PHASES

Moore (in press) has provisionally separated the occupation levels at Abu Hureyra into three cultural phases. These are: the Earlier Aceramic; the Later Aceramic; and the Ceramic

Neolithic. Further divisions are unlikely because the architectural evidence indicates that the occupation was continuous, and does not provide any justification for further divisions (Moore pers. comm.). The three phases are based on increases in the types of artifacts represented.

SUBSISTENCE ECONOMY

Cultivation was practiced from the beginning of the Neolithic occupation (Hillman in press).

The faunal assemblage changes during the aceramic from one where gazelle is the most represented species with a very low proportion of sheep, goat, cattle, and pig (16% of the total assemblage), to one where sheep and goat are the most predominent and gazelle is the second most common. These differences are not clearly separated into Earlier Aceramic and Later Aceramic as yet, leading to two possible interpretations. One is that there is an "early" assemblage and a "late" assemblage, while the second is that there is a functional difference within the site, so the different proportions of animal species could represent different acctivities taking place at the same time (Legge in press).

In the Ceramic Neolithic there is a high frequency of sheep and goat, with gazelle the second most common species. Cattle are uncommon, and pig is rare (Legge in press).

Fish remains are rare in the dry sieved part of the site, but large numbers of fish scales are found in the floated material suggesting this is a factor of lack of survival, rather than lack of exploitation (Moore pers. comm.). The importance of fishing to the economy is not yet known.

The floral and faunal assemblages suggest, as with other aceramic sites in Syria, the subsistence economy of Abu

Hureyra was based on agriculture and hunting. The increase in the numbers of sheep and goat remains suggest domestication was occurring during this time.

EARLIER ACERAMIC

This is the phase of the first Neolithic occupation, occurring either on natural sub-soil or on leveled off Mesolithic occupations levels. The earliest buildings were built on natural sub-soil south of the Mesolithic settlement. The buildings were made of mud brick with multi-roomed rectilinear plans, some with black burnished plaster floors. The tools were primarily made of flint or bone. The stone tools throughout the sequence are based on blades with a minimum amount of abrupt retouch. Tanged flint arrowheads are common. The bone tools are primarily borers. Other artifacts present are basalt rubbers, stone balls, and pecked and polished green stone axes which occur throughout the Neolithic sequence. These levels compare to the latest levels at Mureybet..

LATER ACERAMIC

In this plase the settlement reached its largest size, covering the whole of the mound. These levels are the richest of the site, permitting eventually a fairly detailed reconstruction of the the way of life of the inhabitants. As in the previous phase, the buildings were made of mud brick with multi-roomed rectilinear plans. They were tightly clustered together, separated by narrow lanes and courtyards. The thin walls indicate that most of the buildings were primarily one-story. The black-burnished plaster floors were replaced several times in the lifetime of one building. One building in trench B was still quite complete when excavated, with the walls still standing to the original height of 1.7 metres. In it were the fragments of a large plaster vessel which appears to have been a permanent feature of the room. One complete vessel of this type was found in another building of this phase, while many other fragments have been found. They are similar to the "vaisselle blanche" or white ware found in many aceramic sites in Syria. This white ware is not pottery,. but a moulded plaster made of lime and silica, "with ochrous, friable cores containing large grits"(Singh 1974:50). When first made it is soft enough to make coiled vessels, later hardening to a pozzuolanic cement (de Contenson 1971:283).

The burial practices during this phase are similar to those found throughout the Near East. The graves were shallow pits either beneath the floors of the houses or in the yards outside. There were three main types of burial. Some graves had only a single individual in a crouched position, sometimes without the skull. Others consisted of groups of skulls or parts of skeletons. A third type had skeletons and skulls, not necessarily of the same individual, mixed up together. Grave goods were rare, but were present occasionally. Sometimes one or two river pebbles were placed on or beside the skeleton, or flint artifacts or beads were present. Butterfly beads, some made of serpentine or agate from Anatolia (Moore pers. comm.) were probably specifically funerary objects.

There are many more types of artifacts present in this phase. The chipped stone assemblage is more varied, with more retouch present, and different types of blade production used. Combination tools also appear, such as end-scraper/awls or end-scraper/burins. Sickle blades occur, but are very rare. Bone tools are also more varied than in the previous phase, with many types of borers, spatulae, and needles. In addition there are bone beads and the tubes from which they were cut, a fish hook, and a hook and eye, possibly for clothing. The pecked and polished stone axes and chisels are much more common. Many were made on river stones, but others were made on jadite imported from Anatolia. Polished stone bowls and dishes occur for the first time. Stone rubbers and querns are very common. Beads and pendants made of stone and shell are also common. Baked clay objects are present, even though pottery was still not used. Some of these objects are: "stamp seals", rectangular plaques, and cylindrical beads with strands of thread still preserved. Figurines are present, but are not common.

CERAMIC NEOLITHIC

The size of the settlement was much smaller during this phase, covering perhaps half the mound. Erosion and weathering since abandonment reduced the depth of the deposit to the top metre of the tell, and altered the colour to a dull uniform grey throughout. The first occurrence of pottery is in these levels. The fabric of the pottery found is coarse and crumbly in texture, tempered with straw, and coloured brown or black. It is similar to the dark-faced burnished ware found in other Syrian sites, but it is coarser. The associated flint industry is very similar to that of the previous phase, with the addition of a few new tool types, suggesting that this is one of the earliest occurrances of pottery in Syria. Most of the rest of the artifact types are similar to those used in the previous phase.

The Ceramic Neolithic phase at Abu Hureyra is the least well stratified. Islamic or Byzantine graves are intrusive, as well as small pits filled with occupation debris, possibly dug during the occupation of the site. As examined, it appears to correlate to early pottery levels of other sites in Syria. The closest relationship appears to be with Bouqras level III, the only other ceramic Neolithic site excavated in the Euphrates valley.

TRENCH B

The excavation of trench B is of special interest to this summary, because all of the obsidian being analysed is from this trench. Trench B is located in the centre of the north-south ridge, where the mound reaches its greatest height of 8 metres (Figure 4). It was excavated during both the 1972 and 1973 seasons. In the first season only the top levels were excavated, provisionally divided into Ceramic Neolithic and Later Aceramic phases. The Ceramic Neolithic levels are jumbled, showing no clear stratigraphic building levels, and are disturbed by modern graves. In the 1973 season, excavation began at the level which had been reached in the 1972 excavations, so the first 29 excavation levels represent clear stratigraphic levels of the Later Aceramic phase. Then the trench expanded and two bulk levels were taken off the top of the unstratified Ceramic Neolithic, and excavation continued to the bottom of the trench. Unfortunately, time limitations did not allow the larger area to be excavated to the bottom, therefore the lowest levels representing the Earlier Aceramic are from a trench only 2 by 4 metres. The excavated material was dry sieved with 1 cm square mesh. The cultural sequence divided into excavation levels is shown in

TABLE 2

TRENCH B: PROVISIONAL PHASING (May 1975)

	PHASE	LEVELS
1972 season:	Ceramic Neolithic	1-50
	Later Aceramic	51-68
1973 season:	Ceramic Neolithic	30, 31, 34
	Later Aceramic	1-29,32,33,35-97
	Earlier Aceramic	98-152

EXOTIC MATERIALS

In addition to obsidian, a number of other items were brought into Abu Hureyra. A certain amount of foreign geologica material used, such as granite, was brought to the site naturally by the Euphrates river, but other objects were brought in by some human agency in either a finished or unfinished form (Moore pers. comm.). Jadite used for axes, serpentine and agate for beads all probably came from Anatolian sources. There must have been a fairly extensive trade network into Anatolia which brought these things to Abu Hureyra. In addition to the Anatolian material, there is a turquoise bead from Sinai, cowrie shells from either the Red Sea or the Persian Gulf, steatite probably from Iran, and carnelian of an unknown origin, but not native to Abu Hureyra. Basalt and bitumen, possibly from the Dead Sea (Anati 1962), also occur throughout the sequence.

Exotic materials of the type found at Abu Hureyra are present in most Neolithic sites in the Near East, but very few have been analysed, so there is not much reference to them in publications (Moore, pers. comm.). Examination of the types and amounts of exotic materials present in these sites could lead to considerably greater knowledge about the non-economic and the not essentially economic aspects of the systems of exchange used during the Near Eastern Neolithic.

CHAPTER 3

THE PLACE OF ABU HUREYRA IN THE NEOLITHIC OF THE NEAR EAST

Abu Hureyra was an important site in the aceramic Neolithic of Syria. It was larger than all the other sites in the area, and may possibly have been a regional centre. It was occupied during the important period when agriculture was being accepted in this region, and fills a gap in the Neolithic sequence thus far developed for Syria.

There are not yet any radiocarbon dates available for the site of Abu Hureyra, but from the archaeological evidence, Neolithic Abu Hureyra appears to have been occupied during the seventh and early sixth millenia BC, and Mesolithic Abu Hureyra during the ninth millenium. During this period there was a great deal of change occurring in the region because of the acceptance of new ideas for living and working. To use Braidwood's terminology (1960), the time from 10,000 to 2,000 BC was a period encompassing the Terminal Food-Collecting, Incipient Food-Producing, and Earliest Established Food-Producing Settlements in Syria (Watson 1965). The occupations at Abu Hureyra belong to the early part of this time period. The Mesolithic settlement at Abu Hureyra fits into the incipient food-producing sub-era, while by the time of the Ceramic Neolithic, Abu Hureyra represented an early established food-producing community.

There are a number of sites that are somewhat comparable to different levels at Abu Hureyra. There are Mesolithic levels at occupations at Mureybet, on the Euphrates in Syria, Jericho and Beidha in Jordan, Karim Shahir, Melefa'at, Gird Chai, Zawi Chemi Shanidar in Iraq, Tepe Asiab and Ali Kosh in Iran (Watson 1965). None of these sites have any significant amounts of obsidian, and there is not much evidence for contact. The people of this time appear to have been more concerned with adapting to a semi-sedentary existence than in contact with other peoples. This stage is important in that it shows that there was a definite change in the exploitation of obsidian from the Mesolithic to the Neolithic.

Most of the occupation at Abu Hureyra was aceramic, and the largest settlement at the site was during this phase. The aceramic phase of the Neolithic was quite wide spread in the Near East, appearing in the late eight, early 7th millenia BC. Some of the communities actually appear to be food producing communities at this stage, while others provide no evidence for food producing at all, but still seem to be fully established sedentary communities. Suberde in Anatolia (Bordaz 1966) and Mureybet in Syria (de Contenson) both appear to be the second type of site. Additional sites with aceramic levels are Cayonu in southeastern Turkey, Jarmo and Tell Shemshara in Iran, Hacilar in Anatolia, Beidha and Jericho in Jordan, Munhatta in Israel, Tepe Guran and Ali Kosh in Iran, Ramad, Bouqras, Aswad, and Ras Shamra in Syria. The Pre-Pottery Neolithic B occupation at Jericho is the type site for defining the aceramic occupations in Syria and the Levant. Perrot (1968) classifies the aceramic occupations of Ramad, level I, Bouqras, levels I and II, and Mureybet, levels 10-16, as PPNB. De Contenson (1972) compares the occupations at Aswad to the PPNB at Jericho.

The aceramic levels at Abu Hureyra bear the closest relationship to the aceramic levels at Mureybet and Bouqras, both Euphrates valley sites, belonging to what could perhaps be called the "Euphrates Valley Neolithic" (Moore, pers. comm.). There is also a definite relationship with the sites to the west, in particular the Syrian sites of Ramad and Aswad near Damascus, and generally to the PPNB at Jericho. Abu Hureyra appears to be distinct from the northern Mesopotamiar aceramic sites and from those in Iran and Anatolia, such as Ali Kosh and Cayonu..

Five sites in Syria and the Levant are particularly significant for comparison with the aceramic levels at Abu Hureyra because they have similar archaeological assemblages, indicating there was probably some kind of relationship among the sites. These sites are: Jericho in the Jordan valley (Kenyon); Tell Ramad (de Contenson and van Liere 1964,1966; de Contenson 1967,1971) and Tell Aswad (de Contenson 1972, 1973) in the Damascus region of Syria; and Mureybet (van Loon 1966a,b, 1968; Cauvin 1972) and Bouqras (de Contenson 1966) in the Euphrates valley.

During the Ceramic Neolithic the sites of Ras Shamra, level VB (de Contenson 1963), Tell Judaidah 'Amuq A (Braidwood and Braidwood 1960), Ramad III and Bouqras III are similar to Abu Hureyra. The aceramic level VC at Ras Shamra is not similar to the aceramic at Abu Hureyra (Table 3; Figure 2).

EARLIER ACERAMIC

The Earlier Aceramic at Abu Hureyra may be contemporaneous with levels 10-17 at Mureybet (7900 BC) and Aswad, phase I (7900-6900 BC). This level is most similar to the levels at

TABLE 3

CHRONOLOGICAL TABLE OF IMPORTANT NEAR EASTERN SITES RELATED TO ABU HUREYRA

DATE BC			SITES		
9000					
	Abu Hureyra Mesolithic	Mureybet Mesolithic	Jericho Natufian		
8000					
			Jericho PPNA		
	Abu Hureyra Earlier Aceramic	Mureybet levels 10-16			
			Jericho PPNB	Aswad I	
7000					
	Abu Hureyra Later Aceramic (?)			Aswad II	
		Bouqras I			
6000		Bouqras II		Ramad I	
				Ramad II	
	Abu Hureyra Ceramic Neolithic	Bouqras III		Ramad III	Tell Judaidah 'Amuq A
					Ras Shamra VB
5000					

Mureybet, and less similar to Aswad. Cultivation was present at Abu Hureyra, absent at Mureybet, and is not yet known for Aswad. Like Abu Hureyra, the stone tools at Mureybet include tanged points, end scrapers on blades, borers, burins, and rare sickle blades (Skinner 1968). Rubbers and querns of basalt are common to all three sites. Abu Hureyra's architecture consists of mud-brick rectilinear multi-roomed structures with black burnished plaster floors from the beginning of the Neolithic sequence. At Mureybet rectilinear houses were used in levels 10-17, but the bricks were limestone slabs covered with red clay. The domestic architecture at Aswad is not yet clear, but mud brick was used for floors, though not walls. De Contenson (1972) thinks these structures were too large for hearths, but too small for houses. Baked clay objects, especially female figurines, appear in phase I at Aswad, but are not present during the Earlier Aceramic at Abu Hureyra, and female figurines were never common at Abu Hureyra. Obsidian blades were present from the beginning at Abu Hureyra and Aswad. Obsidian first appears in level 9 at Mureybet, and is rare in the upper levels.

LATER ACERAMIC

Without radiocarbon dates, it is difficult to place this phase at Abu Hureyra. It could be contemporaneous with level II at Ramad (5900 BC), Bouqras I and II (6200-6000 BC), Aswad II (6800-6500 Bc), and Jericho PPNB (7200-6600 BC). There are general similarities among all these sites, and they could all be generally classified as PPNB sites. These are the richest levels at Abu Hureyra, as they seem to be at all of these sites. Bouqras is the most similar to Abu Hureyra but in level I the houses were made of pisé or mud walls with beaten earth floors, and agriculture was not present. In level II mud brick rectilinear houses with plaster floors as at Abu Hureyra are present. Level II at Ramad shows even more developed architecture, with stone foundations and mould made mud brick rectilinear structures. At Aswad there was no evolution of the structures. At Jericho mud brick rectilinear houses were usual. Vaisselle blanche was present at Ramad II, Bouqras II, and at Ras Shamra VC.

The flint tools at Bouqras II generally remained the same as in level I, with the addition of a few new types. These include end-scrapers, two types of arrowheads, sickle elements, obsidian bladelets, and angle burins, with the addition of many more burins, scrapers and arrowheads. Obsidian is rare, but present in level II. At Ramad II, the flint tools are those of a coastal Syrian type with denticulated sickle elements, blades with flat pressure retouch, tanged arrowheads, knives, circular scrapers on thick flakes and bifacial tools. Obsidian blades with retouch are present, and obsidian is well represented. The flint industry at Jericho in the PPNB consists of well made, thin and narrow blades, arrowheads, sickle-blades, burins, long trihedral rods, blades, and borers. Scrapers are rare, and there are no heavy tools such as axes and adzes. Obsidian is present (Kirkbride 1960). At Aswad II the flint industry is characterized by Ramad I type tools, especially non-denticulated sickle blades. Sickle blades are predominent at the non-Euphrates valley sites, but at Abu Hureyra and Bouqras the sickle element is rare, leading to the conclusion that however grain was gathered or harvested at these sites, it was not reaped with sickles.

Funerary practices at all of these sites include separation of the skulls from the rest of the body.

Hunting was probably an important economic occupation at all of these sites during the aceramic. Wild animal species are either predominent or very common at all of these sites where the bones have been examined. Agriculture was probably also quite important to the economy at Abu Hureyra, Ramad, and Jericho. At Bouqras and Aswad collection was probably more important.

CERAMIC NEOLITHIC

The direction of relationships seems to have changed somewhat during the Ceramic Neolithic at Abu Hureyra. There was a break in the occupation at Jericho after the PPNB phase, and the Pottery Neolithic phase occurs after a gap of some time, while at the Syrian sites there was continuous occupation from the aceramic into the ceramic phase. The assemblage at Abu Hureyra is most similar to Bouqras III, and there is a closer relationship to the 'Amuq A defined for the Plain of Antioch (Braidwood and Braidwood 1960) of northwestern Syria than to the sites of the south.

Bouqras III consists of one village made of the same kind of houses as in the previous phase. Fourteen sherds of the dark burnished ware also found at Abu Hureyra, were present.

'Amuq A, defined primarily on the basis of pottery types, has only been definitely identified stratigraphically at Tell Judaidah where there was no identified architecture, and the flint assemblage was the same for both 'Amuq A and B. Two pottery types belong specifically to 'Amuq A, Coarse Simple Ware, and Dark-faced Burnished Ware. Ras Shamra VB is also identified with 'Amuq A.

The assemblage at Abu Hureyra appears to be more distantly related to Ramad III, but not much is known about this level at Ramad.

Abu Hureyra, Bouqras, and Ramad were all abandoned after a Ceramic Neolithic occupation. Aswad and Mureybet were abandoned before the Ceramic phase, as was Jericho, though Jericho was later reoccupied. It is possible that a gradual change from hunting wild animals in the aceramic to herding animals during the early ceramic phase led to the abandonment of a sedentary existence in favour of a pastoral one.

CHAPTER 4

THE ABU HUREYRA OBSIDIAN

Obsidian was present at Abu Hureyra from the beginning of the Neolithic occupation, and continued to be present throughout the occupation of the site. It represents about four per cent of the total chipped stone industry. Table 4 shows the percentage of obsidian for each of the cultural phases in trench B.

Most of the obsidian is in the form of small unretouched bladelets, with edge damage probably caused by use. A general division of the hundred analysed samples into tool type is given in Table 5. Details of the samples are given in Table 6, and drawings of all of the samples are shown in Figure 5, in the same order as they are listed in Table 5.

SAMPLE SELECTION AND PREPARATION

The obsidian from trench B at Abu Hureyra was chosen for sampling for neutron activation analysis. Of the seven trenches excavated at the site, only trenches B and C were dug through the full Neolithic sequence, showing the longest and most complete sequence. Moore (pers. comm.) thought that the earliest material from B was possibly earlier than the earliest material from C. In addition, more pieces of obsidian were present throughout the sequence in B. Out of 1192 pieces of obsidian, 100 pieces were selected for analysis. The samples were not selected completely at random. An attempt was made to select samples from the three determined cultural phases, 25 from the Earlier Aceramic, 35 from the Later Aceramic, and 40 from the Ceramic Neolithic.

TABLE 4

OBSIDIAN COUNTS AND PERCENTAGES OF THE TOTAL TRENCH B CHIPPED STONE ASSEMBLAGE BY CULTURAL PHASE.

CULTURAL PHASE	TOTAL CHIPPED STONE	OBSIDIAN	% OBSIDIAN
EA	1,364	27	2.05
LA	6,049	328	5.42
CN	20,002	837	4.19
TOTAL	27,415	1,192	4.35

TABLE 5

ANALYSED OBSIDIAN DIVIDED INTO GENERAL TOOL TYPE BY CULTURAL PHASE

TOOL TYPE	EA	LA	CN	TOTAL
Blades and Bladelets	16	28	32	76
Flakes	5	6	5	16
Chunks and Chips	3	0	1	4
Retouched objects	1	1	2	4

This meant that all but three of the Earlier Aceramic pieces were examined, but only a part of the obsidian from the other two phases were sampled. In addition, an attempt was made to select samples evenly from excavation levels from the top to the bottom. Once the levels for sampling were chosen, the obsidian from those levels was visually examined. Each piece was selected by such arbitrary considerations as colour and tool type. There were two colours considered, green and grey. Since it is known that most green obsidian is peralkaline obsidian coming from the eastern Anatolian obsidian sources (Renfrew, et al 1966), the main object in examining green obsidian was to see if there were different groups represented, thus representing different sources. In selecting the grey obsidian, the major question was whether central Anatolian sources were also represented. Tool type was considered when a piece of obsidian was not one of the small bladelets most common in the assemblage. In this case the question was whether obsidian in the form of chunks, flakes, projectile points, cores, etc., show any significant differences in the sources exploited than for the bladelets representing the most common element in the tool assemblage.

It was possible to break the obsidian samples to a more manageable sample size, so the larger pieces were broken with a hammer and a sample of less than 300 mg was selected from the fragments. Each sample was then etched in a bath of 10% hydrofluoric acid for five minutes, washed in two changes of distilled water, and dipped in acetone. After drying, each sample was weighed, wrapped in aluminium foil with a zinc flux monitor, labelled, and placed in a polythene can.

TABLE 6

MATERIAL ANALYSED

The sample number refers to the Bradford irradiation procedure. The first three digit number refers to the run number, and the second number is the identifying number within a can of samples. Groups 2b and 1g correspond to Renfrew, et al. Since the green obsidian would all be classified group 4c by Renfrew, et al, the three green groups are identified by G1, G2, and G3. Group identification and assignment are discussed in Chapter 7. Excavation levels with 72-proceeding the number are from the 1972 excavation season. The others are all from the 1973 season. The artifact type is the general category based on appearance. Colour is as viewed in transmitted day light. The transparency index is on a scale from 0-6 with 0 meaning completely opaque, and 6 meaning completely transparent (adapted from Cann and Renfrew 1964). When a range of numbers is given, such as 2-4, it means the sample was of an uneven thickness, and an exact decision about the transparency could not be determined. Comments such as "cloudy" and "striations" refer to the presence of milky clouds and striations in the material. "Gritty" means there are small inclusions present, while "speckled" or "mottled" means there are a lot of visable dots or spots in the body of the material. Abbreviations: EA=Earlier Aceramic; LA=Later Aceramic; CN=Ceramic Neolithic; w/=with. A blade is a straight sided flake that is at least twice as long as it is wide. A bladelet is a small blade that is less than 15 mm wide.

TABLE 6 MATERIAL ANALYSED

SAMPLE NUMBER	GROUP	CULTURAL CONTEXT	EXCAVATION LEVEL	ARTIFACT TYPE	COLOUR	TRANSPARENCY	COMMENTS
445/1	1g	LA	74	bladelet	black	0	
445/2	G1	LA	44	bladelet	grey w/greenish tinge	4	
445/3	G1	CN	34	bladelet	grey/green	2-3	
445/4	1g	LA	23	bladelet	grey w/brownish tinge	4	cloudy
445/5	G1	LA	85	bladelet	grey w/greenish tinge	4	
445/6	1g	LA	3	bladelet	grey/black	1	
445/7	G1	EA	99	bladelet	grey w/greenish tinge4	5	cloudy, striations
445/8	1g	LA	59	blade	black	0	
445/9	1g	LA	13	bladelet	black	0	
445/10	G2	LA	44	bladelet	grey w/greenish tinge	2-3	
445/11	2b	EA	147	bladelet	grey	5	
445/12	G1	EA	133	bladelet	green	5	striations
445/13	G1	EA	150	flake	green	2-4	striations
445/14	1g	CN	34	bladelet	grey	3-4	cloudy,gritty
445/15	G1	LA	85	bladelet	grey/black w/greenish tinge	1	cloudy,gritty
445/16	G1	LA	23	bladelet	grey w/greenish tinge	4	cloudy
445/17	G1	LA	3	bladelet	grey/green	3-4	
445/18	G1	EA	99	retouched	grey w/greenish tinge	4	

(continued)

SAMPLE NUMBER	GROUP	CULTURAL CONTEXT	EXCAVATION LEVEL	ARTIFACT TYPE	COLOUR	TRANSPARENCY	COMMENTS
449/1	G1	LA	56	bladelet	grey w/greenish tinge	5	gritty
449/2	G1	LA	10	bladelet	green w/greyish tinge	5	striations
449/3	1g	LA	38	bladelet	grey w/brownish tinge	0-1	
449/4	G1	LA	79	bladelet	green	4	
449/5	1g	LA	40	retouched	black	0	
449/6	G1	LA	49	flake	green w/greyish tinge	5	gritty
449/7	G1	LA	53	bladelet	light green	5-6	
449/8	G1	LA	70	bladelet	grey w/greenish tinge	5	cloudy, striations
449/9	G1	LA	16	bladelet	grey w/greenish tinge	4-5	streaky, striations
449/10	G1	LA	13	blade	grey w/greenish tinge	3-5	
449/11	1g	LA	10	bladelet	brown	1-3	
449/12	1g	LA	40	flake	grey	1-3	striations
449/13	1g	LA	53	bladelet	greyish/brown	1-3	dark bands
449/14	G1	LA	56	bladelet	grey w/greenish tinge	5	cloudy, gritty
449/15	G1	LA	59	bladelet	green w/greyish tinge	3-5	
449/16	G1	LA	49	bladelet	green	5-6	cloudy
449/17	G1	LA	38	blade	grey/green	3	cloudy, gritty
449/18	2b	LA	74	flake	grey	5	cloudy, striations
449/19	G2	LA	79	flake	grey/green	1-2	

(continued)

SAMPLE NUMBER	GROUP	CULTURAL CONTEXT	EXCAVATION LEVEL	ARTIFACT TYPE	COLOUR	TRANSPARENCY	COMMENTS
453/1	G1	EA	102	flake	green	2	
453/2	G1	EA	103	bladelet	green	5	
453/3	G1	EA	104	bladelet	grey/green	5-6	gritty
453/4	G1	EA	108	bladelet	grey/green	3	cloudy
453/5	2b	EA	135	flake	grey	5	gritty, striations
453/6	G1	EA	136	flake	green	4-6	stress lines
453/7	2b	EA	137	bladelet	grey	6	gritty, striations
453/8	1g	EA	145	bladelet	light and dark grey	4-5	striations
453/9	G1	EA	108	bladelet	green w/greyish tinge	5	
453/10	G2	EA	135	bladelet	green	1	striations
453/11	G1	EA	145	bladelet	green w/greyish tinge	5	striations
453/12	2b	EA	136	bladelet	grey	5	dark streaks
453/13	G1	EA	146	chip	green	4	stress lines
453/14	G1	EA	136	bladelet	green/grey	4-5	stress lines
453/15	G1	EA	146	flake	green	3-4	
453/16	G1	EA	145	chunk	green w/greyish tinge	0-1	
453/17	G1	EA	136	chip	grey/green	1-4	gritty

(continued)

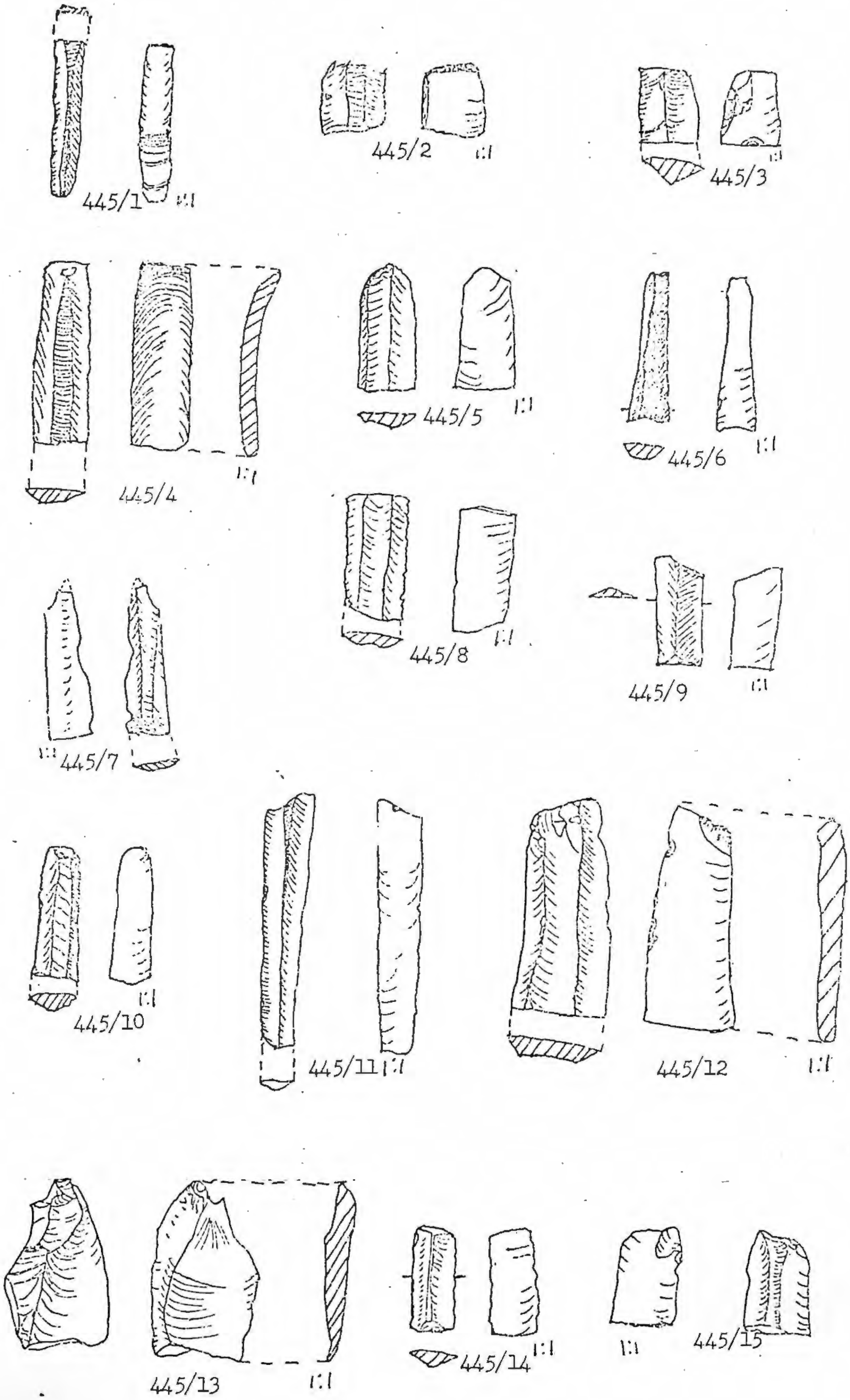
SAMPLE NUMBER	GROUP	CULTURAL CONTEXT	EXCAVATION LEVEL	ARTIFACT TYPE	COLOUR	TRANSPARENCY	COMMENTS
459/1	2b	CN	30	flake	blue/grey/black	0-5at edges	cloudy,gritty
459/2	1g	CN	30	bladelet	black	0	
459/3	2b	CN	30	chunk	black	0	
459/4	2b	CN	30	retouched	black	0	
459/5	2b	CN	30	bladelet	grey	5	cloudy,streaky
459/6	1g	CN	30	blade	grey/black	1-3	striations
459/7	G2	CN	30	bladelet	green	3-4	cloudy,gritty striations
459/8	2b	CN	30	bladelet	grey	5	cloudy,gritty
459/9	1g	CN	30	bladelet	black	0	
459/10	2b	CN	30	bladelet	grey	6	
459/11	1g	CN	30	bladelet	green w/brownish tinge	2-4	cloudy
459/12	2b	CN	30	bladelet	grey	5	

(continued)

SAMPLE NUMBER	GROUP	CULTURAL CONTEXT	EXCAVATION LEVEL	ARTIFACT TYPE	COLOUR	TRANSPARENCY	COMMENTS
466/1	1g	CN	72-32	bladelet	grey	5	
466/2	2b	CN	72-24	bladelet	grey w/brownish tinge	5	streaks
466/3	2b	CN	72-30	flake	grey	5	striations
466/4	G2	CN	72-32	bladelet	green	3	cloudy
466/5	1g	CN	72-32	bladelet	black	0	
466/6	1g	CN	72-36	bladelet	black	0	
466/7	1g	CN	72-36	bladelet	grey	2-3	dark streaks
466/8	2b	CN	72-40	blade	blue/grey/black	1	
466/9	G1	CN	72-40	flake	green	3	cloudy, speckled surface rough
466/10	2b	CN	72-40	flake	grey	2-3	
466/11	2b	CN	72-42	bladelet	grey	4	dark streaks, striations
466/12	1g	LA	72-53	bladelet	grey w/brownish tinge	5	dark streaks
466/13	1g	LA	72-53	flake	grey w/brownish tinge	5	dark streaks
466/14	1g	LA	72-58	bladelet	grey	1	dark streaks
466/15	1g	LA	72-68	flake	grey w/brownish tinge	1	

(continued)

SAMPLE NUMBER	GROUP	CULTURAL CONTEXT	EXCAVATION LEVEL	ARTIFACT TYPE	COLOUR	TRANSPARENCY	COMMENTS
468/1	2b	CN	72-26	bladelet	grey	0 and 6	dark and light streaks
468/2	2b	CN	72-28	bladelet	grey	6	
468/3	G2	CN	72-4	bladelet	grey w/greenish tinge	5	gritty
468/4	G3	CN	72-32	bladelet	green	1	
468/5	2b	CN	72-12	bladelet	grey	6	
468/6	G3	CN	72-14	retouched	green	0-1	
468/7	2b	CN	72-18	bladelet	blue/grey/black	2-3	cloudy, smokey
468/8	1g	CN	72-47	bladelet	grey	1 and 6	dark and light streaks
468/9	G2	CN	72-18	blade	green	3	striations
468/10	G2	CN	72-16	bladelet	green	3	gritty, striations
468/11	1g	CN	72-53	blade	grey	4-5	striations
468/12	2b	CN	72-20	bladelet	blue/grey/black	0-1	mottled
468/13	1g	CN	72-22	bladelet	grey	3-4	cloudy, smokey
468/14	1g	CN	72-22	bladelet	grey	5	cloudy
468/15	2b	CN	72-26	flake	blue/grey/black	0-3	mottled
468/16		LA	72-68	bladelet	black	0	
468/17	2b	EA	135	bladelet	grey	5	gritty
468/18	G1	EA	136	bladelet	grey	5	gritty
468/19	G1	EA	145	bladelet	grey w/greenish tinge	5	gritty, striations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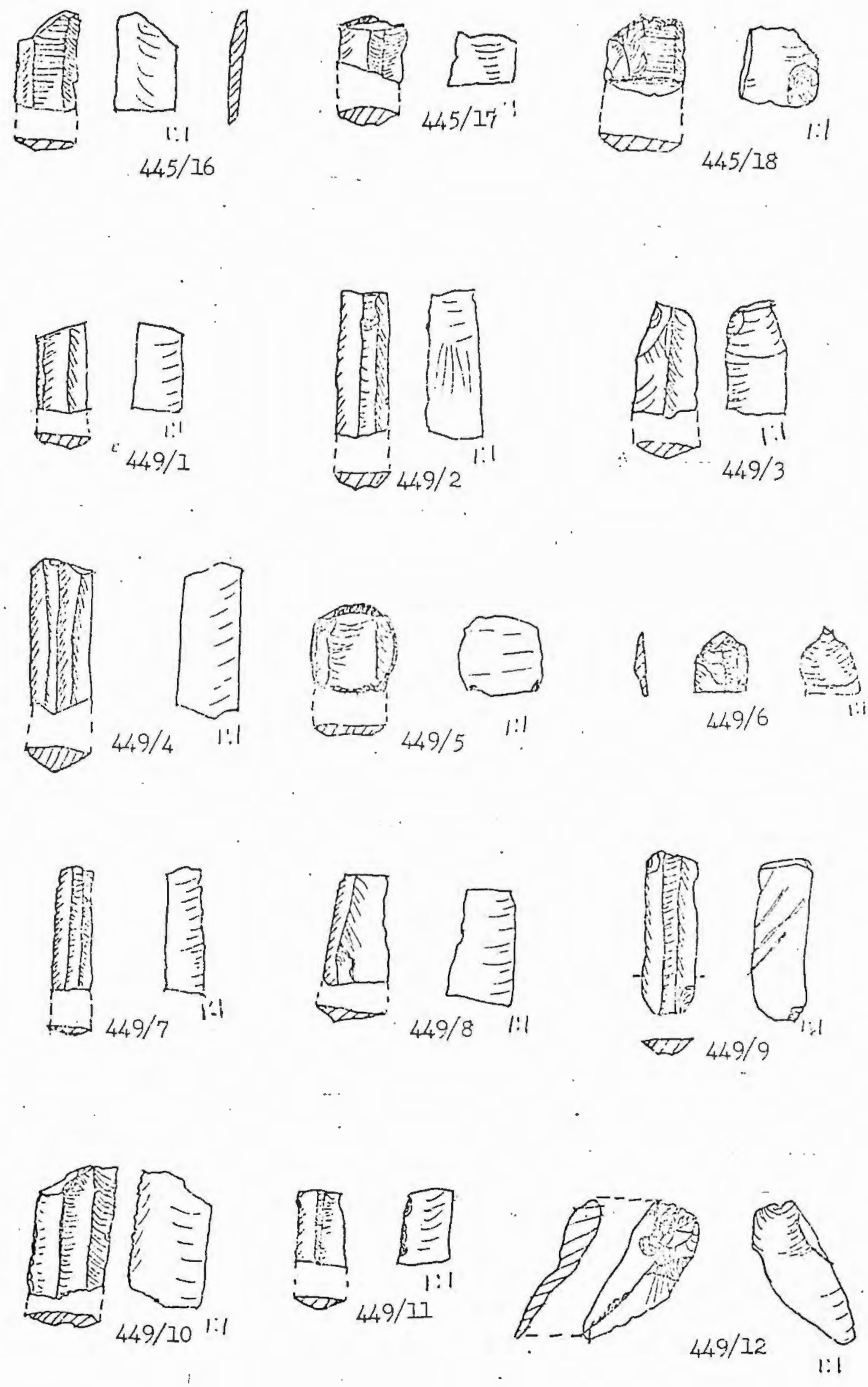
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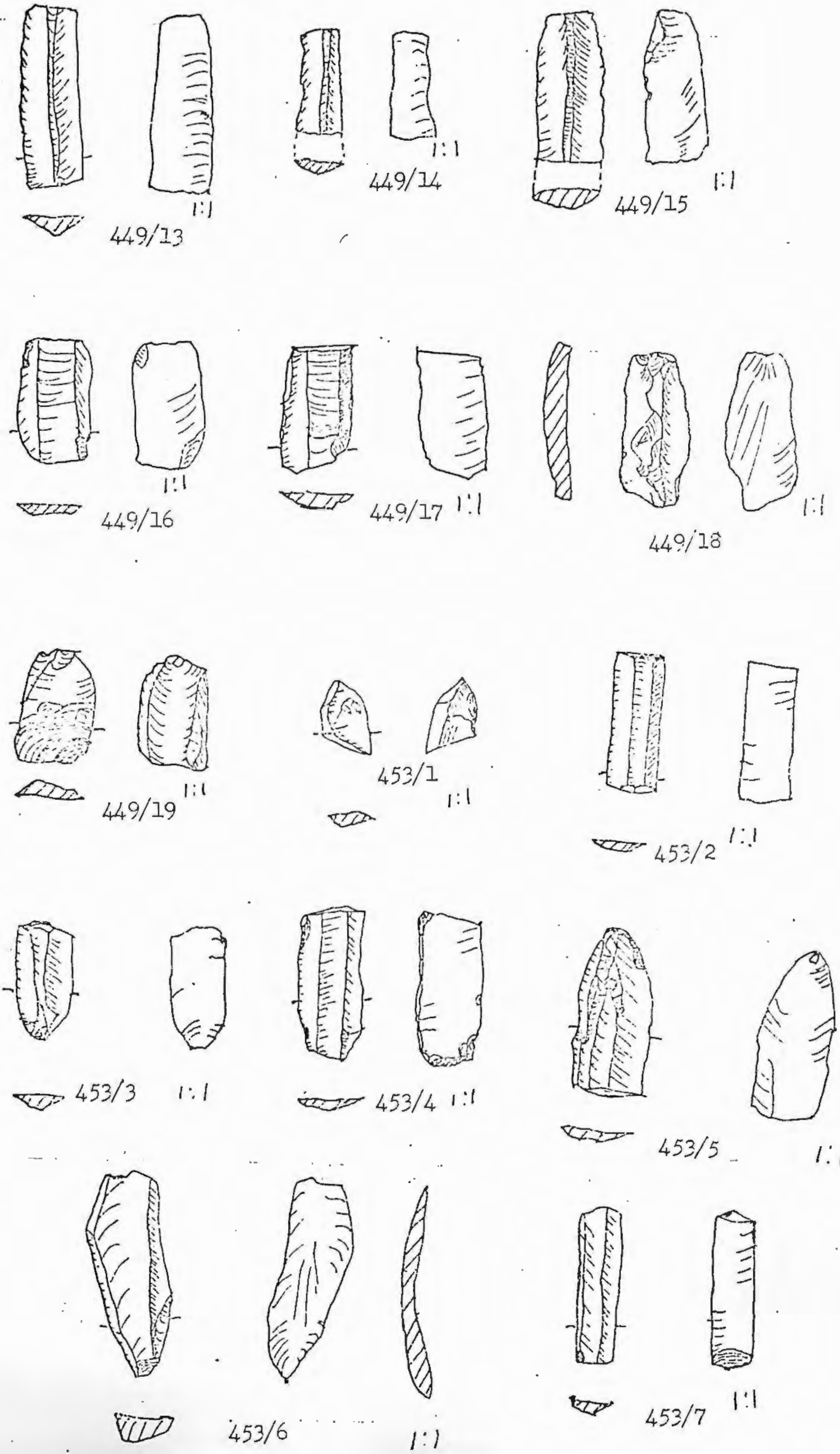
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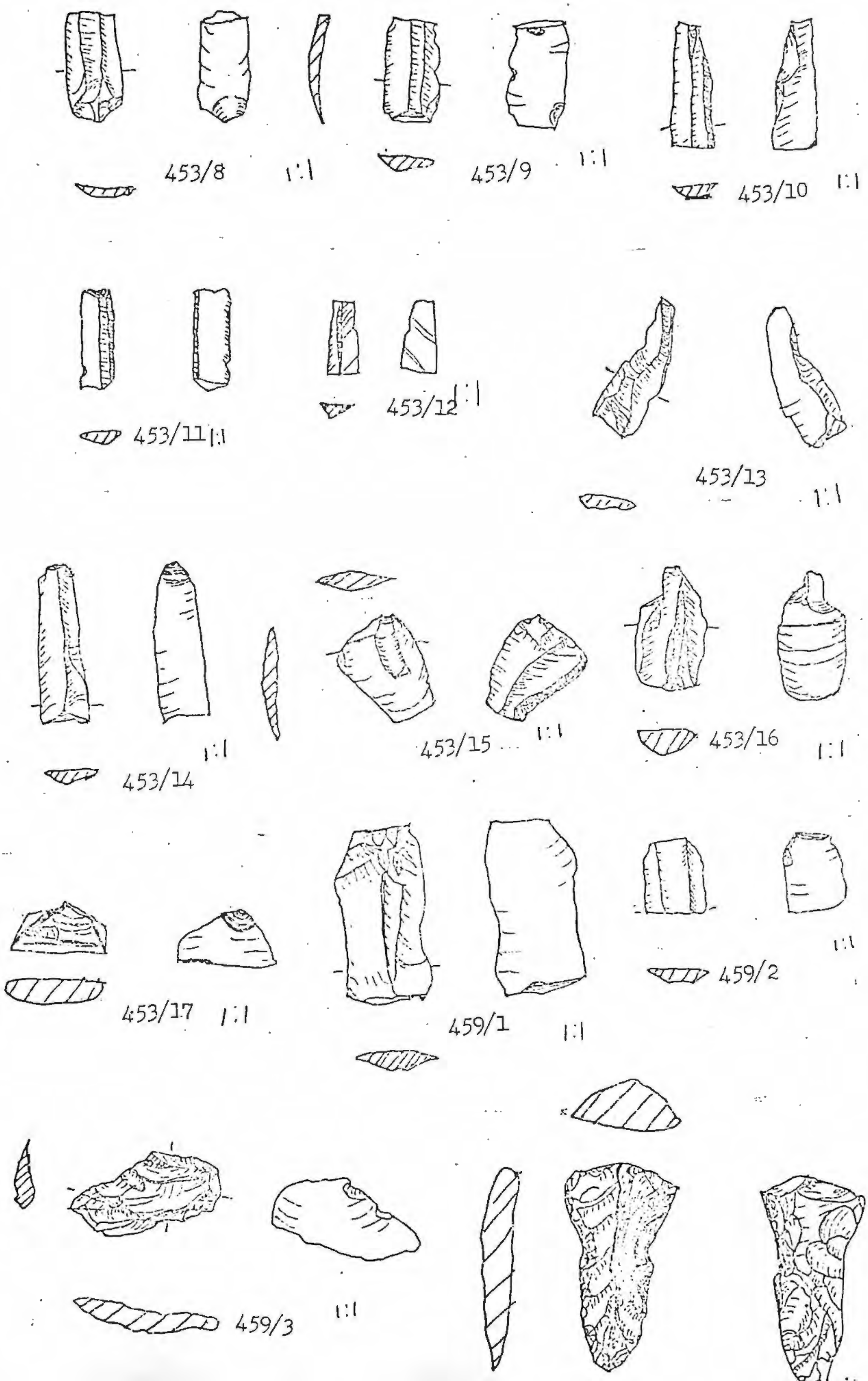
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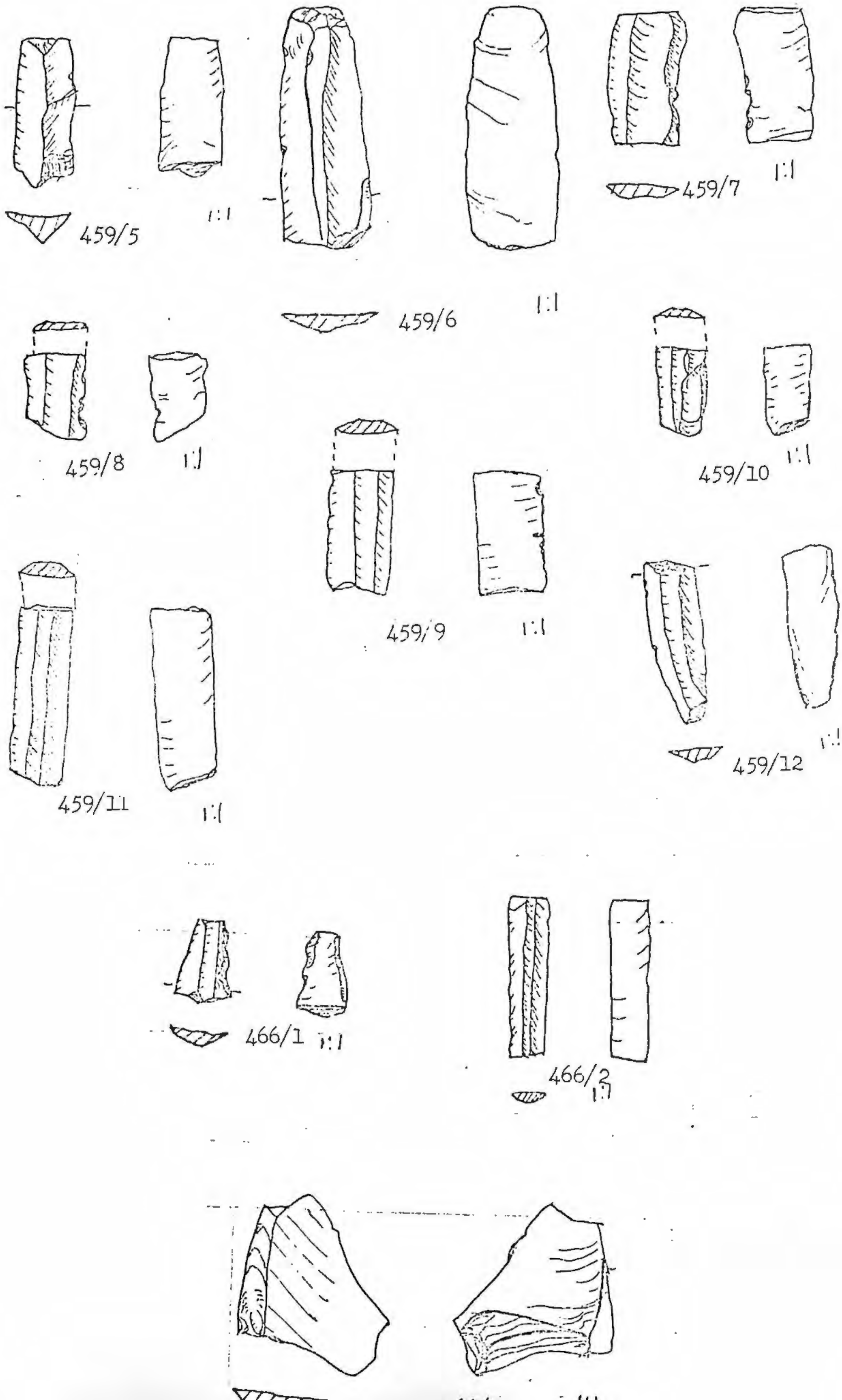
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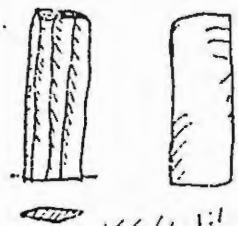
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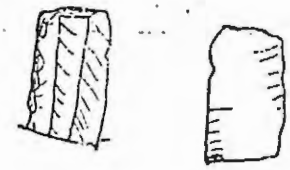
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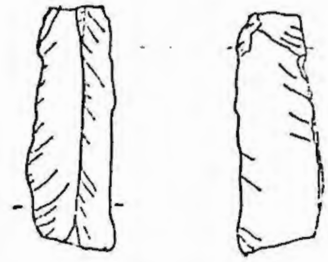
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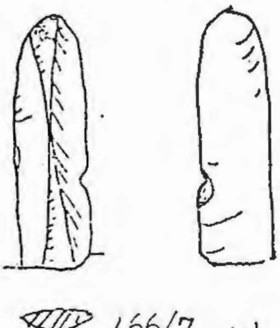
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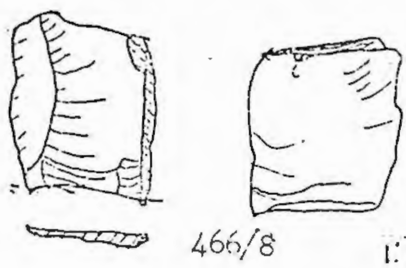
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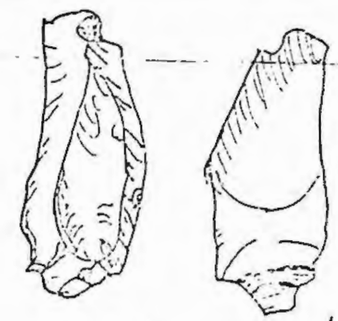
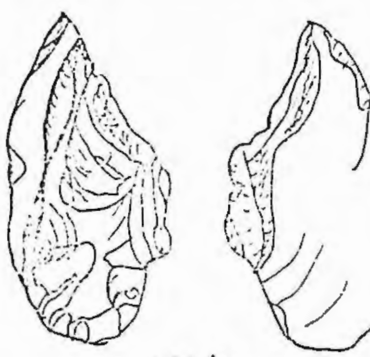

466/9 1:1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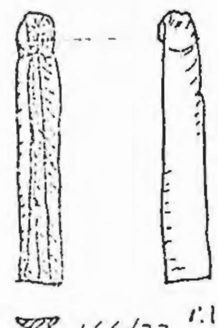
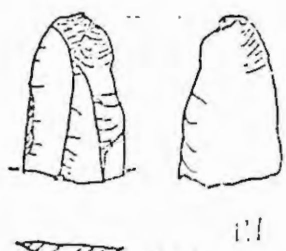

466/11 1:1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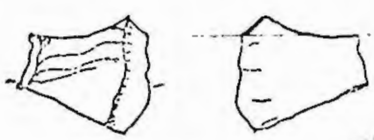
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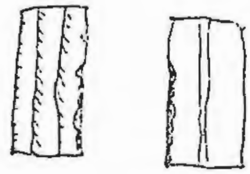
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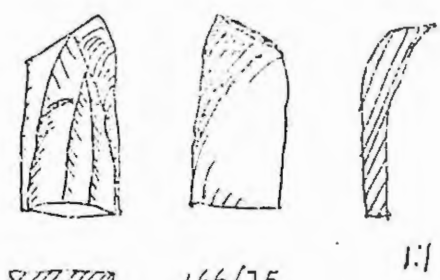
466/15 1:1


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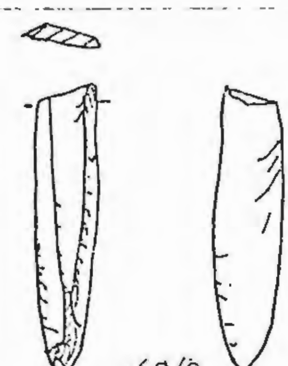
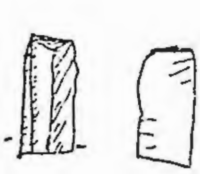

468/2 1:1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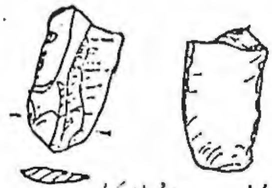
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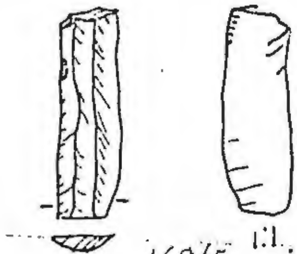
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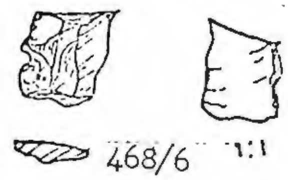
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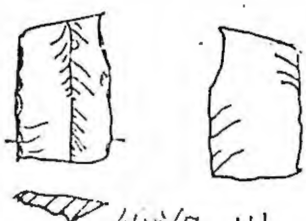
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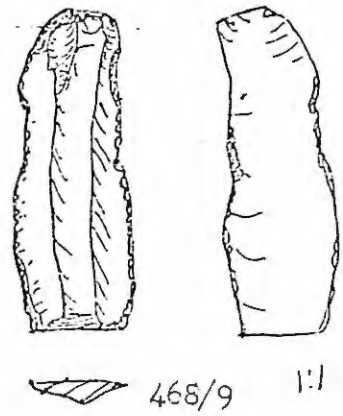
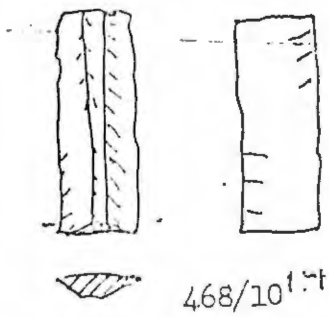
468/8 1:1


468/9 1:1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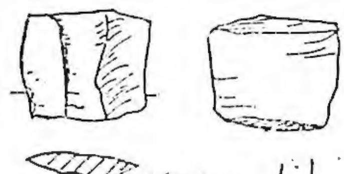
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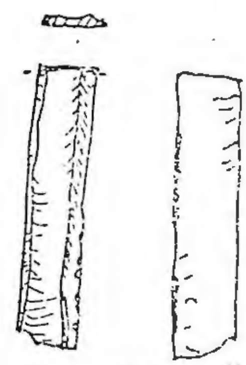
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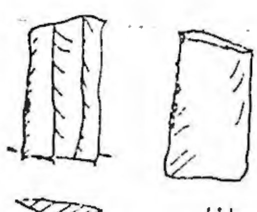
468/13 1:1


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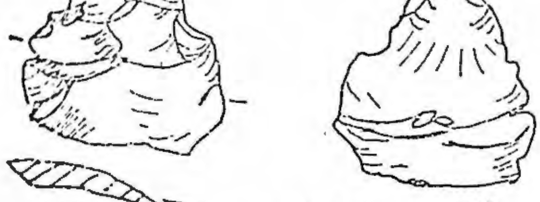
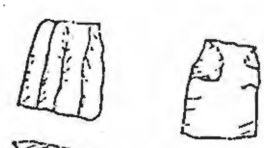
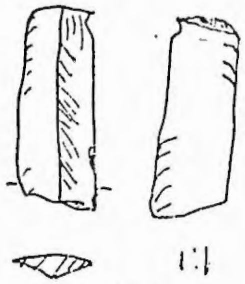

468/15 1:1


468/16 1:1



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CHAPTER 5

METHOD OF ANALYSIS

THEORY

Neutron activation involves the bombardment of atomic nuclei by neutrons normally of the thermal energies (about 0.025 eV). These thermal neutrons interact with the nuclei of the constituent atoms of the sample, transforming some of them into unstable radioactive isotopes which then decay back into stable forms with the emission of beta particles and gamma rays. As each isotope decays with a characteristic half-life, gamma rays of energies also characteristic of each constituent isotope are emitted. Identification of the gamma ray energies and a knowledge of the half-life identifies the presence of a particular isotope, while measurement of the intensity determines the approximate concentration of the isotope, and therefore of the elemental composition within the sample.

The resulting gamma activity of an isotope, C, after irradiating isotope B with thermal neutrons is given by:

$$A_C=N_B\sigma_B\phi(1-e^{-\lambda t})$$

where

A_C=the gamma activity of the isotope at the end of the irradiation period.

N_B=the number of atoms of isotope B present in the sample

σ_B=the cross section, or the probability that a thermal neutron will interact with the atomic nucleus of isotope B to produce the detected gamma radiation

ϕ=the thermal neutron flux in neutrons $cm^{-2}sec^{-1}$

λ=the disintegration constant of isotope C

t=the irradiation time

A_C is measured, N_B is unknown, σ_B is not well known for many isotopes, but generally quite small, of the order of $10^{-24}cm^2$, or one Barn. When σ is small and N is limited either by small sample size, or by low concentration, a high thermal flux is required. This means that a reactor giving a thermal neutron flux of the order of $10^{12}n\ cm^{-2}sec^{-1}$ must be used to ensure a measureable activity for each isotope in samples under 1 gram in mass. The Herald Reactor, Atomic Weapons Research Establishment, Aldermaston, Reading, was used to irradiate the samples in this analysis. Measurement of A, and a knowledge of irradiation conditions gives N, assuming a constant isotope ratio from sample to sample. t is accurately known, but λ may not be accurately known, and σ and ϕ are not accurately known. To overcome the uncertainty in the irradiation conditions, the Bradford laboratory uses a multi-element sub-standard, NPS-1, the composition being determined relative to that of the Perlman and Asaro Standard Pottery (1969). The composition of NPS-1 compared to Standard Pottery is given in Table 7 (Hunter 1975). A standard sample is included in each irradiation batch and is thus irradiated under the same conditions as the rest of the samples, reducing the uncertainties in σ and ϕ. Experiment has shown, however, that within a can of samples the thermal flux can vary by up to twenty-five per cent over the length of approximately seven centimetres. To correct for local variations in flux, approximately 5 mg of pure zinc was put with each sample and the standard. Zinc is suitable for

Table 7 CROSS ANALYSIS OF STANDARD NPS 1 WITH STANDARD POTTERY

Standard Pottery PPM		Short Lived Isotopes PPM						Long Lived Isotopes PPM										
		Na^{24}	K^{42}	La^{140}	Np^{239}	Sm^{153}	As^{76}	Sc^{46}	Fe^{59}	Co^{60}	Cs^{134}	Eu^{152}	Hf^{181}	Ce^{141}	Pa^{233}	Tb^{160}	Cr^{51}	Ta^{182}
		2610	14500	44.9	4.8	5.78	30.8	20.6	10170	14.1	8.31	1.42	6.2	80.3	13.96	1	115.1	1.55
NPS 1	PPM																	
Run No	Counter																	
354/80	Laben	1252.7	30346	42.0	ND	(7.24)	30.19	15.98	56500	15.25	10.50	1.50	5.65	78.55	10.09	0.72	217.1	0.87
354/81	Laben	1283.7	32463	41.93	1.43	6.83	26.16	17.05	61417	15.09	11.07	1.72	5.74	71.38	9.63	0.89	153.0	0.95
354/82	Laben	1269.2	32585	41.93	2.72	6.86	29.80	17.34	60593	15.43	10.86	1.72	5.43	82.06	11.33	0.96	154.6	0.89
357/80	Laben	1250.9	28717	40.93	4.88	6.34	28.20	15.16	57879	14.27	9.28	1.44	4.73	68.37	8.73	0.75	522	0.62
357/81	Laben	1260.1	30007	41.13	2.41	6.81	28.83	15.55	59176	15.08	9.05	1.55	6.33	68.38	10.26	0.72	279.8	1.06
357/82	Laben	1275.8	30065	41.11	ND	(7.22)	27.67	15.87	60338	15.42	9.34	1.30	6.20	64.57	9.58	0.82	340.0	0.70
363/80	Laben	1273.0	33042	42.12	2.20	7.03	25.53	18.99	63028	17.15	14.02	2.07	5.82	100.3	12.50	1.19	199.2	0.79
363/81	Laben	1315.8	34651	43.21	3.62	7.09	27.16	18.62	61519	17.51	12.59	2.30	6.57	90.76	11.77	1.21	175.6	0.92
363/82	Laben	1293.8	34296	42.89	6.37	6.85	26.17	19.15	63231	16.94	15.99	2.28	6.50	89.77	12.34	0.86	160.9	1.44
354/80	Hewlett-	1275.2	30020	42.20	2.24	6.91	31.16											
354/81	Packard	1256.4	30887	41.71	3.11	7.00	27.60											
354/82	"	1280.4	29912	42.16	2.99	6.84	30.71											
	Mean	1273.9	31417	41.94	3.20	6.86	28.27	17.08	60409	15.79	11.41	1.76	5.89	79.35	10.69	0.90	244.7	0.92
	σ	18.57	1919	0.68	1.45	0.21	1.88	1.54	2245	1.12	2.37	0.37	0.59	12.29	1.34	0.19	121.7	0.24
		Mean and σ does not include bracketed figures																

Rb was not analysed in this comparison. A value of 131 ppm in NPS 1 was taken from later cross-analyses and used in obsidian analyses presented here.

use as a flux monitor because it has a low cross-section and a long half-life of 245 days. Corrections were then made for variations in the flux.

EQUIPMENT

All of the measurement of A_C was done using a semi-conductor counting system with a germanium (lithium drifted) crystal and a multi-channel analyser. Two different systems were used. One was an Ortec system with a Hewlit-Packard 4096 channels Multi-Channel Analyser, while the other was a Canberra system linked either to the HP MCA, or to a Laben 1024 channel MCA. The spectrum data was output on punch tapes, which were processed using a Hewlit-Packard 2116B 16 K computer.

DATA PROCESSING

Program Absolute Spect developed at Bradford by S E Warren and J G Crummett was used to analyse the data. The program contains all the information about the standard NPS-1. Details of the program are given by Williams (1975). The data is reduced to the count rate per unit mass of the sample at the instant of removal from the reactor for each isotope. The count rate per unit mass for the corresponding isotope in the standard is determined. Assuming a constant isotope abundance from sample to sample, one can calculate the elemental composition as follows:

$$\% \text{ of element in sample} = \% \text{ of element in standard} \times \frac{\text{specific isotopic activity in sample}}{\text{specific isotopic activity in standard}}$$

The elements analysed, with the energy peak used for determining parts per million and the characteristic half-life are shown in Table 8 (De Bruin, et al nd).

TABLE 8

ANALYSED ISOTOPES, ENERGY, AND HALF-LIFE

ISOTOPE	ENERGY IN KeV	HALF-LIFE	ISOTOPE	ENERGY IN KeV	HALF-LIFE
^{24}Na	1368.5	15.00 H	^{46}Sc	889.2	83.90 D
^{42}K	1524.6	12.42 H	^{59}Fe	1099.2	45.00 D
^{140}La	1596.1	40.22 H	^{60}Co	1332.5	5.26 Y
^{175}Yb	396.4	4.21 D	^{86}Rb	1076.7	18.66 D
^{239}Np	228.1	2.38 D	^{134}Cs	795.8	2.05 Y
			^{141}Ce	145.4	32.53 D
			^{152}Eu	1408.0	12.00 Y
			^{160}Tb	879.4	72.10 D
			^{181}Hf	482.3	42.50 D
			^{182}Ta	1221.5	115.00 D
			^{233}Pa	311.9	27.00 D

The energy given is for the peak used to determine parts per million. The isotopes were identified during two separate counts. The isotopes with short half-lives were determined within a week of irradiation, while the others were determined approximately a month later. H=hours, D=days, Y=years.

CHAPTER 6

RESULTS

TABLE 9

RESULTS OF THE ANALYSIS

Table 9 gives the results of the analyses of sixteen elements by group expressed in parts per million, except where labelled per cent. They are presented in order of group. The group identification and assignment is discussed in Chapter 7.

TABLE 9 RESULTS OF THE ANALYSIS

SAMPLE NUMBER	GROUP	Na%	K%	Sc	Fe%	Co	Rb	Cs	La	Ce	Np U	Eu	Tb	Yb	Hf	Ta	Pa Th
445/1	1g	3.12	4.71	2.47	1.52	1.34	223	13.0	34.9	83.3	5.04	0.65	nd	3.61	8.74	1.50	29.5
445/4	1g	3.02	4.32	2.31	1.43	1.03	221	12.3	33.2	60.1	4.10	0.71	nd	3.85	8.17	1.40	27.1
445/6	1g	3.22	3.56	2.28	1.44	1.05	228	11.6	35.3	59.6	6.35	0.53	0.46	2.93	8.09	1.48	26.7
445/8	1g	3.82	5.71	2.67	1.67	1.41	249	13.8	43.3	70.5	7.78	0.65	0.72	3.99	9.32	1.76	31.1
445/9	1g	3.21	3.94	2.38	1.47	1.09	210	11.3	36.6	63.2	5.40	0.60	0.53	3.89	7.97	1.58	27.4
445/14	1g	3.24	5.60	2.35	1.46	1.51	240	13.7	36.3	72.3	7.18	0.52	0.49	3.04	7.82	1.51	27.8
449/3	1g	3.72	5.65	2.66	1.72	1.24	233	13.3	38.7	83.6	8.87	0.57	1.55	nd	9.66	1.49	31.3
449/5	1g	3.61	3.67	2.45	1.54	1.11	207	12.1	38.4	78.9	7.68	0.49	1.33	3.60	8.88	1.44	28.6
449/11	1g	3.75	nd	2.18	1.32	1.11	189	11.7	43.2	71.1	7.32	0.49	1.29	4.00	8.22	1.32	26.5
449/12	1g	3.73	4.82	2.33	1.44	1.25	201	12.0	38.0	80.5	7.03	0.53	1.30	4.44	8.92	1.51	28.5
449/13	1g	3.63	3.77	2.30	1.36	1.41	181	11.5	38.8	73.1	5.33	0.52	1.25	3.73	8.55	1.30	27.2
453/8	1g	4.13	5.83	2.82	1.75	1.44	264	14.1	43.3	89.0	2.44	0.71	1.47	3.70	10.8	1.71	31.6
459/2	1g	3.40	5.11	2.48	1.55	1.34	223	12.6	39.2	83.0	8.05	0.47	1.57	3.38	9.57	1.51	30.8
459/6	1g	3.47	4.43	2.46	1.53	1.27	226	11.4	39.0	83.6	8.44	0.57	1.54	3.75	9.47	1.55	30.1
459/9	1g	3.47	3.95	2.46	1.53	1.20	206	12.3	37.6	81.0	5.75	0.42	1.54	3.07	9.29	1.55	29.6
459/11	1g	3.40	4.10	2.51	1.54	1.39	223	12.5	39.4	81.4	8.55	0.42	1.41	2.86	9.43	1.49	30.6
466/1	1g	3.78	7.14	2.77	1.77	1.27	283	13.4	41.4	78.4	5.91	0.64	1.33	2.77	10.3	1.92	35.8
466/5	1g	3.44	4.55	2.75	1.69	1.44	271	12.8	37.0	75.7	3.96	0.49	1.43	2.83	9.30	1.88	34.2
466/6	1g	3.45	4.68	2.71	1.66	1.43	275	13.8	36.7	76.4	nd	0.61	1.31	5.80	9.81	1.99	34.5
466/7	1g	3.35	4.21	2.82	1.75	1.52	277	13.0	35.6	79.0	6.08	0.54	1.54	1.87	9.89	2.09	35.8

(continued)

SAMPLE NUMBER	GROUP	Na%	K%	Sc	Fe%	Co	Rb	Cs	La	Ce	Np / U	Eu	Tb	Yb	Hf	Ta	Pa / Th
466/12	1g	3.45	4.62	2.51	1.58	1.28	268	11.9	38.3	72.3	nd	0.59	1.25	3.12	9.25	1.45	32.7
466/13	1g	3.11	4.76	2.17	1.39	1.09	232	11.2	35.7	60.7	6.48	0.47	1.04	3.61	8.25	1.58	28.2
466/14	1g	3.56	nd	2.45	1.61	1.41	262	13.2	36.6	69.6	2.33	0.57	1.30	3.05	9.43	1.86	33.1
466/15	1g	3.41	4.68	2.76	1.76	1.30	301	13.1	36.9	80.4	nd	0.68	1.58	2.47	10.3	1.97	36.2
468/8	1g	3.75	4.60	2.85	1.95	1.37	299	16.6	38.9	91.1	5.38	0.67	2.17	2.26	9.92	2.09	43.3
468/11	1g	3.47	5.22	3.04	2.04	1.38	299	16.0	38.3	93.8	9.20	0.60	2.42	3.01	10.6	2.21	44.5
468/13	1g	3.77	4.62	2.52	1.62	1.06	246	14.0	39.8	83.2	5.40	0.38	2.39	4.27	8.44	1.83	36.2
468/14	1g	3.65	4.53	2.52	1.62	1.03	234	13.3	39.6	79.6	4.92	0.42	2.34	3.16	8.42	1.80	35.6
445/11	2b	2.78	4.19	1.91	0.63	0.46	191	10.1	22.9	46.8	5.62	0.28	0.16	2.22	2.91	2.24	22.2
449/18	2b	3.11	nd	1.84	0.60	0.13	165	8.48	24.0	40.8	5.80	0.13	1.00	3.04	3.52	1.93	21.6
453/5	2b	3.55	4.58	2.22	0.74	nd	212	10.4	26.1	56.0	1.76	0.17	1.07	nd	3.55	2.35	21.1
453/7	2b	3.53	4.92	2.17	0.75	nd	208	10.1	25.3	54.9	1.81	0.26	1.06	nd	4.25	2.48	25.4
453/12	2b	3.26	nd	2.10	0.69	nd	197	9.76	26.1	53.9	nd	0.20	1.07	2.58	3.99	2.21	23.5
459/1	2b	1.00	1.08	2.02	0.69	0.16	198	9.23	15.8	49.1	7.09	0.08	1.17	2.60	2.94	2.16	23.5
459/3	2b	2.81	nd	2.05	0.65	0.10	195	9.27	23.3	50.1	8.62	nd	1.20	2.46	3.62	2.15	24.2
459/4	2b	2.87	2.46	1.96	0.65	0.64	189	9.19	23.1	47.3	8.27	0.07	1.17	2.47	3.19	2.12	23.1
459/5	2b	2.87	2.65	2.01	0.65	0.70	187	9.10	23.4	49.2	2.95	n3	1.18	2.69	3.28	2.15	23.5
459/8	2b	0.94	1.18	1.96	0.68	nd	191	8.07	15.7	52.4	9.93	0.11	1.21	3.01	4.04	2.11	24.5
459/10	2b	2.96	6.16	1.99	0.69	0.10	202	9.30	24.8	49.3	6.91	nd	1.13	0.91	3.62	2.11	25.0
459/12	2b	2.98	3.79	1.98	0.66	nd	178	8.81	25.3	49.0	6.14	0.14	1.09	2.57	3.44	2.19	24.4

(continued)

SAMPLE NUMBER	GROUP	Na%	K%	Sc	Fe%	Co	Rb	Cs	La	Ce	Np U	Eu	Tb	Yb	Hf	Ta	Pa Th
466/2	2b	2.69	4.46	1.99	0.67	0.73	221	8.29	20.6	42.1	4.27	0.17	1.01	nd	3.09	2.29	25.4
466/3	2b	2.90	4.14	2.39	0.73	nd	273	11.0	20.8	47.0	10.5	nd	1.22	1.37	3.68	2.86	29.2
466/8	2b	3.12	5.01	2.38	0.78	nd	271	11.7	23.5	49.7	3.78	nd	1.19	nd	3.72	3.84	30.0
466/10	2b	2.95	4.42	2.19	0.70	0.10	243	9.76	22.1	45.6	nd	0.17	0.98	2.91	3.52	2.29	27.0
466/11	2b	3.47	4.74	2.63	1.03	nd	270	12.2	36.8	79.2	5.80	0.57	1.33	nd	6.11	1.87	34.1
468/1	2b	2.99	4.01	2.44	0.84	nd	255	12.3	21.5	55.1	6.76	0.10	1.86	1.66	4.06	2.96	34.5
468/2	2b	2.95	3.98	1.98	0.69	nd	215	9.08	24.3	44.8	4.61	0.20	1.53	0.86	3.12	2.36	28.6
468/5	2b	3.27	4.18	2.47	0.87	nd	251	11.2	27.7	59.1	nd	0.19	1.83	nd	3.43	2.68	36.2
468/7	2b	1.88	2.37	1.30	0.44	0.05	127	6.63	14.7	28.8	6.81	nd	0.84	1.27	1.20	1.51	17.6
468/12	2b	2.79	3.52	2.09	0.69	0.42	211	10.3	21.3	46.9	7.20	0.05	1.83	2.32	2.96	2.60	28.2
468/15	2b	3.18	3.76	2.04	0.70	nd	207	9.52	23.7	47.2	6.13	0.14	1.74	nd	2.93	2.49	27.8
468/17	2b	3.27	4.18	2.03	0.71	nd	255	9.68	24.7	48.5	nd	0.09	1.83	nd	2.84	2.42	29.1
445/2	G1	3.62	3.47	0.21	2.41	3.87	226	8.32	87.7	237	4.33	0.57	5.59	nd	29.9	4.14	26.8
445/3	G1	3.52	1.43	0.22	2.28	3.74	213	8.56	88.7	208	3.16	0.50	2.24	12.8	27.8	3.98	25.0
445/5	G1	3.53	3.43	0.22	2.32	3.69	210	8.56	90.7	215	4.95	0.49	4.86	13.0	28.4	3.83	25.4
445/7	G1	3.37	3.45	0.22	2.41	0.34	234	8.97	84.2	175	4.49	0.60	2.56	12.4	29.9	3.96	26.9
445/12	G1	3.62	3.67	0.20	2.21	0.17	197	9.19	91.5	205	7.33	0.57	2.11	13.0	27.4	3.66	23.9
445/13	G1	3.58	4.83	0.19	2.19	0.39	191	9.47	89.3	200	7.07	0.53	2.18	13.1	26.7	3.75	23.8
445/15	G1	3.54	1.77	0.21	2.21	3.27	206	9.35	85.5	202	2.77	0.54	2.07	12.5	27.7	3.67	24.4
445/16	G1	3.46	3.95	0.24	2.38	3.50	206	10.3	85.8	217	5.17	0.58	2.28	12.1	28.9	3.98	25.4

(continued)

SAMPLE NUMBER	GROUP	Na%	K%	Sc	Fe%	Co	Rb	Cs	La	Ce	Np U	Eu	Tb	Yb	Hf	Ta	Pa Th
445/17	G1	3.37	1.66	0.19	2.24	3.38	204	8.30	84.6	203	3.74	0.56	2.10	12.0	27.5	3.90	24.4
445/18	G1	3.48	nd	0.21	2.22	3.16	230	9.64	88.7	206	2.85	0.58	2.14	12.1	28.4	3.86	24.4
449/1	G1	4.01	nd	0.21	2.35	nd	212	9.00	103	231	6.30	0.45	3.06	14.1	31.4	3.67	27.1
449/2	G1	3.84	nd	0.23	2.37	0.12	197	9.27	92.1	232	7.68	0.68	3.49	14.2	31.8	3.84	27.2
449/4	G1	3.94	4.82	0.25	2.46	nd	211	9.38	93.2	246	5.47	0.60	3.13	13.5	33.3	4.08	27.7
449/6	G1	3.96	nd	0.21	2.25	0.11	197	8.45	92.0	217	10.0	0.46	2.89	13.2	30.1	3.61	25.4
449/7	G1	3.64	nd	0.16	1.81	nd	162	6.48	106	158	4.38	0.46	2.19	11.5	23.4	2.91	19.8
449/8	G1	3.83	4.72	0.21	2.33	nd	211	8.71	93.5	229	2.41	0.49	2.97	13.6	31.2	3.79	35.6
449/9	G1	4.24	3.37	0.20	2.17	0.09	184	8.30	104	199	8.44	0.55	2.72	14.7	28.5	3.53	24.1
449/10	G1	3.91	nd	0.20	2.07	nd	169	7.76	95.2	191	6.16	0.46	2.61	14.1	27.6	3.35	22.9
449/14	G1	3.64	nd	0.18	1.99	nd	165	7.04	127	186	11.3	0.43	2.45	12.9	25.8	3.14	21.7
449/15	G1	3.75	4.37	0.22	2.27	nd	206	8.65	91.8	218	5.29	0.52	2.85	12.4	30.3	3.62	25.9
449/16	G1	3.67	nd	0.21	2.31	nd	197	8.64	91.1	225	6.40	0.61	2.98	13.5	30.7	3.81	26.3
449/17	G1	3.85	4.24	0.20	2.33	nd	200	8.65	91.9	223	9.14	0.52	2.99	12.6	31.1	3.72	26.3
453/1	G1	4.23	4.40	0.23	2.67	nd	230	9.77	96.2	251	2.56	0.68	2.94	nd	35.5	4.26	27.3
453/2	G1	4.50	nd	0.23	2.78	nd	253	9.30	104	368	6.53	0.68	3.15	13.8	37.2	4.61	29.2
453/3	G1	4.38	4.93	0.23	2.75	nd	253	10.6	102	262	7.68	0.65	3.08	13.7	36.8	4.48	28.6
453/4	G1	4.42	5.30	0.25	2.82	nd	238	10.4	99.0	276	9.05	0.92	3.18	7.96	37.6	4.41	29.7
453/6	G1	4.41	4.97	0.26	2.75	nd	238	10.5	99.3	261	8.83	0.55	3.00	12.8	36.2	4.62	28.6
453/9	G1	4.43	4.38	0.24	2.78	0.20	238	10.6	103	369	9.25	0.73	3.13	10.3	37.3	4.41	29.1

(continued)

SAMPLE NUMBER	GROUP	Na%	K%	Sc	Fe%	Co	Rb	Cs	La	Ce	Np U	Eu	Tb	Yb	Hf	Ta	Pa Th
453/11	G1	4.33	4.32	0.25	2.66	nd	230	9.45	98.9	256	8.14	0.71	3.04	11.6	36.3	4.29	27.7
453/13	G1	3.96	nd	0.23	2.49	nd	206	9.65	95.5	229	5.72	0.63	2.72	11.5	33.1	4.31	25.0
453/14	G1	3.95	nd	0.24	2.69	nd	232	9.96	101	253	5.62	0.69	2.98	12.1	35.3	4.14	27.5
453/15	G1	3.95	5.40	0.26	2.61	0.90	230	9.67	97.7	247	7.89	0.72	2.94	nd	35.3	4.36	26.6
453/16	G1	4.26	4.62	0.25	2.75	nd	245	10.3	96.6	257	8.58	0.76	3.07	11.6	35.8	4.06	28.0
453/17	G1	4.24	4.01	0.23	2.69	nd	238	10.1	98.8	252	7.99	0.59	3.07	12.6	35.9	4.34	27.8
466/9	G1	3.66	3.92	0.20	2.47	nd	266	8.98	89.1	201	7.60	0.63	2.88	10.7	33.0	4.13	30.7
468/18	G1	4.09	3.62	0.22	2.63	nd	236	10.2	98.3	239	4.17	0.51	4.87	13.9	30.1	4.58	34.3
468/19	G1	3.51	3.97	0.22	2.57	nd	230	9.29	89.4	224	2.61	0.37	4.59	12.0	29.1	4.33	32.2
445/10	G2	4.25	5.86	0.18	3.57	0.27	234	18.0	98.3	227	10.6	0.80	2.67	13.9	29.6	3.98	31.8
449/19	G2	4.35	2.68	0.16	3.41	1.06	222	17.3	94.1	230	6.38	0.80	1.09	14.3	33.7	3.96	33.1
453/10	G2	4.68	5.04	0.20	3.98	nd	263	15.6	151	379	10.5	1.17	3.43	nd	35.6	3.85	33.5
459/7	G2	4.12	4.33	0.19	3.68	nd	219	14.2	148	349	10.7	0.88	3.54	11.6	33.7	3.72	34.4
466/4	G2	3.79	4.02	0.21	4.12	nd	313	18.1	88.3	227	6.49	0.81	3.66	11.0	35.6	4.68	40.4
468/3	G2	5.07	4.18	0.25	5.04	nd	324	24.1	108	280	13.6	0.99	6.50	nd	38.9	5.85	52.5
468/9	G2	3.98	nd	0.26	4.94	0.07	313	23.9	91.3	275	15.3	0.91	6.33	13.0	37.8	5.69	50.9
468/10	G2	6.78	5.86	0.30	6.18	nd	425	30.0	142	340	8.57	1.20	7.61	17.0	48.2	7.25	64.8
468/4	G3	3.72	2.94	0.26	4.22	nd	288	20.5	81.9	234	6.92	0.81	5.29	11.2	32.8	5.09	41.3
468/6	G3	3.43	4.19	0.22	3.38	nd	223	16.4	78.7	194	6.45	0.68	4.23	11.0	26.9	3.86	36.3

CHAPTER 7

TREATMENT OF THE RESULTS

The results shown in Table 8 were divided into five obsidian groups, representing at least five obsidian sources. These groups were determined by taking certain elements determined to be characteristic of Aegean obsidians, relative to scandium (Aspinall 1972). The following formula was applied:

$$\left(Cs + Ta + \frac{Rb}{100} + \frac{Pa + La + Ce}{10}\right)/Sc$$

The number obtained was then plotted against Fe%/Sc. When this formula was applied to the results, five obsidian groups were found. The grey and green obsidians show vastly different results, while the primary difference within the green and grey groups is the figure determined by the Fe%/Sc ratio. The plot of the log of the determined coordinates is shown in Figure 6, and Table 10 gives the coordinates for each sample. The log of the coordinates is plotted because the differences between the grey and the green obsidians is so great.

The obsidian groups and sources were identified by comparison with analyses of geological obsidian done at the Bradford laboratory by Aspinall and Pearson. Aspinall has analysed geological obsidian from the central Anatolian sources, while Pearson has analysed geological obsidian from the eastern Anatolian sources. Three of the groups were definitely identified by this comparison: group 2b from Çiftlik, group G2 from Bingöl, and group 1g from somewhere in eastern Anatolia. Group G1 is thought to be from the

TABLE 10

COORDINATES USED FOR OBSIDIAN GROUP IDENTIFICATION

RUN NO.	GROUP	$(Cs+Ta+\frac{Rb}{100}+\frac{Pa+La+Ce}{10})/Sc$	Fe%/Sc
445/11	2b	12.3	0.33
449/18	2b	11.3	0.33
453/5	2b	11.4	0.33
453/7	2b	11.6	0.35
453/12	2b	11.6	0.33
459/1	2b	11.0	0.34
459/3	2b	11.3	0.32
459/4	2b	11.6	0.33
459/5	2b	11.3	0.32
459/8	2b	10.9	0.35
459/10	2b	11.7	0.35
459/12	2b	11.4	0.33
466/2	2b	10.9	0.34
466/3	2b	11.0	0.31
466/8	2b	11.6	0.33
466/10	2b	10.9	0.32
466/11	2b	12.1	0.39
468/1	2b	11.9	0.34
468/2	2b	11.8	0.35
468/5	2b	11.6	0.35
468/7	2b	11.9	0.34
468/12	2b	11.8	0.33
468/15	2b	11.7	0.34
468/17	2b	12.3	0.35

(continued)

RUN NO.	GROUP	$(Cs+Ta+\frac{Rb}{100}+\frac{Pa+La+Ce}{10})/Sc$	Fe%/Sc
445/1	1g	12.8	0.62
445/4	1g	12.1	0.62
445/6	1g	12.1	0.63
445/8	1g	12.2	0.63
445/9	1g	11.6	0.62
445/14	1g	13.3	0.62
449/3	1g	12.2	0.65
449/5	1g	12.3	0.63
449/11	1g	13.3	0.61
449/12	1g	13.0	0.62
449/13	1g	12.4	0.60
453/8	1g	12.4	0.62
459/2	1g	12.8	0.63
459/6	1g	12.4	0.62
459/9	1g	12.5	0.62
459/11	1g	12.5	0.61
466/1	1g	12.2	0.64
466/5	1g	11.7	0.62
466/7	1g	11.7	0.62
466/6	1g	12.3	0.61
466/12	1g	12.1	0.63
466/13	1g	12.7	0.64
466/14	1g	12.9	0.66
466/15	1g	12.1	0.64
468/8	1g	13.7	0.68
468/11	1g	12.8	0.67
468/14	1g	13.1	0.64
468/13	1g	13.6	0.64

(Table 10 continued)

RUN NO.	GROUP	$(Cs+Ta+\frac{Rb}{100}+\frac{Ba+La+Ce}{10})/Sc$	Fe%/Sc
445/2	G1	239	11.5
445/3	G1	213	10.4
445/5	G1	216	10.6
445/7	G1	200	11.0
445/12	G1	234	11.1
445/13	G1	244	11.5
445/15	G1	220	10.5
445/16	G1	205	9.9
445/17	G1	239	11.8
445/18	G1	227	10.6
449/1	G1	242	11.2
449/2	G1	218	10.3
449/4	G1	209	9.8
449/6	G1	226	10.7
449/7	G1	248	11.3
449/8	G1	235	11.1
449/9	G1	232	10.9
449/10	G1	219	10.4
449/14	G1	252	11.1
449/15	G1	218	10.3
449/16	G1	232	11.0
449/17	G1	243	11.7
453/1	G1	234	11.6
453/2	G1	246	12.1
453/3	G1	247	11.9
453/4	G1	231	11.3
453/6	G1	217	10.6
453/9	G1	240	11.6
453/11	G1	217	10.6

(Table 10 continued)

RUN NO.	GROUP	$(Cs+Ta+\frac{Rb}{100}+\frac{Pa+La+Ce}{10})/Sc$	Fe%/Sc
453/13	G1	222	10.8
453/14	G1	227	11.2
453/15	G1	206	10.1
453/16	G1	220	11.0
453/17	G1	238	11.7
466/9	G1	239	12.4
468/18	G1	247	12.0
468/19	G1	230	11.7
445/10	G2	334	19.8
449/19	G2	370	21.3
453/10	G2	392	19.9
459/7	G2	386	19.4
466/4	G2	293	19.6
468/3	G2	309	20.2
468/9	G2	286	19.0
468/10	G2	231	20.6
253/5	G2	356	20.6
468/4	G3	290	16.2
468/6	G3	243	15.4

(Table 10)

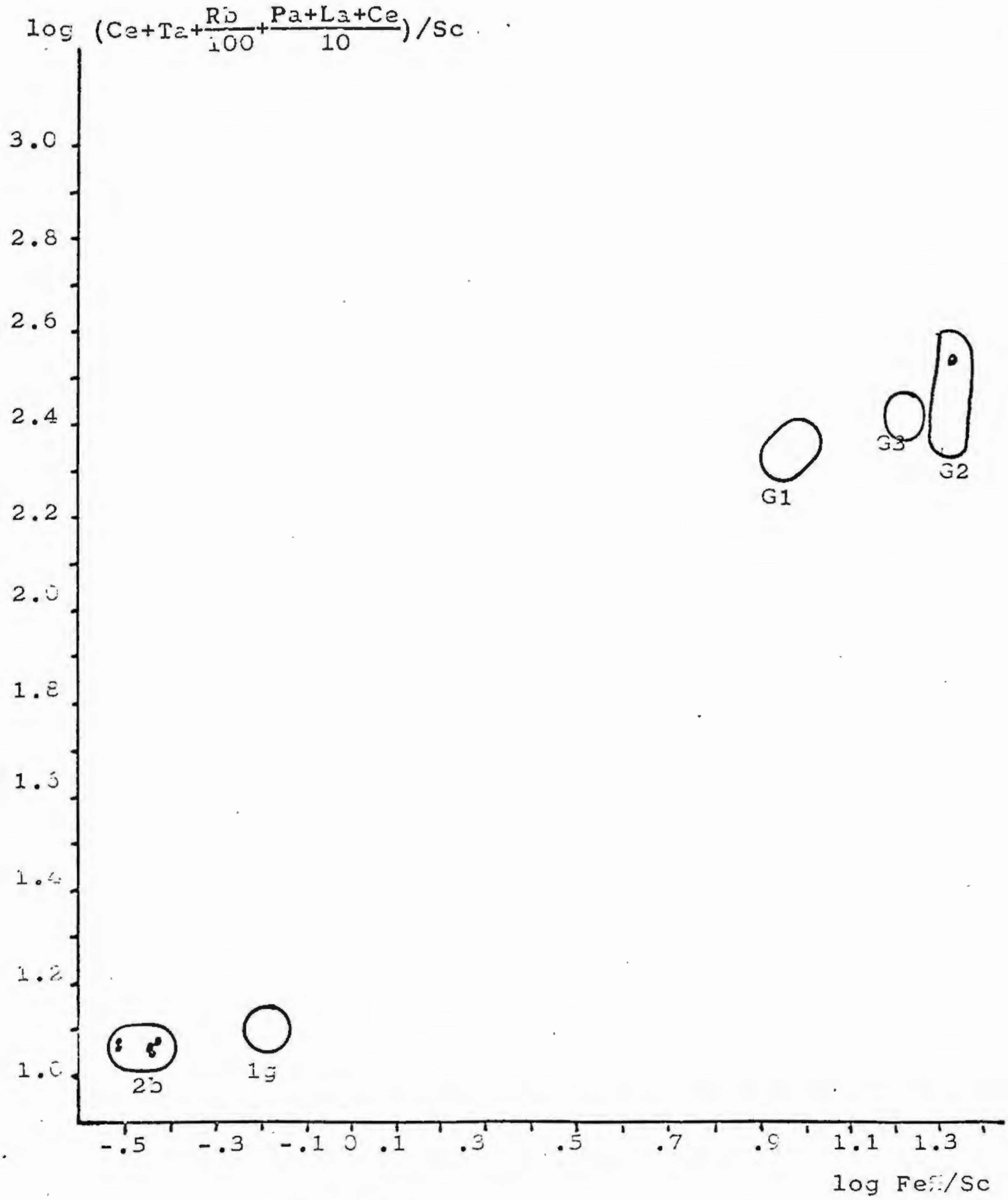


FIGURE 6

ABU HUREYRA OBSIDIAN GROUPS

There are 24 members of group 2b, 23 members of group 1g, 37 members of group G1, 8 members of group G2, and 2 members of group G3. Most of the points are too tightly clustered to show the plot of each point. The points marked are geological samples analysed by Aspinall and Pearson in the Bradford laboratory.

Nemrut Dağ, Lake Van source, the major source of group 4c obsidian, because the Cs content is half that for the Bingöl obsidian. The analytical method used by Renfrew, et al (1968) was not sensitive to Cs, but the only difference they were able to determine between group 4c from Nemrut Dağ and group 4c from Bingöl was the presence of Cs in the Bingöl sample. It has not been possible to compare group G3 with any geological material. It may be from one of the other flows on the Nemrut Dağ (Wright 1969), but it cannot be definitely identified at this time. The source is thought to be located in eastern Anatolia, however, because it is peralkaline obsidian, and no source of peralkaline obsidian is known in the Near East outside of eastern Anatolia.

When the groups are separated into cultural phases, changes in he exploitation of the different sources seem to have taken place, as shown in Table 11.

TABLE 11

OBSIDIAN GROUPS BY CULTURAL PHASE

PHASE	2b	1g	G1	G2	G3	TOTAL
EA	5	1	18	1	0	25
LA	1	14	17	2	0	34
CN	18	13	2	5	2	40

COMMENT ON SAMPLING

There is a major problem in trying to decide how many samples to take for analysis when there is no data available on the number of sources being exploited. There is a possibility that at least nine sources could have been exploited, with a partial visual discrimination on the basis of the grey or green colour of the obsidian. A limited number of analyses can be made. Originally, S E Warren suggested that 20-25% of the total population would be a suitable amount, but practical limitations led to a selection of 100 samples, or about 10% of the total for the purposes of this study. In this study, the division of the groups in each of the three cultural phases was as important as the division of the obsidian into the different groups.

The problem is one essentially of multinomial sampling, but with a diminishing population because of a small total sample size with an unknown distribution among sources. There is no readily available statistical treatment for this particular case, therefore it was considered better to approach it using the computer to sample from a restricted population subdivided into the groups determined by analysis. The total population equals the number of pieces found within a phase. The size of the sample, or draw, is the number of samples analysed for each phase. Both the population and the draw can be randomized before the computer selection. The draw is repeated 100 times to give the variation in proportions of the groups. This can be expressed in terms of the mean number of samples belonging to each group and the standard deviation. The mean over a large sample should correspond to the number determined by the analysis. Tables 12a and 12b show the distribution of the selected samples for the Later Aceramic and the Ceramic Neolithic, divided into five groups as determined by the analysis.

TABLE 12a

COMPUTER SELECTION OF GROUPS FROM THE LATER ACERAMIC

GROUP	EXPECTED VALUE	MEAN OF THE DISTRIBUTION	S.D. OF THE MEAN	S.D. OF AN INDIVIDUAL SAMPLE
2b	1	1.09	.10	1.03
1g	14	13.75	.29	2.89
G1	17	17.09	.31	3.13
G2	22	2.07	.14	1.41
G3	not present			

Samples were selected from a total population of 327, with a sample size of 34.

TABLE 12b

COMPUTER SELECTION OF GROUPS FROM THE CERAMIC NEOLITHIC

GROUP	EXPECTED VALUE	MEAN OF THE DISTRIBUTION	S.D. OF THE MEAN	S.D. OF AN INDIVIDUAL SAMPLE
2b	18	18.34	.31	3.08
1g	13	12.73	.28	2.75
G1	2	2.02	.13	1.26
G2	5	4.89	.18	1.79
G3	2	2.02	.14	1.44

Samples were selected from a total population of 837, with a sample size of 40.

Since only one sample draw is used in practice, the standard deviation of an individual sample is regarded as a more meaningful quantity than the standard deviation of the mean. Thus with a mean of 18.34 and an effective standard deviation of 3.08, 95% of the draws can be expected to give the number of samples belonging to group 2b in the Ceramic Neolithic as a number between 12 and 24. Thus, the proportions of the larger groups are reasonably confident, but when considering the smaller groups, a variation between 0 and 6 can be reasonably expected. Group G3 is present only in the Ceramic Neolithic, but it could also be present in the aceramic phases, since with a group size of 2, the standard deviation on a single sample is approximately 1.5. The group then has a reasonable probability of not being represented in the sample draw because 0 is only 1.3 standard deviations away from the expected mean. This would occur in about 15% of the draws from the total population, therefore it is not significant that group G3 is not represented in the aceramic phase.

Expressing the data of Tables 12a and 12b in terms of the standard error (Table 13) and plotting against the number of obsidians for a group as shown in Figure 7, one can estimate the likely error in group size due to sampling error. For example, with 95% confidence limits and an observed group size of 10, the group size might vary between 5 and 15.

Histograms of the draws for groups 2b, 1g, G1, and G2 for the Later Aceramic and Ceramic Neolithic phases are shown in Figure 8. There is a significant difference in the exploitation of group 2b and group G1 in the two phases. There is a significant difference in the exploitation of groups 1g and G2.

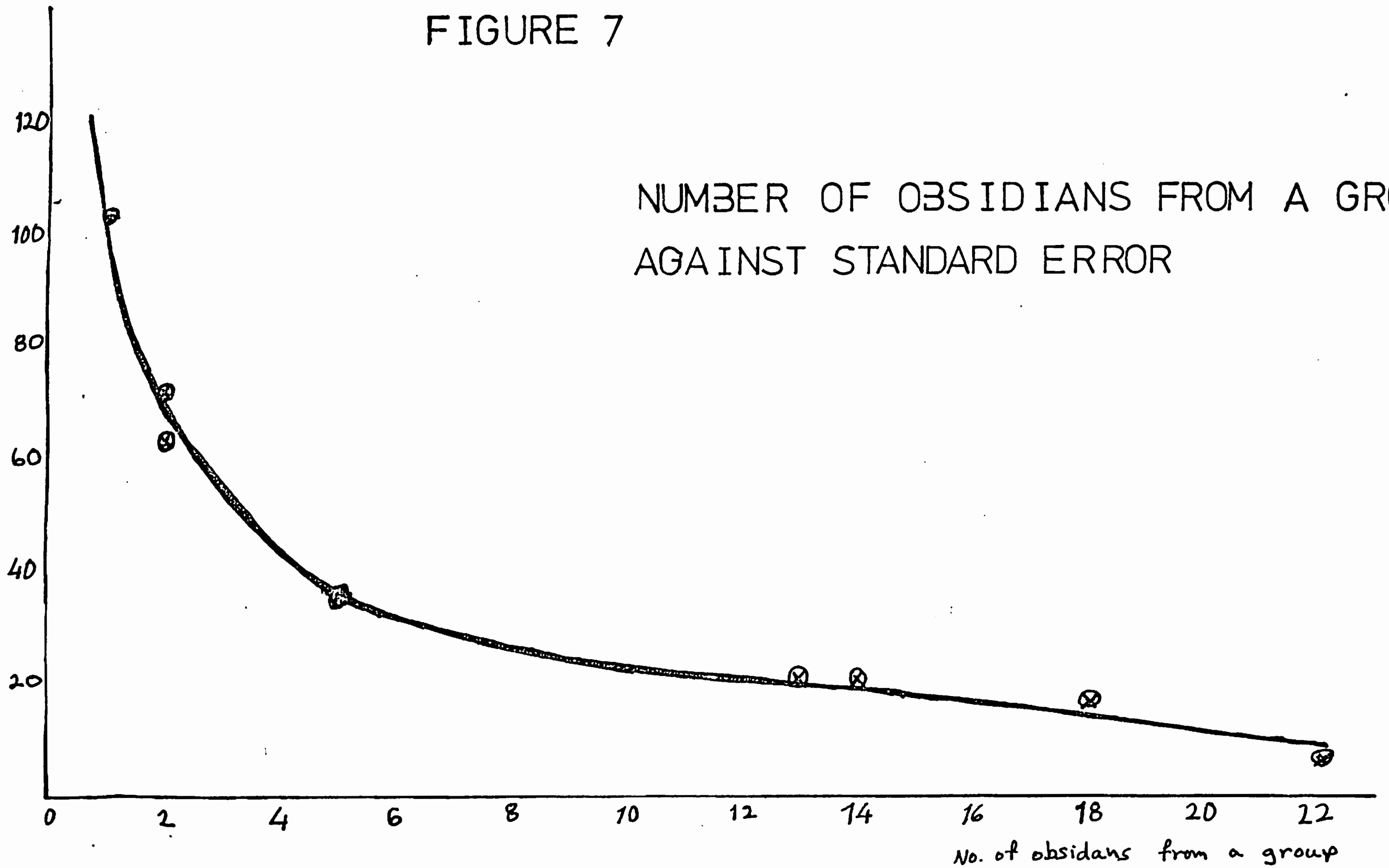
Sampling from the Earlier Aceramic phase resulted in an almost total population sample of 25 out of 27 pieces of obsidian. Therefore, one is forced to assume that the proportions of the groups present in this phase is as determined by the analysis.

TABLE 13

DATA OF TABLES 12a AND 12b
EXPRESSED IN TERMS OF STANDARD ERROR

EXPECTED VALUE	STANDARD ERROR
1	103%
2	63%
2	72%
5	36%
13	21%
14	21%
17	18%
18	17%
22	6%

FIGURE 7


NUMBER OF OBSIDIANS FROM A GROUP AGAINST STANDARD ERROR
120
100
80
60
40
20
0
2
4
6
8
10
12
14
16
18
20
22
No. of obsidans from a group

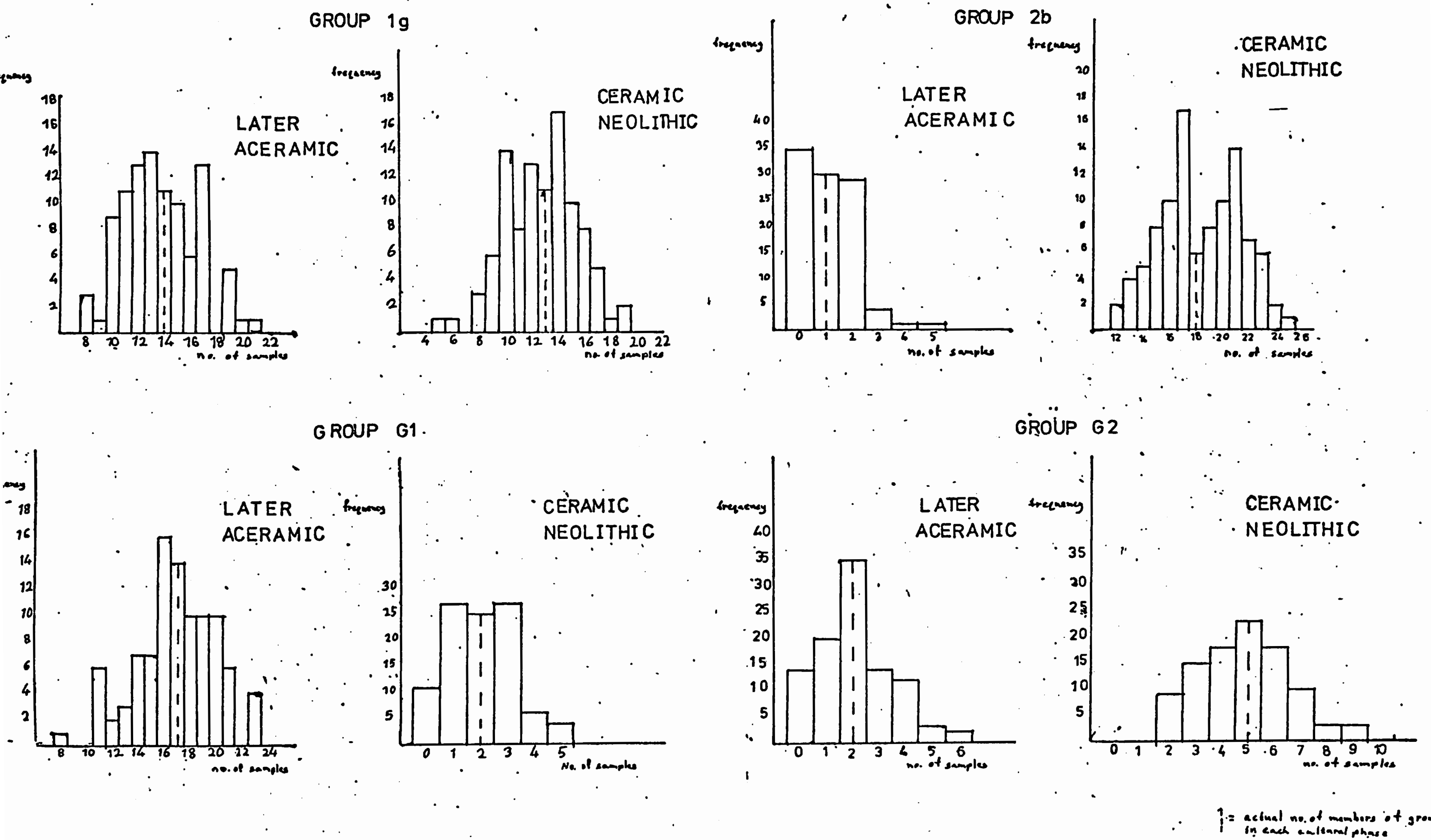


FIGURE 8

HISTOGRAMS OF RANDOM COMPUTER DRAWS

The changes in the exploitation of different sources through time as shown in Table 14 as percentages of the total in each phase, seem to be significant when examined by this method of computer randomization and selection. Group 2b was exploited in the Earlier Aceramic, the use dropped in the Later Aceramic, when it was again exploited in the Ceramic Neolithic. Group 1g was not significantly exploited in the Earlier Aceramic, but was consistently exploited during the succeeding two phases. Group G1 was consistently exploited during the aceramic phases, but use dropped off significantly during the Ceramic Neolithic. Groups G2 and G3 do not vary significantly throughout the occupation of the site.

TABLE 14

PERCENTAGE OF OBSIDIAN GROUPS IN EACH CULTURAL PHASE

PHASE	2b%	1g%	G1%	G2%	G3%
EA	20	4	72	4	0
LA	3	41	50	6	0
CN	45	32.5	5	12.5	5

CHAPTER 8

DISCUSSION

The question of prehistoric trade mechanisms or systems of exchange has long been of concern to prehistorians. Mixed with the purely economic questions are also questions of culture contact, exchange of ideas, culture change, and the possibilities of independant invention. Source identification of objects suitable for trade such as obsidian and other exotic materials such as turquoise, cowrie shells, bitumen, etc., establish that some form of contact has taken place. Merely establishing the fact of contact is an important first step, and is a primary goal of the analysis discussed in this dissertation, but the results of physical analysis must be followed by considerations of the mechanics and meanings of the systems of exchange. If this is not done, then the investigations are pointless. Questions to be considered are : Are there any social or ritual implications in the exchange mechanism? Is the relation completely economic because of a system of supply and demand? What combinations of social and economic importance are possible for a particular commodity? Obsidian in particular is a commodity which should be examined with these questions in mind. Admittedly, sites at some distance from the source of the material are much more likely to use alternate raw materials, but in some cases there does not seem to be any economic significance to the presence of obsidian at all. Why are there only three pieces of obsidian present at the site of Beidha? It could not have had much significance to the economy. It is possible that there could be some sampling bias, but it seems highly unlikely that all of the obsidian should be missed. The argument that the recovery methods could be faulty may or may not be valid, but other sites excavated with similar recovery techniques have yielded more obsidian.

At Abu Hureyra the obsidian is usually in the form of small straight-sided unretouched bladelets. Some of the flint is present in the same form. What were the incentives for going to a certain amount of trouble to obtain obsidian when it was possible to use local flint for the same purpose. It could simply be that the edge on the obsidian was enough sharper for its particular use to justify the added effort in obtaining it, it could also be that there were social implications in the trade with Anatolia, especially when the Anatolian source for other exotic materials found at the site is taken into consideration. The first step in answering such questions is to establish the actual sources and the degree of utilization

The results of the neutron activation analysis performed on the Abu Hureyra obsidian show that the people of Abu Hureyra were using obsidian from at least five different obsidian groups found at sources located in two different geographical regions, and there were changes in the exploitation of these sources through time.

Preliminary analyses performed by Renfrew, et al, (1966; 1968) showed that Levantine sites during the time Abu Hureyra was occupied were receiving most of their obsidian fom the central Anatolian source of Çiftlik, though a small amount was coming from the peralkaline eastern Anatolian sources. Group 1g was not found in the Levant during this time. At

Ramad the obsidian exploitation was about 90% central Anatolian obsidian, and 10% eastern Anatolian obsidian (Renfrew, et al 1966). Abu Hureyra has the closest archaeological association with the sites to the west in the Levant, but about 75% of the obsidian analysed is from eastern Anatolia.

The direction of the movement of eastern Anatolian obsidian into the Levant is not yet fully understood. Renfrew, et al (1968) postulate that contact between the Levant and the Zagros occurred indirectly by means of nomadic group travelling through the desert. They suggest that the site of Bouqras on the Euphrates intermediate between the Levant and the Zagros may have been the contact and exchange centre. Analysis of obsidian from Bouqras did not allow confirmation of the hypothesis, however, because all of the obsidian analysed came from eastern Anatolian sources, despite selection for obsidian that might have come from central Anatolia on the basis of appearance. Only six pieces of obsidian from Bouqras were analysed, however, so it is possible that further analysis might alter this picture. The current lack of any obsidian from central Anatolia does suggest that the movement of eastern Anatolian obsidian into the Levant is a result of the movements of nomads in the desert regions who had no reason to move into the Anatolian plateau, rather than of the farmers of the Levant responsible for the movement of central Anatolian obsidian in the region (Renfrew, et al 1968). The location of Bouqras at the junction of the Khabur river with Euphrates could perhaps explain the utilization of eastern Anatolian sources, since the Khabur provides a fairly direct link into eastern Anatolia, thus facilitating the movement of goods.

The movement of group 2b into the Levant was probably through the Cilician Gates into Syria-Cilicia, and then traded by land or sea routes along the coast. The significant increase in the use of group 2b obsidian during the Ceramic Neolithic could be related to the change in the direction of influence noted in the archaeological assemblage. Contact with peoples living on the Plain of Antioch could have provided a more direct link with Çiftlik obsidian source.

The results of the analysis of the Abu Hureyra obsidian tend to confirm a pattern of exploitation observed in the Zagros Group 1g does not seem to have been utilized extensively during the eight millenium BC. Seven pieces of obsidian from the site of Ali Kosh on the Deh Luran Plain were analysed by Renfrew, et al (1966), and two eastern Anatolian groups were identified, 4c and 1g. Renfrew (1969a) examined the rest of the obsidian from Ali Kosh visually. In his analyses Renfrew has found that most green obsidian is peralkaline, while grey obsidian is not, but there are some exceptions to this generalization, so a separation on the basis of colour alone is not sufficient. However, as a preliminary indicator of groups, colour is an important clue. Since there were only two groups represented at Ali Kosh, this was a good clue. In the earliest aceramic phase, the Bus Mordeh phase, (c.7500-6700 BC: Hole, et al 1969), there is no grey obsidian present at all. This means that the source of group 1g was not significantly utilized during that phase at Ali Kosh. This group also is not important at Abu Hureyra during the Earlier Aceramic. Only one piece of Earlier Aceramic obsidian belongs to group 1g. The significance of this to the archaeology of the time period will not be fully realized until the geological source for lg obsidian is located, and more sites are analysed loking for changes in the exploitation of obsidian sources through time. It is possible that the assumption that the source for lg obsidian is near Nemrut Dağ should be reconsidered, since there are significant differences in the exploitation of the two sources at the same time.

The decrease in the use of obsidian from Nemrut Dağ at Abu Hureyra can only be commented upon at this point because this change has not been noted in any of the published accounts of obsidian usage. All of the green obsidian found at Abu Hureyra would have been classified 4c by Renfrew, et al, and the other two groups of green obsidian are present at Abu Hureyra during the Ceramic Neolithic. Wright's analytical technique allows separation of the green groups, but only one other piece of archaeological obsidian has been identified from Bingöl (group G2), and that is from Çayönü, an eastern Anatolian site unrelated to Abu Hureyra.

Renfrew, et al (1968; Renfrew 1969b) have proposed a Locational Analysis Model of the obsidian trade in the Near East, based on the premise of a supply zone and a contact zone, for the later seventh and sixth millenia BC. Within an area of 250 km or 350 km for the central and eastern Anatolian sources respectively, more than 89% of the chipped stone industry (90% at Suberde; 99.9% at Asikli Hüyük (Renfrew, et al 1968) 25 km from Çiftlik) should be obsidian. Outside the contact zone, the fall off in the percentage of obsidian present is almost exponential, so that when plotted on a logarithmic scale, the points provide a reasonable straight line, with a few exceptions at the most distant of the sites in the contact zone. Renfrew's model suggests that trade was from site to site from the supply zone, through the contact zone. Each site would originally have received twice as much obsidian as it kept, trading half of it down to sites further away from the sources. If sites from the later eight, early seventh millenia are included, there is no longer a straight line graph, but a fall off by powers of 3 or 4 (Wright 1969).

There are a number of problems with the model as presented. It is not disputed that there is a significant difference in the pattern of exploitation at sites a greater distance from the sources. At sites close to the sources obsidian is a material utilized for all types of tools. At Ilicapinar, in northern Anatolia, most of the chipped stone tools are made of obsidian. These tools include lance and arrowheads, awls, chisels, burins, scrapers, sickle blades, and other blades (Mellaart 1958), while at sites at a greater distance from the sources, obsidian tends to be used for much more specialized tools, especially small unretouched bladelets, possibly used for knife blades (L. Braidwood 1961). Alternatively, at eastern Anatolian sites such as Çayönü, where flint is readily available as a raw material, it was used as much or more than obsidian. At Çayönü, a distance of 195 km from Lake Van sources, the percentage of obsidian for the top and surface level is 48.2%, and only 17.6% for the lowest levels, while theoretically, to fit Renfrew's model, it should have more than 80% obsidian (Wright 1969). Abu Hureyra does not fit the pattern either. At a distance of approximately 450 km from both source areas, exploiting primarily eastern Anatolian obsidian, obsidian should be about 35% of the total chipped stone industry when the Lake Van supply zone is considered.

three to four per cent of the chipped stone should be obsidian, while the actual percentage is about 4-5%, but 75% of that is from the eastern sources.

Wright (1969) suggests that the percentage of obsidian present is not the important factor when considering the utilization, but the weight of that obsidian is much more important. Trade in the period from 7500 to 5500 BC was primarily carried out by the use of human transport, since pack animals were not used this early. Therefore, the weight of the material is going to be considerably more important than the actual number of pieces. At Abu Hureyra most of the obsidian was brought in as roughly prepared blade cores. There is very little waste present in the obsidian assemblage, and much of what there is seems to be in the form of core trimming flakes, or the remains of cores too small to continue using. The weight of the Abu Hureyra obsidian is higher than that calculated for sites in the Zagros, where after examination of obsidian from Jarmo, Renfrew (1969a) calculates a reasonable weight is 20 grams per 1000 pieces of obsidian. The average mass of the 100 samples of obsidian analysed from Abu Hureyra is 939 mg, thus making the weight of 1000 pieces just under one kilogram. Variations in the weight of obsidian from site to site in the Near East is probably as significant as the variation in the percentage of the chipped stone assemblage, but it will be difficult to determine this accurately for many excavated sites in the Near East because excavation methods used in the past frequently did not include any sieving of excavated dirt or the saving of lithic debitage. If these problems could be worked out, however, use of weight as an indicator would be considerably more useful, since the method the method for obtaining the rest of the raw material for the chipped stone industry. The percentage of obsidian of the total chipped stone may vary because of differences in the requirements for the flint, rather than for the obsidian.

The major problem with Renfrew's model is that it is a mathmatical one based on possibly invalid criteria, and does not sufficiently consider archaeological and human factors. Many contemporaneous archaeological sites had certain functional and/or economic differences. A site where the major subsistence base is hunting will have different requirements for a tool assemblage than will a site where the major subsistence base is agriculture or the herding of domestic animals. These differences may well be reflected in the requirements for a particular raw material such as obsidian.

Most of the obsidian at Abu Hureyra is from eastern Anatolia, while the closest archaeological relationships are with the sites to the west. This has important archaeological implications. Trade is an indication of intercultural contact, and is a motive for such contact. It can be a causative factor for culture change as an agent in communication by establishing an area of cultural and material exchange (Renfrew 1969b). Trade is defined as "the reciprocal traffic, exchange, or movement of materials or goods through peaceful human agency" (Renfrew 1069b:152). At Abu Hureyra the evidence indicates some kind of material exchange, without much evidence of cultural exchange. It has been argued (Bhattacharya 1969) that a migrating population might take a supply of obsidian with them and gradually switch to local materials as the stock of obsidian was exhausted, but as the percentage of obsidian at Abu Hureyra increases during the occupation of the site this is not a likely explanation for the presence of obsidian at Abu Hureyra.

Contact was occurring, though it must have been indirect, between Abu Hureyra and the sites to the east because of the presence of eastern Anatolian obsidian and other exotic materials from Anatolian sources show that exchange systems were operating. Cultural contact was taking place with the people to the west in the Levant as shown by the archaeological similarities and confirmed by the presence of group 2b obsidian. This leads to the question: What kind of trade mechanisms were working between Abu Hureyra and the sites to the east? For some reason cultural exchange was not occurring along with material exchange. Extensive contact may have been undesirable, or the actual exchange may have occurred between two groups with such different cultural standards that there was no reason to make any cultural exchange. If, as Renfrew postulates, much of the obsidian trade was carried out by means of nomadic groups travelling through the unsettled regions, this could represent early stages of the distrust and dislike between nomadic groups and settled communities that still exists today in the Near East and other parts of the world.

Ethnographic analogy is a method of interpretation that must be used with extreme caution because the possibility of similar actions having very different meanings is entirely too likely when examining human behavior. However, consideration of how peoples on a similar level of cultural and economic development handle similar kinds of problems, such as exchange, can be extremely useful when examining archaeological material.

It is unlikely that specialized traders existed during the early Neolithic. This is a possibility that cannot be completely excluded (Adams 1974), and if Anati (1962) is correct that Jericho was supported by being the centre of the salt, sulphur, and bitumen trade, may even turn out to be a valid explanation, but there is not any real evidence for the existence of a specialized trading class during this time. Simpler societies are known that manage successful systems of exchange without specialized traders. Ceremonial gift exchange is practiced in many societies, and is an important part of the social contact among groups. Obsidian in the Near East was exchanged in an unfinished state, but ceremonial exchange of raw materials is known ethnographically (Berndt 1951; Harding 1967).

Silent trade is practiced in the Congo. In this system, exchange occurs without any actual contact at all. When this system is present, however, it is usually between two groups at different levels of social complexity such as state-tribe contacts. These different levels were unlikely to have existed in the early Neolithic (Wright 1969).

It is unlikely that any exchange mechanism with complete lack of contact existed, though, because while there are very few archaeological similarities between sites in the Levant and sites in the Zagros, agricultural innovations were spread fairly quickly between the two regions. Harlan and Zohary (1966) suggest that wheat was domesticated in the Jordan river watershed, and it is found in the Zagros by 6500 BC, while wild goat, native to the Zagros mountains, was found outside of its natural habitat during the PPNB at Jericho.

The most likely routes for the spread of economic ideas are those established for the exchange of commodities such as obsidian, and possibly occurred at the same time.

CHAPTER 9

CONCLUSIONS

1. Five chemically distinct obsidian groups were identified in the analysis of the obsidian from Tell Abu Hureyra.

2. There were significant changes in the exploitation of three of the groups, 2b, 1g, and G1, during the occupation of the site.

3. Group G3 was present only in the Ceramic Neolithic, is not identified to a particular source, but it is important because this is the first documented case of its presence at any archaeological site in the Near East.

5. The presence of the obsidian from the Bingöl source is very important. It is present in small amounts throughout the occupation of Abu Hureyra, indicating continuous exploitation, yet this isthe first documented occurrance of obsidian from Bingöl at a site outside of Anatolia.

6. The pattern of exploitation of group 1g obsidian at Abu Hureyra confirms a pattern suggested by examination of the obsidian from Ali Kosh, that the source for group 1g was not significantly exploited in the earliest phases of the Neolithic in the eight millenium BC.

7. Group G1, currently identified as from Nemrut Dag, and group 1g have different exploitations at Abu Hureyra at the same time. There are three possible conclusions suggested by this: 1. The assumption that the source for 1g must be close to Nemrut Dağ because the distributions are so similar should be reconsidered; 2. Group 1g is replacing G1, and the sources are near; and 3. The sources are not close, but 1g is replacing G1. The source for 1g must be located before

such questions can be answered.

8. Utilization of obsidian from Çiftlik, in central Anatolia, significantly increased during the Ceramic Neolithic, corresponding to an increase in contact with sites to the northwest, closer to the Cilician Gates, the most likely route for the entry of central Anatolian obsidian into Syria and the Levant.

CHAPTER 10

SUGGESTIONS FOR FURTHER RESEARCH

The anthropological questions brought up at the beginning of Chapter 8 have not yet been answered. Further work in source identification of obsidian found in archaeological sites is necessary, and research into ethnographic examples that might lead to explanation of trade mechanisms would be useful. The anthropological perspective is very important and should be brought into any discussion of the prehistoric obsidian trade in the Near East.

In addition to the general further work suggested above, there are some specific points suggested by the results of this analysis to consider for future work:

1. The question of sampling and the significance of the proportion of groups as analysed to the whole of the site is an important one. One way of partially checking the proportions is to examine the ratio of grey to green obsidian in other parts of the site. As more of the excavated material from Abu Hureyra becomes available for examination, the obsidian should be examined for the ratio of grey to green to see if it compares to that for trench B and the analysed obsidian.
2. It would be desirable to continue analysing obsidian from Abu Hureyra to confirm the changes in exploitation patterns determined in this analysis. It would also be useful to look for the presence of group G3 in the aceramic phases, to see if there is any significance to the current absence of that group in the analysed obsidian.

3. The evidence for the utilization of obsidian from Bingöl throughout the occupation of Abu Hureyra is quite interesting. The obsidian identified as group 4c at other sites in the Near East should be reexamined, looking for evidence that obsidian from Bingöl may also be present.

4. The use of the obsidian should at some point be determined, possibly by edge wear analysis. Postulations about the social importance of theobsidian trade will need to include consideration of the degree of demand for the obsidian. Different conclusions might be drawn if the obsidian was used to make necessary items, rather than used for luxuries.

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ABBREVIATIONS USED

AAS	Les Annales Archeologiques de Syrie
AAAS	Les Annales Archeologiques Arabes Syriennes
BASOR	Bulletin of the American School of Oriental Research
PEQ	Palestine Exploration Quarterly
PPS	Prehistoric Society Proceedings