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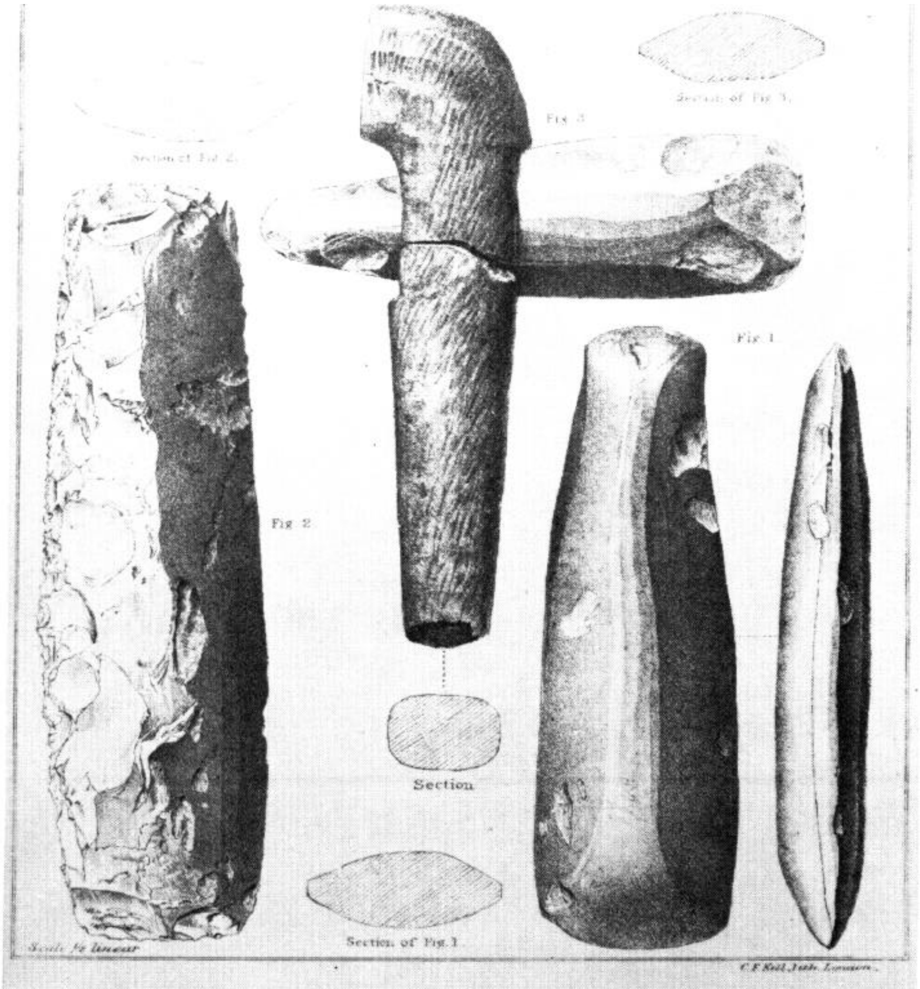
No 23

STONE AXE STUDIES

Archaeological, Petrological, Experimental and Ethnographic

Edited by
T H McK Clough and
W A Cummins



STONE IMPLEMENTS, EHENSIDE TARN.

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Research Report No 23

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Council for British Archaeology

Contents

Editors' foreword

This volume contains the papers given at a conference on Neolithic and Bronze Age Stone Implements which was held at the University of Nottingham in January 1977 and organized by the Implement Petrology Committee of the Council for British Archaeology.

We believed that after many years of work in this field, summarized by Professor Grimes below, the time was ripe for a full appraisal of the results obtained. The success of the conference and the scope of the papers assembled here together show that this was so. Petrological studies will have much to offer the archaeologist and the anthropologist in the years to come, and this volume is far from representing the final word on any aspect of the subject.

Throughout the Conference it was clear that the achievements of research in implement petrology depend ultimately on fruitful cooperation between archaeologists and geologists in museums, universities, and elsewhere. It was therefore very gratifying to witness at Nottingham the renewal and forging of friendships and contacts between workers in the several disciplines represented. We were particularly glad and fortunate to be able to welcome our contributors from France, the Netherlands, and Australia.

Both personally, for the CBA, and on behalf of delegates at the Conference, we wish to express our thanks to all the contributors for their ready cooperation with our editorial demands; to Professor John Mulvaney for his remarkable unscheduled lecture out of which arose, at short notice, the paper by Isabel McBryde with Alan Watchman; to Professor Stuart Piggott for his closing remarks at the Conference; to the chairmen of the various sessions, Professor J V S Megaw, Mr R J Mercer, and Dr A P Phillips; to Dr A Harding and Dr A Tooley for making available the Danish stone axe film; to all those individuals and museums who provided thin sections and specimens from their collections for the practical petrology session, and especially to Professor F W Shotton and Mr R V Davis; to Mr H F Cleere, Miss C A Lavell, and other members of the CBA staff for carrying the administrative burden of the Conference and of the consequent publication of this volume; and to the University of Nottingham and the staff of Hugh Stewart Hall for providing such excellent facilities and accommodation.

A summary and brief discussion of the Conference proceedings has already appeared in *Current Archaeology* **57,** 1977, 294–302.

TC
WAC
October 1977

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The history of implement petrology in Britain

W F Grimes

Abstract

This paper outlines the development of the implement petrology survey from its beginnings as a small working party of the CBA to its present form as a full committee organized on a regional basis. The major landmarks in its history are cited.

One of the first acts of the Council for British Archaeology (CBA) was the formation in 1945 of a Natural Sciences Panel. One function of the Panel, under its chairman, K P Oakley, was to examine by means of small working parties the various contacts between archaeology and the natural sciences and to consider ways by which collaboration might be developed. The Implement Petrology Committee started life as one such group; its members were F S Wallis, F J North, and W F Grimes (convenor). The working party met on a number of occasions, finally suggesting that it be allowed to prolong its existence as a standing committee under the CBA whose function should be the organization of an implement petrology survey on a national basis. After a long period of gestation the scheme finally emerged, fully formed (for the time) in 1952 (*CBA Annual Report* 1952).

The development of implement petrology seems natural enough now, but in those days it marked something of a revolution, though like other archaeological revolutions it was of the gradual kind. It signalled the biggest step so far in the departure from the 'collector's approach'. The interests of the collector had been an important and necessary driving force in the archaeological dialectic. Its concern was with objects, valued, reasonably enough, in their own right, regarded therefore as sacrosanct and to be subjected to no interference, even in the interests of additional knowledge.

The beginnings of change in this attitude can be detected in the early 1920s. The credit for this belongs to no individual: it was another example of a developing climate of thought in which individuals, independently and in discussion, recognized that if progress was to be made in a particular direction and if the discipline was not to lose momentum a new approach was inevitable. The pioneers in the field were workers in Wessex and the south-west (of whom more later); an important factor was the work of Thomas (1923) on the Stonehenge 'blue-stones' and other petrological determinations to do with stone implements. For Wessex and the south of England generally all greenstone axes are 'foreign'. Their presence in country which for the tool-maker is stoneless, apart from flint, in itself constitutes a challenge to research. The challenge was sharpened by the fact that the famous spotted dolerite from Preselau (Group XIII), later nicknamed 'Preselite', a rock the distinctive characters of which could not be erased by weathering, could be recognized as the raw material of some of the 'foreign' implements.

For a museum archaeologist working in Wales a further spur to thought was provided by the products of the Graig Lwyd axe-factory (Group VII), first described in 1919 and for a long time the only igneous rock axe-factory known in Britain – known in the full sense that some at least of its working floors had actually been located (Houlder 1956). Graig Lwyd and its axes had a singular effect on attitudes to newly-found greenstone axes in the National Museum of Wales, to be summed up in the question: 'Graig Lwyd: yes or no?' But while in 1923 and again in 1929 Thomas (1923; Thomas & Passmore 1929), using his own technique, had demonstrated that microscopic examination could yield positive decisions about origins as compared with determinations arrived at by macroscopic means, the macroscopic method was still followed.

Throughout this time one stone axe exercised an influence far out of proportion to its size or quality. It was one of four found as a hoard at Upper Paper Mill, Llangenny, Brecknockshire (Grimes 1951, 149, no 136). The implement had been cut in an effort to establish whether its material was an argillite from the south of England; and the necessary section had been obtained by the removal of a thick sector right through the axe, leaving blade and butt as two disconnected pieces. Such insensitive treatment had an understandable effect on archaeologists accustomed to treating their artefacts with respect. There was nevertheless a growing reaction from the geologists to demands from the archaeological side to be provided with precise determinations of origins on the evidence only of the altered surface of the stone; and the uneasiness was the greater when such determinations were in danger of finding their way unqualified into print. The resulting frustrations, archaeological and petrological, were reflected in published comments by Grimes (1932; 1938) and North (1937).

The unashamedly autobiographical tone of these paragraphs reflects a situation which in these early years was in some ways peculiar to Wales. It has already been observed that in southern England archaeologists were concerning themselves more positively with the problems of their intrusive axes. Thus in 1935 Piggott (1935) was commending Mr Butt of Kingsclere for allowing two axe-fragments in his possession to be thin-sectioned and urging others to do likewise.

But discussions had been taking place long before that. As Piggott has recalled (I F Smith 1965), Alexander Keiller had been interested in implement petrology from the late 1920s, and had collaborated with Thomas over the stone axes and other material at Windmill Hill. To Keiller, with Piggott and C D Drew of the Dorchester Museum, belongs the credit for the establishment in 1936 of the Sub-Committee of the South-Western Group of Museums and Art Galleries on the Petrological Identification of Stone Axes. With Keiller as chairman, Piggott as secretary, and F S Wallis as petrologist this was the true pioneer organization. Its aims and methods, originally set out by Keiller (1937a, b), formed the pattern which was followed in all subsequent developments. In addition to defining the first petrological groups, the Committee adopted the now familiar technique of axe-cutting whereby a thin-section is obtained with minimum damage to the implement. The technique had apparently been devised independently by several petrologists – by Keiller and Thomas, as well as by O T Jones of Cambridge. Its significance of course was that in acknowledging the importance of the specimen *qua* specimen it allayed the anxieties of curators and owners about the effect on the appearance of the implements in their care.

The first report of the South-Western Committee was delayed by the outbreak of war and did not appear until 1941. It was the work of Keiller, Piggott, and Wallis, and dealt with 'over 200' specimens. Here too the report has been the model for subsequent reports. The first groups were established and petrologically described, with standardized drawings of the implements and distribution maps, though the numbered list was to come later. The report also summarized earlier petrological work, in which the name of Thomas had always been particularly prominent. Also established at this time was the practice, now a tradition, of publication in the *Proceedings of the Prehistoric Society,* which has been the vehicle for virtually all later reports (apart from those from Scotland), with regular grant aid from the CBA.

The manner of the creation of the national survey was set out in the opening paragraphs. The originators of the scheme were in no doubt about their aims. They were to originate and to organize, but not to undertake or usurp publication, which was to remain in the hands of the people in the regions who were responsible for compiling the record. During the prolonged organizational phase various changes took place. In particular it was found impossible to extend the Museums Federation arrangement beyond the south-west. The federation areas did not correspond on the whole with the distribution of workers. Many were on the large side; these were broken down into ad hoc units, directly related to what people were prepared to undertake. The problem had an obvious dual aspect: the compilation of the archaeological record; and the petrological examination of the actual implements. The latter was the more difficult, petrologists being harder to come by; but there was no reason why one should wait upon the other. It seemed sensible to complete the archaeological work even without a petrologist at hand, in the hope that when done it might be presented to the petrologist as a more or less finite task rather than as an open-ended commitment, the limits of which he could not see.

Two further policy decisions were made. First, the survey should not attempt to deal with flint. It was said at the time that it would be another ten years before the petrological study of flint would be sufficiently advanced to be applied to flint sources. Second, attention should be concentrated on stone implements in the more restricted sense of axes, axe-hammers, maces, and the like. Whatever the desirability of taking on other objects such as querns or whetstones the implements in themselves were a large enough assignment. Later some work was done on the petrology of querns and more recently, under the aegis of the British Museum, the petrology of flint has received attention (Bush & Sieveking, this volume).

Lastly, a new numbering system was adopted. The south-western arrangement was one of straightforward running numbers appropriate to a regional survey. In the course of time, however, the South-Western Committee, as the only body engaged in implement petrology, had undertaken a number of determinations of implements from outside their area; and these were scattered sporadically through the lists. For the national survey numbering was on a county basis with an appropriate prefix for the county, thus maintaining a regional entity within the national system.

In these early years the CBA itself was operating on an exiguous (but gratefully accepted) grant from the Carnegie Foundation and there was no money for implement petrology or similar activities. The first records were kept on sheets of paper or cards, according to what was available to the individual compiler, and tribute must be paid here to the pioneers: Sheppard Frere and R F Jessup in the south-east, W Bulmer in the north. The financial breakthrough took place in 1949, when an application to the Leverhulme Trust resulted in a grant of £100 towards the expenses of the survey. In these inflationary days the amount seems small enough. Its value was out of all proportion to its size. It now became possible to produce a standard record-card (which was on the lines of that used by the South-Western Committee) and above all to meet the cost of technical work and postage. In 1953 the Leverhulme Trust made a second grant of £300. Although some of the better-endowed museums helped by meeting their own charges and some petrologists also contributed by making their laboratory facilities available free, the Leverhulme grants formed the main financial basis of the survey. At a very much later date it emerged that the Trust regarded the grants as having been made not to the survey as such but to the convenor personally. Progress was slow and the demands made on the funds in any one year were not large, so that only in the late 1960s did it become necessary to seek an annual subvention from CBA central funds. Grateful thanks go to the Trustees for their timely help; for the plain fact is that without the Leverhulme money at that time the survey as a national project might well have collapsed, dependent as it would have been on the uncertainties of regional support.

The South-Western Committee's second report (Stone & Wallis 1947) was relatively brief. The total of specimens examined was now 274, some 101 of which had been ascribed to petrological groups. The report also incorporated summary accounts of other petrological work. In view of the establishment of the national survey, the Committee had decided to restrict its activities to its originally defined south-western area, but generous help was still given to others needing it. When Bunch and Fell undertook their independent investigation of the Great Langdale factory and its products, the petrological work was done largely by the south-western group (Bunch & Fell 1949; Fell 1954).

In the third report (Stone & Wallis 1951) the group continued its system of running numbers. The list of specimens examined by this time totalled 710, of which 291 were placed in nineteen main petrological groups. It was thought that with certain exceptions 'all available material in the south-western region, comprising Wiltshire, Gloucestershire, Hampshire, Somerset, Dorset, Devon, and Cornwall' had been covered. Yet in the fourth report, the total had grown to 1200, with 504 placed.

In the fourth report (Evens *et al* 1962) a complete list, embodying 25 years' work, was further systematized. In particular, while the running number was retained, the county system (with a slightly modified abbreviation) was also provided. This tedious task, which involved correlations with the records of other regions for specimens not of south-western origin, was carried out by L V Grinsell.

With the integration of the South-Western Committee's records with those of the other regions the organization of the national survey may be said to be complete. Study of the *CBA Annual Reports* will nevertheless show how variable was the progress made over the years, with some regions more active than others, some at times coming to a complete standstill. This is a state of affairs not unknown in regionally organized enterprises. Apart from dispensing grants for technical work and routine supply-activities, the all-important function of the central organization was to maintain continuity and a sense of purpose, especially since over the 30 years of the survey's existence there were inevitable changes in the working teams. After the early years the active members of the central committee maintained contact through correspondence. The first working party, confined to active participants, archaeologists and petrologists, took place in Birmingham as late as May 1972 *(CBA Annual Report* 1971—2, 49). Earlier meetings had been debated, but were not proceeded with, partly because of pressures elsewhere and partly on the (probably mistaken) ground that the state of the survey was too uneven to make the formulation of a more active policy possible. By 1972 the indications were that for various reasons the survey was at last gathering momentum. The Leverhulme grant, for instance, was much more rapidly reduced in the late 1960s and, as already noted, it had been necessary to seek an annual subvention from CBA central funds.

The first reports to be produced under the aegis of the survey rather than the South-Western Committee were those of the West Midlands (Shotton *et al* 1951; Shotton 1959). They were not comprehensive surveys but studies of individual petrological groups, XII, and XIV, XV, and XX respectively. From 1971 a spate of systematic reports began to appear, bringing to fruition the work of earlier years: Yorkshire (first report, Keen & Radley 1971); East Anglia (first report, Clough & Green 1972); Lincolnshire, Nottinghamshire, and Rutland (first report, Cummins & Moore 1973); Derbyshire and Leicestershire (first report, Moore & Cummins 1974). The fifth report of the South-Western Committee also appeared in 1972 (Evens *et al* 1972), and its total of specimens examined stood at 1285. The total for the country as a whole, arrived at by the 1972 working party, came to about 4000.

In Scotland, the survey has proceeded on rather different lines from those in the rest of Britain, in accordance with the policy adopted by CBA Regional Group 1 in 1969, which continued and developed earlier practice *(CBA Annual Report* 1968—9, 30—1). Study of museum collections (Livens 1959) has been combined with attention to particular petrological groups (VI & IX) and is now extended to systematic area-survey in selected areas in the south-west and north-east of the country. It is intended that this shall lead to area reports of the type now standardized in the south. A general survey of Scottish petrological work has in the meantime been published by Ritchie (1968), who identified two new petrological groups, XXIV (Killin) and XXII (Northmaven, Shetland).

Finally, note should be taken of a number of important contributions to implement petrology which lie outside the national survey, though some were related to it. There have been definitive studies of Group IX (Tievebulliagh and Rathlin Island: Jope 1952; Morey & Sabine 1952); Group VII (Graig Lwyd: Houlder 1956); Group XXI (Mynydd Rhiw: Houlder 1961); Group XXIII a, b (north Pembrokeshire: Shotton 1972); jade axes (W C Smith 1963; 1965; 1972); and the 'Cumbrian' axes of Group VI (Fell 1964). The problem of Group VIII/Group XI has been discussed (Morey 1950; Ritchie 1953). The Institute of Geological Sciences, which has been helpful on many occasions, has published a number of petrological determinations independently (Sanderson 1970). This list is not a complete bibliography of the subject; and it makes no attempt to deal with continental activity.

It is 40 years since Keiller, Piggott, and their colleagues took the first steps in the systematic approach to implement petrology in 1936. The study may now be said to have come of age and indeed to have achieved international status. The experiences of workers in the field have shown that it is never likely to be complete, but it is rapidly reaching the stage when synthesis, archaeological and petrological, will become both possible and necessary, demanding a high degree of cooperation between regional units which have hitherto been free to operate more or less independently. Here a contribution that has been concerned with the past of the subject may perhaps include a comment on its future. Some at least of the next steps appear obvious enough. In particular, the body of material is now such that computerization will be called for if inconsistencies which are unavoidable in any many-handed enterprise are to be removed, with the further possibility of the recognition of new groups. The benefaction to provide for such a development would require to be much larger than the Leverhulme grants which sustained the survey over the first twenty or so years of its existence.

It has been said that over this time there were many changes in the personnel of the survey. It has been said also that progress depended more than anything else on the availability of petrologists to undertake the petrological work. In an inter-disciplinary exercise for which there does not appear at present to be an exact parallel, it is probably not unfair to claim that the archaeologists have reaped the greater benefit. Their part in the compilation of the archive is of course invaluable and thanks are due to all of them for efforts which in many cases have been maintained over periods of years. But the thanks of the archaeologists must go to the petrologists, who have given their time patiently and generously to the pursuit and objectives which take them into cul-de-sacs in the terms of their own discipline. Here the names of E D Evens and F S Wallis, closely followed by F W Shotton and now by W A Cummins, are outstanding. Their knowledge and expertise have been readily available in places far beyond the regions with which they have been nominally linked. The survey would have failed without them.

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Neolithic stone axes: distribution and trade in England and Wales

W A Cummins

Abstract

Distribution studies have been carried out on the eight most abundant stone axe groups. Six of these show factory-centred distribution patterns. Two of them, Groups I and VI, with axe factories in the west, have distribution patterns centred on coastal areas in the east. These two eccentric patterns are interpreted in terms of two stages of trade: first, bulk transport from the factory to a distant centre, and second, distribution from this new centre. The first stage may simply have involved the transport of axes from one area to another, without exchange for any other goods at all. The primary trade route for the Group I axes was from Cornwall, along the south coast, probably to the London area; and for the Group VI axes, from the Lake District to Humberside.

Introduction

During the past 30 years, the petrological examination of stone implements, which began in the south-west (Keiller *et al* 1941), has spread over the whole country, under the general direction of the CBA Implement Petrology Committee (Grimes, this volume). The distribution map (Fig 1) is based on over 3000 axes and axe fragments, which have been examined petrologically. It excludes all shafthole implements and other types of artefact and also all axes identified as chert or flint, as these are not generally sectioned and are thus under-represented in the published lists. Even this relatively homogeneous sample covers a period of about 1500 years (Smith, this volume) and includes implements which, except in this very broad sense, were by no means all contemporary. The axes which make up the sample are very unevenly distributed over the country, and several factors contribute to this distribution pattern.

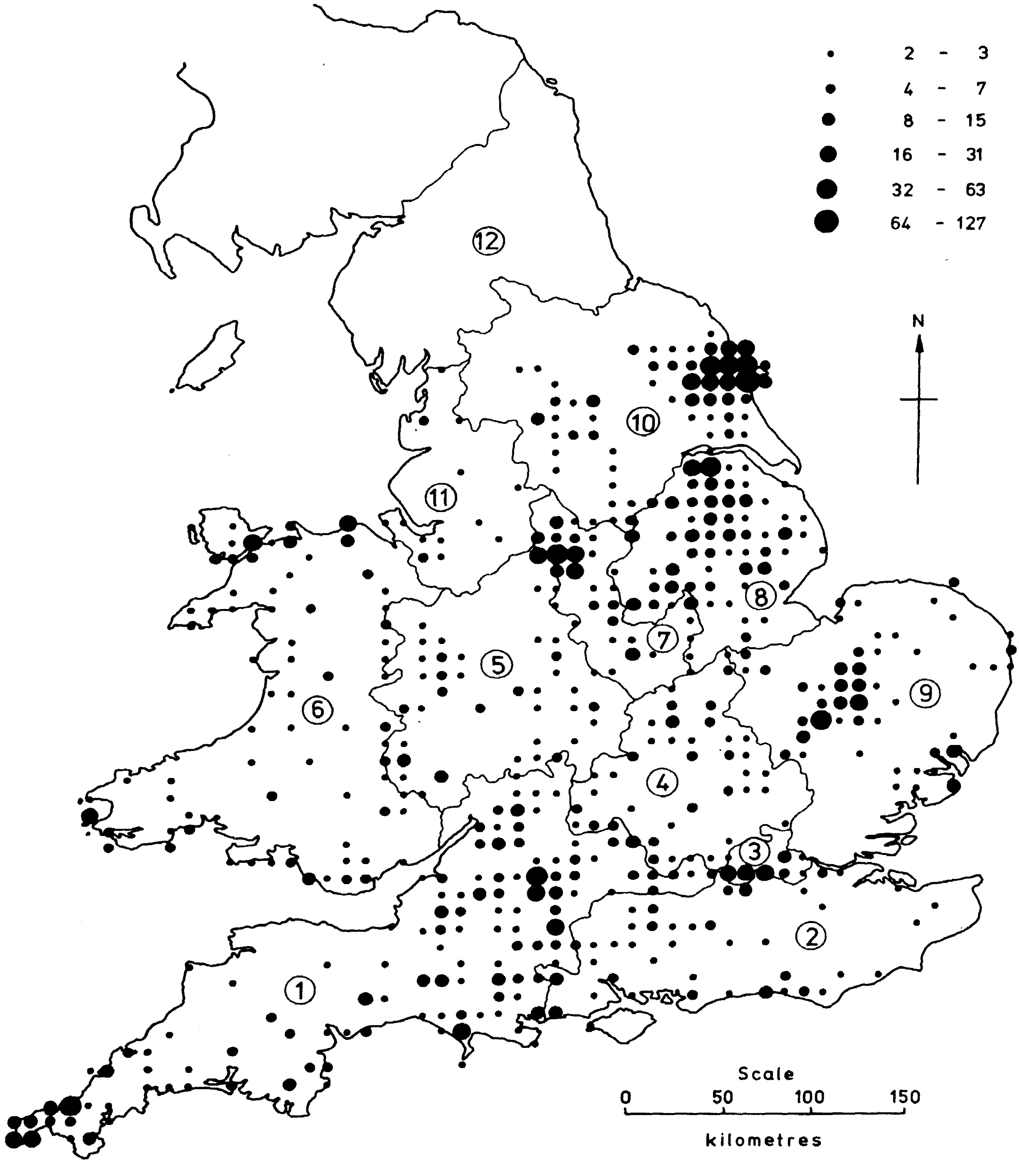
The total Neolithic stone axe population, of which this is a small and non-random sample, should have a distribution related to that of the human population during the period under consideration. The light soils on chalk and limestone, for example, were likely to have been favoured, as compared with heavily forested areas on clay sub-soils. Thus stone axe concentrations on the Cretaceous Chalk, in Yorkshire, Cambridgeshire and Wessex, and on the Carboniferous Limestone, in Derbyshire, are among the most notable on the map.

Conditions suitable for the discovery of stone axes depend on a variety of modem activities, such as deep ploughing, gravel extraction, building and, of course, archaeological excavation. Actual discovery depends on the presence of competent collectors at the right place and time. Finds breed interest, which encourages more collectors, who make more finds, thus increasing the apparent disparity between different areas. A combination of suitable agricultural conditions and assiduous collectors helped to produce the greatest concentration of stone axe finds in the whole country, in the Yorkshire Wolds (Manby, this volume). Gravel working has been responsible for many of the finds concentrated along the river valleys of the Thames and Trent. Building activity has resulted in minor concentrations in urban areas in many parts of the country, where axes are otherwise scarce. Archaeological excavations at sites such as Maiden Castle, Windmill Hill, and Avebury have contributed in large part towards the concentration of finds in Wessex.

Petrological identification of the stone axes of an area depends on the establishment and maintenance of contact and effective collaboration between the archaeologists, the petrologists, and the museums and private owners, who hold the collections. The progress of this work has varied from area to area, and much of it still remains unpublished. On the whole, however, coverage of the important regional collections of England and Wales has been fairly good, as far north as Lancashire and Yorkshire. It is unfortunate that petrological work in the northernmost counties of England, an area important for stone implement production (Groups VI, XV, and XVIII), has barely begun. Much work has been done in Scotland, but no part of the country has been covered as fully as most of the counties of England and Wales.

Distribution maps of axes belonging to individual petrological groups are strongly influenced by regional variations in the overall abundance of axes (eg Fig l), that is to say, those axes which had been examined petrologically at the time the maps were produced. Such maps give a good idea of the extent of dispersal of the particular groups studied, but they generally defy further analysis. For this reason, I decided to study the *relative abundance* of selected groups (Cummins 1974).

A study of variations in the relative abundance of petrological groups demands that the axes studied must, as far as possible, be a random sample of the total stone axe population in each area. For this purpose, the five reports on south-western England (Keiller *et al* 1941; Stone & Wallis 1947; 1951; Evens *et al* 1962; 1972), the two reports on London and Middlesex (Celoria 1974; Stanley 1976) and the reports on Yorkshire (Keen & Radley 1971), East Anglia (Clough & Green 1972), Nottinghamshire and Lincolnshire (Cummins & Moore 1973) and Derbyshire and Leicestershire (Moore & Cummins 1974) have been accepted because, in each case, the study has been as complete as the circumstances allowed and there is no suggestion of a bias towards any of the petrological groups. The Geological Survey report (Sanderson 1970) cannot be used, because it lists only those axes to which a more or less certain provenance can be ascribed. The West Midlands reports (Shotton *et al* 1951; Shotton 1959), in which new petrological groups



1 Distribution of petrologically identified stone axes in England and Wales. The frequency scale gives the number of stone axes per 10 km square. In several places the symbols appear off-shore. This is because they are placed at the centre of the appropriate square, not because they were actually recovered from the sea. The areas covered by published reports and by work in progress are numbered on the map, as follows: 1 south-western England; 2 south-eastern England; 3 London and Middlesex; 4 south-east Midlands; 5 west Midlands; 6 Wales; 7 Derbyshire and Leicestershire; 8 Nottinghamshire and Lincolnshire; 9 East Anglia; 10 Yorkshire; 11 Lancashire and Cheshire; 12 northern England were defined, cannot be used because the lists of axes are restricted to those particular groups. The extension of this study, to cover most of England and Wales, has been made possible by the generosity of the archaeologists and petrologists who have allowed me to make use of their unpublished results, the raw data on which future reports will be based.

All the axes were listed under 50 km squares, based on the National Grid, with their county numbers and petrological identifications. In coastal areas, where the squares are incomplete, parts of adjacent squares were combined, where necessary, to form suitable sample areas. The relative abundance of each group was then calculated as a percentage of the total number of axes in each sample area. For this purpose, an axe fragment, blade or butt, was counted as half an axe, while flakes were counted as a quarter each. This was to avoid over-representation of fragmentary material found during archaeological excavations or close field walking. The sample areas and the number of axes in each, rounded up to the nearest whole number above, are shown in Figure 2. The size of the sample available for analysis varies considerably, and areas containing less than 25 axes, in which one complete axe would form more than 4% of the sample, were arbitrarily considered unacceptable. For such areas, the size of the sample was increased by including all the axes from a 10 km wide strip around the original 50 km square, thus almost doubling the area.

The major axe groups are listed in Table 1, which shows three ways in which their importance may be assessed:- (i) abundance, given as a percentage of all the axes in the area studied (Fig 2); (ii) spread, indicated by the number of areas in which each group exceeds 10% of the sample; and (iii) dominance, given by the number of areas in which each is the most abundant individual group. In this table and in the discussion which follows, Group I includes all those axes identified as 'near Group I' and as 'Group Ia'. Other groups are treated in the same way. There can be no doubt at all that, on a national scale, Group VI is the most important group, followed by Groups I and VII, with the others a long way behind.

Table I

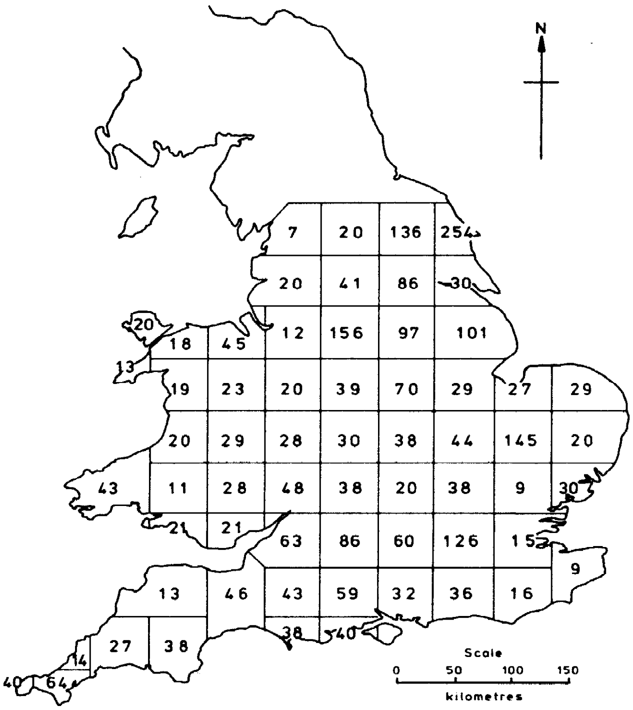
Group	Abundance	Spread	Dominance	(a)	(b)	(c)
VI	25.0	36	28		120	
I	9.9	28	15	420	230	160
VII	8.6	20	10	200		
VIII	2.5	4	4	160		
XVIII	2.4	1	0			
XX	2.2	3	0	120		
XVI	1.7	3	2	140		
IV	1.4	5	4	120		

Abundance, given as a percentage of all the axes studied.

Spread, given by the number of sample areas (Fig 2) in which each group exceeds 10% of the sample.

Dominance (Fig 3), given by the number of sample areas in which each is the most abundant individual group.

(a) shows the distance (km) from the axe factory within which 50% of all the axes belonging to each group have been found; (b) the distance (km) from the centre of the Humberside maximum (Fig 8) and the Essex coast maximum (Fig 7a) within which 50% of all the axes belonging to Groups VI and I respectively have been found; (c) the distance (km) from the centre of London within which 50% of all Group I axes have been found.

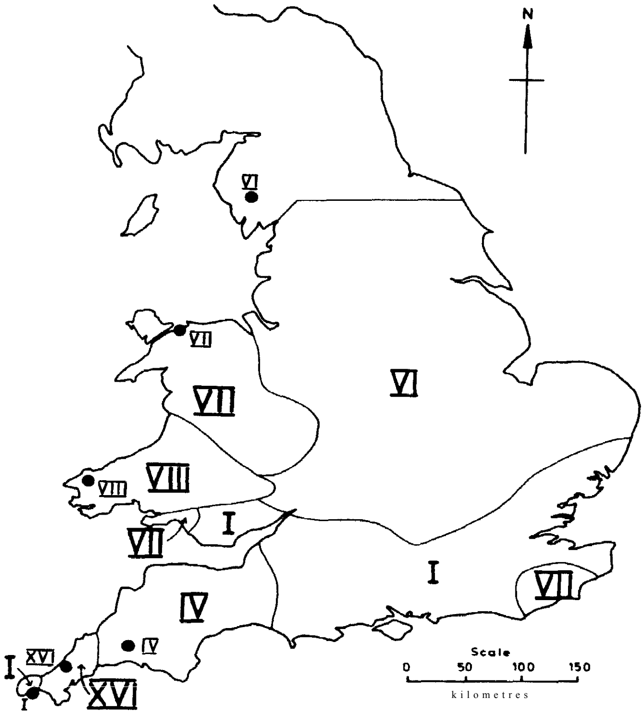


2 Sampling grid, showing the number of axes in each sample area

Regionally, Wales is dominated by Welsh groups, and the south-western peninsula by Cornish groups (Fig 3). The rest of the country is dominated by Group VI in the north and middle, and by Group I in the south. The indications, from unpublished and largely unsectioned collections in the north, are that Group XVIII may become dominant in the northeast, and that Group VI will remain dominant in the north-west (R V Davis, personal communication). The dominance of Group VI extends across the border into south-western Scotland (J G Scott, personal communication).

Distribution

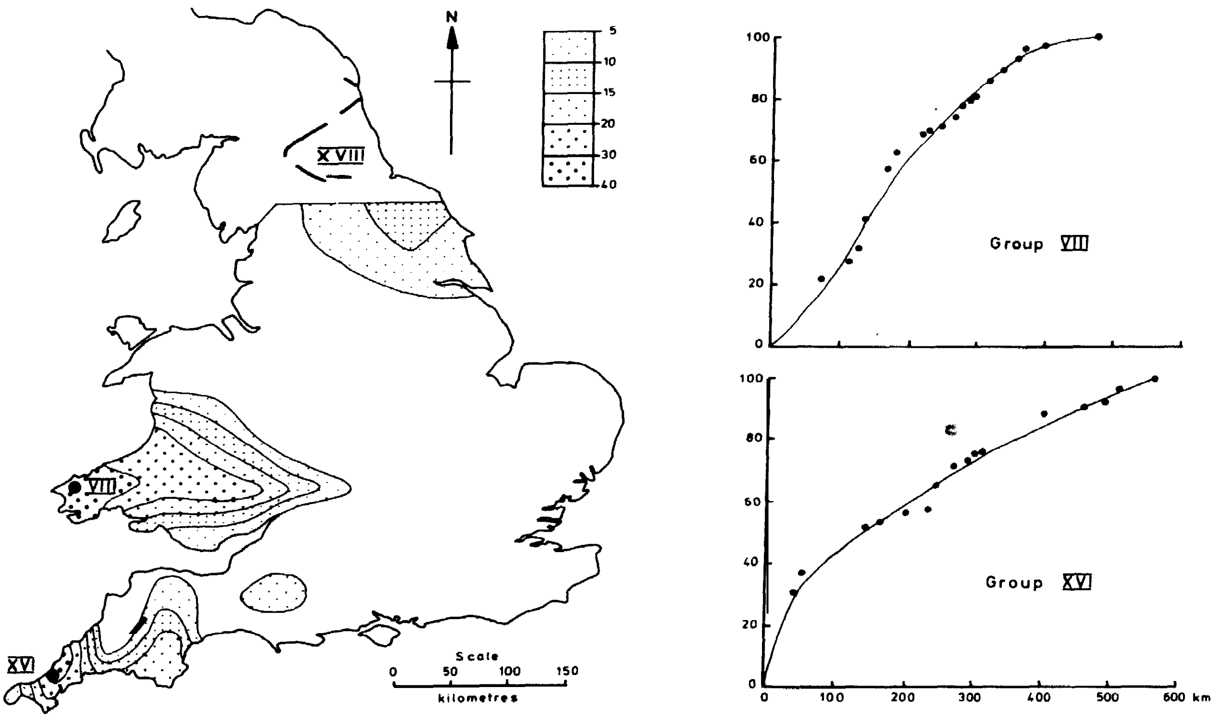
The relative frequency distributions of the stone axe groups listed in Table 1, are shown in a series of contoured maps (Figs 4 to 8). These maps generally show a concentric pattern for each group, centred about a maximum, and very clearly controlled by the location of the axe factory or presumed source area for the group. This is the case for Groups VIII, XVI, and XVIII (Fig 4a), for Groups IV and XX (Fig 5a), for Group VII (Fig 6a), and also for the Type A dolerite of Brittany (Le Roux, this volume, Fig 3). The factory-centred character of these distributions may be further illustrated by plotting the cumulative percentage of all axes belonging to each group against distance from the axe factory or presumed source of the group (Figs 4b, 4c, 5b, 5 c, 6b). This is the type of distribution to be expected if dispersal took place from the axe factory itself; whether by gift exchange, or through the efforts of an army of itinerant axe pedlars or Neolithic salesmen.



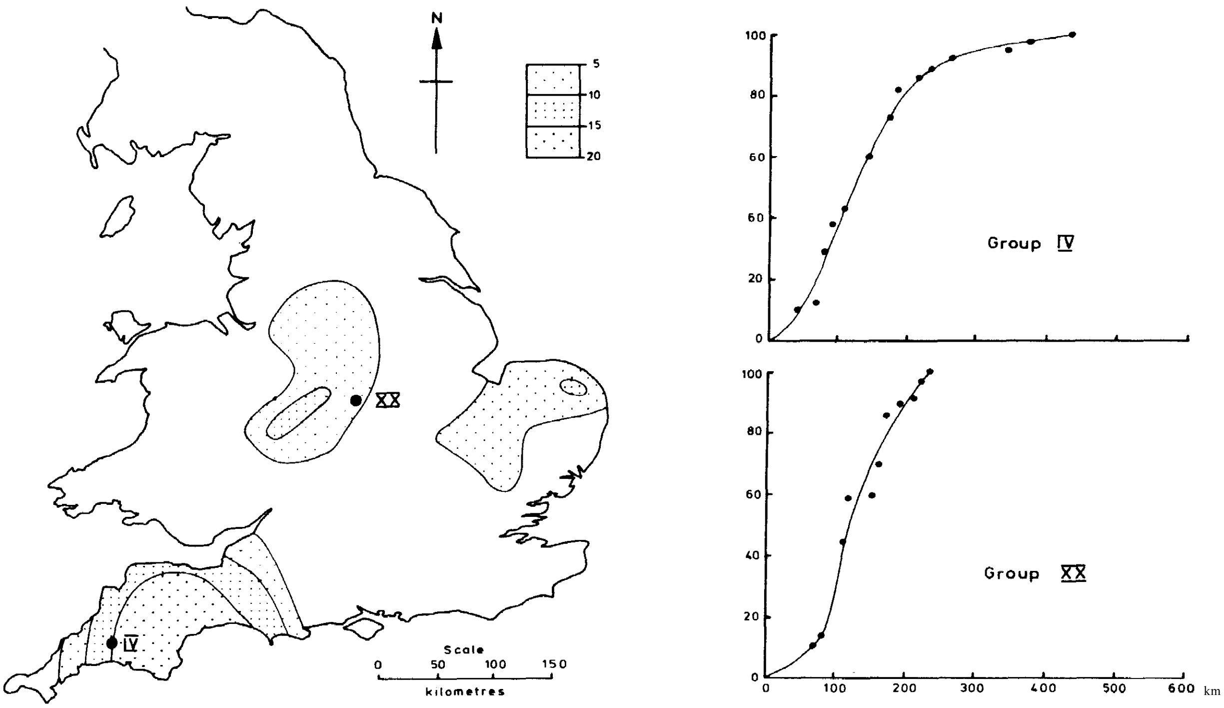
3 Dominant axe groups. The dots indicate the known (VI and VII) and probable (I, IV, VIII, XVI} positions of the axe factories. The areas outlined are those in which each is the most abundant individual group

Two groups show significant deviations from the standard factory-centred pattern. Group VI gives an excellent concentric pattern (Fig 8), but the maximum is centred on the Humber estuary, more than 200 km from the axe factory. Group I shows a more complicated pattern (Fig 7a), but the strongest maximum is centred on the Essex coast, about 500 km from the source area. Some 50% of all known Group I axes have been found more than 420 km from the source area (Fig 7b). This contrasts with the factory-centred groups, in which 50% of the known products have been found within distances ranging from 120 to 200 km from their sources (Table I). Comparable figures are not available for Group VI, because the axe factories lie beyond the area for which adequate data are available (Fig 8). It should be noted here that further study in the north of England may, and probably will, reveal another Group VI maximum in the Lake District, centred about the axe factories, but will not remove the Humberside maximum, which is the subject of the present discussion.

Cumulative percentage plots against distance from these 'eccentric maxima' (Figs 7c, 9) give an indication of absolute frequency distribution, as opposed to the relative frequency pattern shown on the maps (Figs 7a, 8). They compare well with similar plots for other groups, against distance from their sources (Figs 4b, 4c, 5b, 5c, 6b), but contrast strongly with the lot for Group I axes against distance from their source Fig 7b). Some 50% of all known Group I axes have been found within 230 km of the Essex coast centre. This is a somewhat greater distance than is usual for the factory-centred groups (Table I), but a glance at the distribution map



4 a *Relative frequency (%) distribution map for axes belonging to Groups VIII, XVI and XVIII, showing the probable positions of the axe factories.* b, c *Cumulative frequency (%) plots of all Group VIII and Group XVI axes against distance from the respective axe factories*



5 a *Relative frequency (%) distribution map for axes belonging to Groups IV and XX, showing the probable positions of the axe factories.* b, c *Cumulative frequency (%) plots of all Group IV and Group XX axes against distance from the respective axe factories*

(Fig 7a) suggests that the Essex coast might not be the only significant maximum. Some 50% of known Group VI axes, within the area studied (Fig 2), have been found within 120 km of the Humberside centre. It might be suggested that the large number of Group VI axes in northern England and southern Scotland would change this pattern, but the effect of these is likely to be counter-balanced by the thousand or so Yorkshire axes still awaiting petrological identification.

Two stage trade

The implication of the eccentric distribution patterns shown by Groups I and VI is quite clear. The dispersal of the axes took place in two stages:- (i) movement of the bulk of the factory products to a distant centre or centres, and (ii) dispersal from these new centres, in the same way as the other groups spread out from the axe factories themselves. This is the limit of what can be deduced directly from the distribution patterns and the important point is the first stage, the bulk movement from the source area to a distant centre.

Three possible interpretations can be put on this bulk movement:- (i) trade from the production area (Cummins 1974), (ii) exploitation from the consumer area, and (iii) natural processes (Briggs 1976).

Glacial action is the only natural process capable of the bulk transport of rock from one part of the country to another, without regard to the fluvial drainage network. Briggs cites Harmer's (1928) classic study of the distribution of glacial drift and erratics, and states that 'the widespread distribution of Great Langdale axes certainly bears some relationship to known scatters of Lakeland derived erratic boulders' (Briggs 1976, 269). Harmer's map clearly shows that the main concentration of Lake District drift is down the western side of the Pennines and southwards into Worcestershire, with an eastward extension through the Stainmore Gap and down into the Vale of York (Harmer 1928, Pl V). The relationship to the great eastern concentration of Group VI axes is hardly a close one and, in view of the considerable extent of the Neolithic axe factories in the Langdale and Scafell Pike area (Houlder, this volume), seems a very insecure basis for hypothesis. Further south, the difficulties of explaining the distribution of Group I axes by natural processes are even greater. The 'fine selection' of 'metamorphic and igneous erratic boulders', which are 'believed to derive variously from the North and West of Britain as well as from North-west France and the Channel Islands' (Briggs 1976, 268), can contribute nothing to our understanding of the dominance of one very individual Cornish rock type among the stone axes of much of south-eastern England (Fig 3). What natural process can possibly have transported masses of Group I rock from west to east, across southern England, while at the same time leaving Group IV rock (Fig 5a), Group XVI rock (Fig 4a), and a great quantity of ungrouped but superficially similar Cornish greenstones behind? Though the Group I axe factory has never been found, many rough-outs have been recorded in Cornwall (Evens *et al* 1962), whereas the Group I axes from south-eastern England are all finished products

(Clough & Green 1972; Celoria 1974; Stanley 1976). The geological and archaeological evidence combine to indicate that Group I and Group VI axes, made in western source areas, were transported by Neolithic man to eastern centres of distribution. Briggs's hypothesis must be rejected.

The motivation for bulk transport of axes from one area to another might have come from either end of the 'trade route' and there is little direct evidence which can be brought to bear on this question.

My first interpretation of the evidence was that the makers of Group I and Group VI axes, unlike all their contemporaries, saw the great potential of their products as a source of wealth, and realized that 'successful trade . . . depended on finding and exploiting distant markets' (Cummins 1974, 204). But did such modern thoughts ever really enter a Neolithic mind? Would a Neolithic axe maker ever have gone into mass production, in an area where the raw materials were abundant but the demand for his products small?

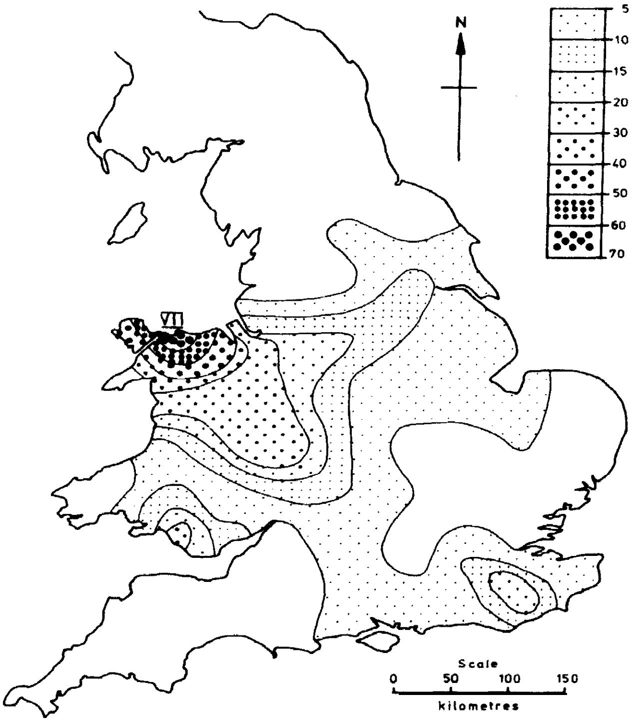
The other possibility is that certain communities in eastern England, with a need for good axes but lacking a reliable supply of suitable stone, sent prospecting expeditions into the Highland Zone to try and remedy this deficiency. Location of a suitable rock source might have been followed directly by exploitation, without any need for trade. Indeed there may have been no native population to trade with. Such exploitation would probably have been accompanied early by the establishment of a permanent colony in the source area.

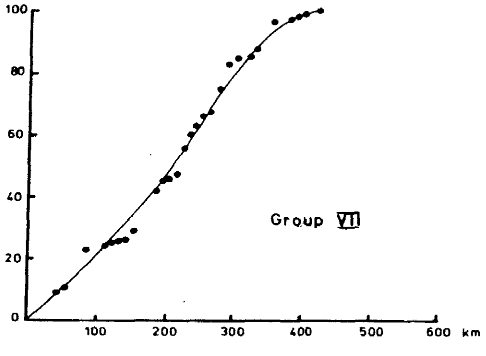
If the distribution of the stone axe sample (Fig 1) bears any relationship to that of the Neolithic population, then it would seem that, in general, the Highland Zone was sparsely populated by comparison with many parts of the Lowland Zone. For this reason alone, the eastern (Lowland) communities would seem to have had more reason to explore and exploit, than the western (Highland) communities had to engage in mass production and long distance trade.

The Humberside centre had excellent communications to the north and the south, and was also linked by a reasonable route to the Group VI axe factories in the Lake District. By way of the River Hull and the Yorkshire Wolds, it was connected to the great Neolithic population centre around Bridlington and Flamborough Head. To the south, the River Trent and its tributaries provided a link, through Nottinghamshire, to most of the Midland counties, while Lincoln Edge and the Lincolnshire Wolds served the whole of Lincolnshire. The route to the axe factories was most probably up the River Aire to its source, over into Ribblesdale, and then by way of Settle, Ingleton, Kirkby Lonsdale, Kendal, and Ambleside, into Great Langdale.

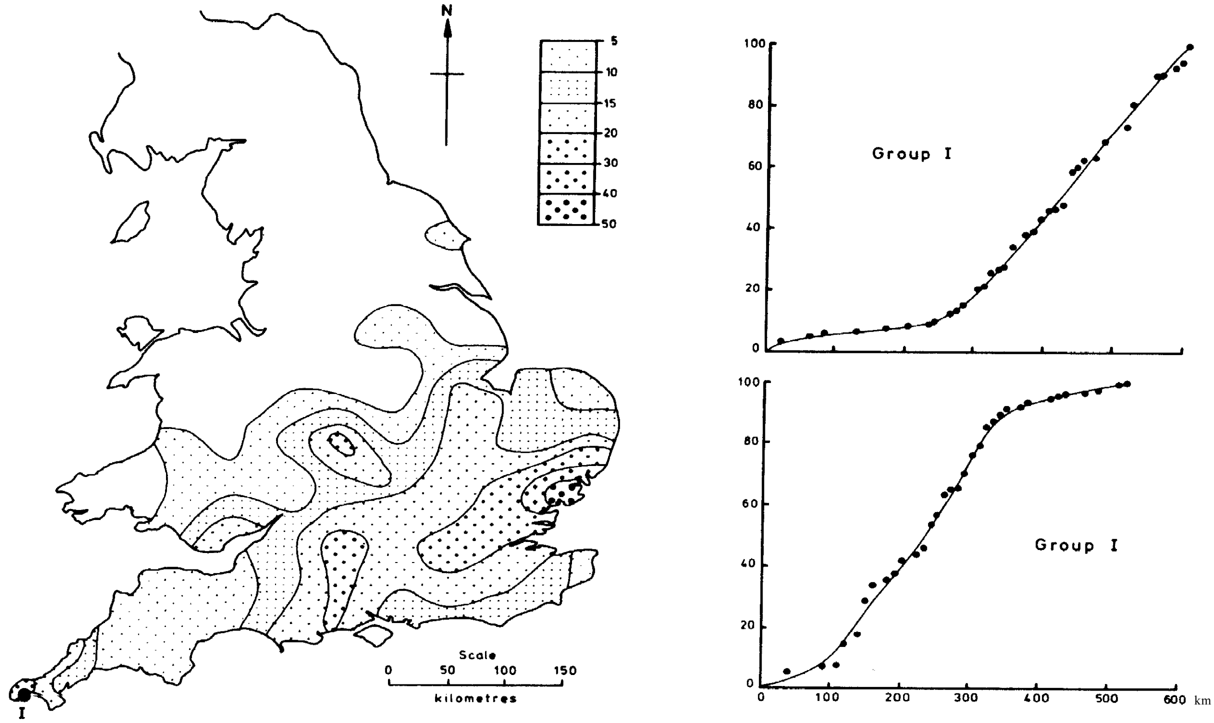
The Essex coast centre, by contrast, seems to have been isolated from any communities further inland (Clough & Green 1972), though having a perfectly good route to the Group I axe factory by sea, along the south coast. London would then, as now, have been a much better centre for the distribution of goods. The River Thames cuts through the Chalk ridge just west of Reading, whence the Chilterns lead north-eastwards to East Anglia, and the Berkshire Downs and the River Kennet lead westwards to Avebury and Windmill Hill. Further north-west, the Thames and its tributaries can be followed up into the Cotswolds, whence there are routes by river or ridgeway into the Midland counties. But the Essex coast maximum is well defined and soundly based; nor is there any reason to suppose that the axes still awaiting petrological examination from the London area will raise Group I to a comparable percentage there. The explanation for this anomaly may lie in the accidents of marine transport; in the possibility of boats being blown off course and perhaps even wrecked.

The isolated Essex coast community would have been dependent largely on local erratics for making stone axes. Accidental landings and wrecks bringing good Cornish axes into their hands would have been more than welcome and, if frequent, could have supplied a large part of their needs. In the London area, on the

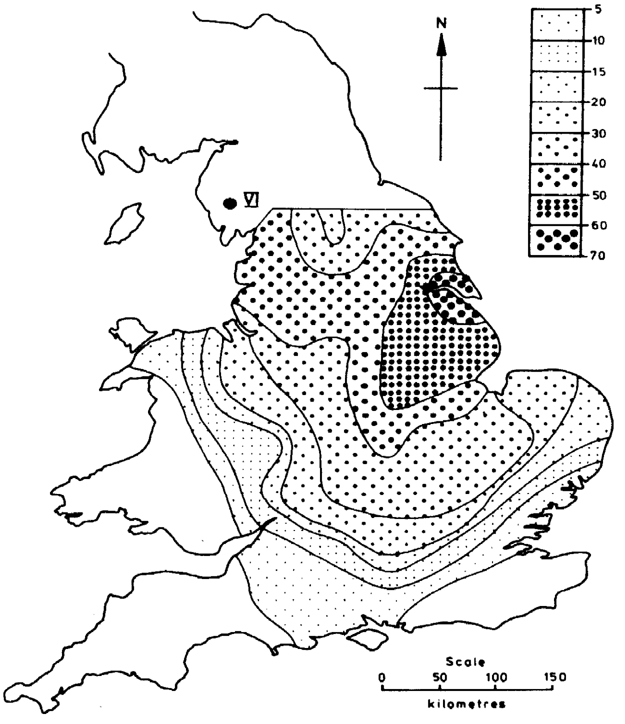




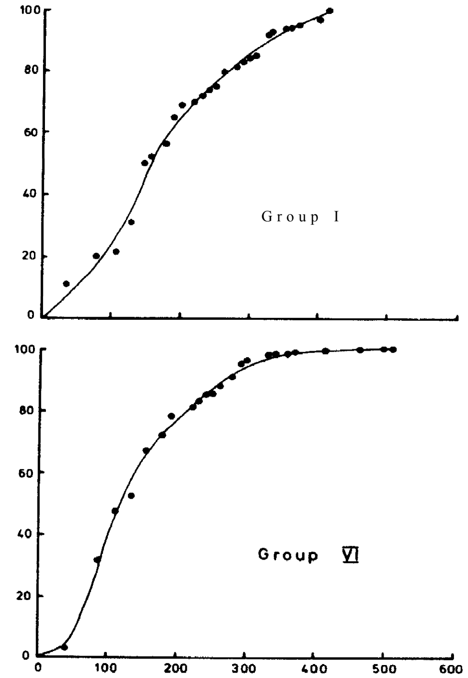
6 a *Relative frequency (%) distribution map for Group VII axes, showing the position of the axe factory.* b *Cumulative frequency (%) plot of all Group VII axes against distance from the axe factory*



7a Relative frequency (%) distribution map for Group I axes, showing the probable position of the axe factory. b, c *Cumulative frequency (%) plots of all Group I axes against distance from the axe factory and the centre of the Essex coast maximum (Fig 7, a) respectively*



8 Relative frequency (%) distribution map for Group VI axes, showing the position of the axe factory



9 Cumulative frequency (%) plots of all Group I and Group VI axes against distance from the centre of London and the centre of the Humberside maximum (Fig 8) respectively other hand, the communications were so good that axes from all over the country are found. Groups VI and VII, from the Lake District and North Wales, are together as abundant as Group I itself, and Group IX, from Northern Ireland, also occurs in significant numbers. Groups VIII, XVIII, and XX, from South Wales, Northern England, and the Midlands, are found in the London area too. The presence of these groups, while emphasizing the wide connections of London with other areas, tends to reduce the relative importance of Group I, particularly by comparison with the Essex coastal area, which lacked such connections. The Essex coast maximum, though it is so prominent on the distribution map for Group I (Fig 7a), could in fact be an accidental by-product of a stone axe 'trade' which was really based in the London area. A cumulative percentage plot of all known Group I axes against distance from the centre of London (Fig 9) is consistent with this suggestion. Some 50% of all known Group I axes have been found within 160 km of the centre of London, a distance which compares well with similar figures for the factory-centred groups (Table I).

Half way along the south coast, there is another Group I maximum extending up the River Avon into Salisbury Plain (Fig 7a). This suggests the possibility that Christchurch Bay may have been a regular port of call on the journey between Cornwall and the Thames estuary.

Conclusions

1. Most stone axe groups have distributions centred around their respective axe factories or presumed source areas. This is just what would be expected from a simple model of primitive trade.
2. Two groups, I and VI, are exceptional in having their distribution patterns centred several hundred kilometres from their source areas. For these groups, the trade started with bulk carriage of axes from the factory to a secondary distribution centre.
3. Motivation for this bulk trade probably came from the consumers and is unlikely to have been the result of a sales drive from the axe factory.
4. The secondary distribution centre for Group I axes may have been the Neolithic precursor of the modern port of London.

Acknowledgements

A paper of this sort inevitably relies heavily on the work of others. Much of this work is published and is acknowledged in the text, but there are still considerable areas for which the published data are very incomplete. I am most grateful for the generous cooperation of workers in this field, who have willingly supplied me with unpublished information from these areas and brought me up to date with the latest results on published areas:- Professor F W Shotton and Dr Helen Bamford (West Midlands), Mr C H Houlder (Wales), Mr D Robinson (Lancashire and Cheshire), Dr Isobel Smith (south-western counties), Mr A M Burchard (Hampshire), Mr E E Harrison (Surrey), Mr A G Woodcock (Sussex), Mr D B Kelly (Kent), and Drs A R Woolley and A C Bishop, who sent me a large collection of new thin sections from the south-eastern counties, as soon as they were made. Mr R V Davis and Mr J C Scott also kindly supplied information, from northern England and Scotland respectively, but results from these areas have not yet reached the stage where they can be used in relative frequency distribution maps with any degree of confidence. I am also grateful for the continuing help received from the archaeologists with whom I am myself collaborating in this work:- Dr Pat Phillips (Yorkshire), Mr T H McK Clough (Lincolnshire, Nottinghamshire, and Leicestershire), Mr C N Moore (Derbyshire), Mr A Gregory (East Anglia), Mr W R Moore (Northamptonshire), Mr J Rhodes (Oxfordshire), and Mr C N Gowing (Buckinghamshire).

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The chronology of British stone implements

I F Smith

Abstract

A chronological framework, based mainly on radiocarbon dates, is sketched for Neolithic and Early Bronze Age stone implements. The nature and reliability of the dating evidence for axes and shafthole implements in general is discussed. Attention is focused on the chronology of imported artefacts and of those that have been identified as 'factory' products. Axes can be dated only by the associations of the relatively few specimens found in context; shafthole implements can, on the other hand, be dated with varying degrees of precision by typology.

Introduction

The aim of this paper is to bring together the dating evidence for implements of the types conventionally assigned to the Neolithic period and to the Early Bronze Age, *c* 3250 BC to *c* 1250 BC, with special reference to those that have been identified as imports or as the products of 'axe factories' (Fig 1). Recent discoveries have suggested that the manufacture of artefacts resembling Neolithic polished stone axes (Evans 1975, 3) and the utilization of fine-grained rocks ascribed to some of the factories (Ireland & Lynch 1973, 171) may have a long pre-Neolithic history. The implications of these discoveries are not yet sufficiently clear to be incorporated in this paper, but are touched upon again in connection with Group VIII rock *(see below,* Section III).

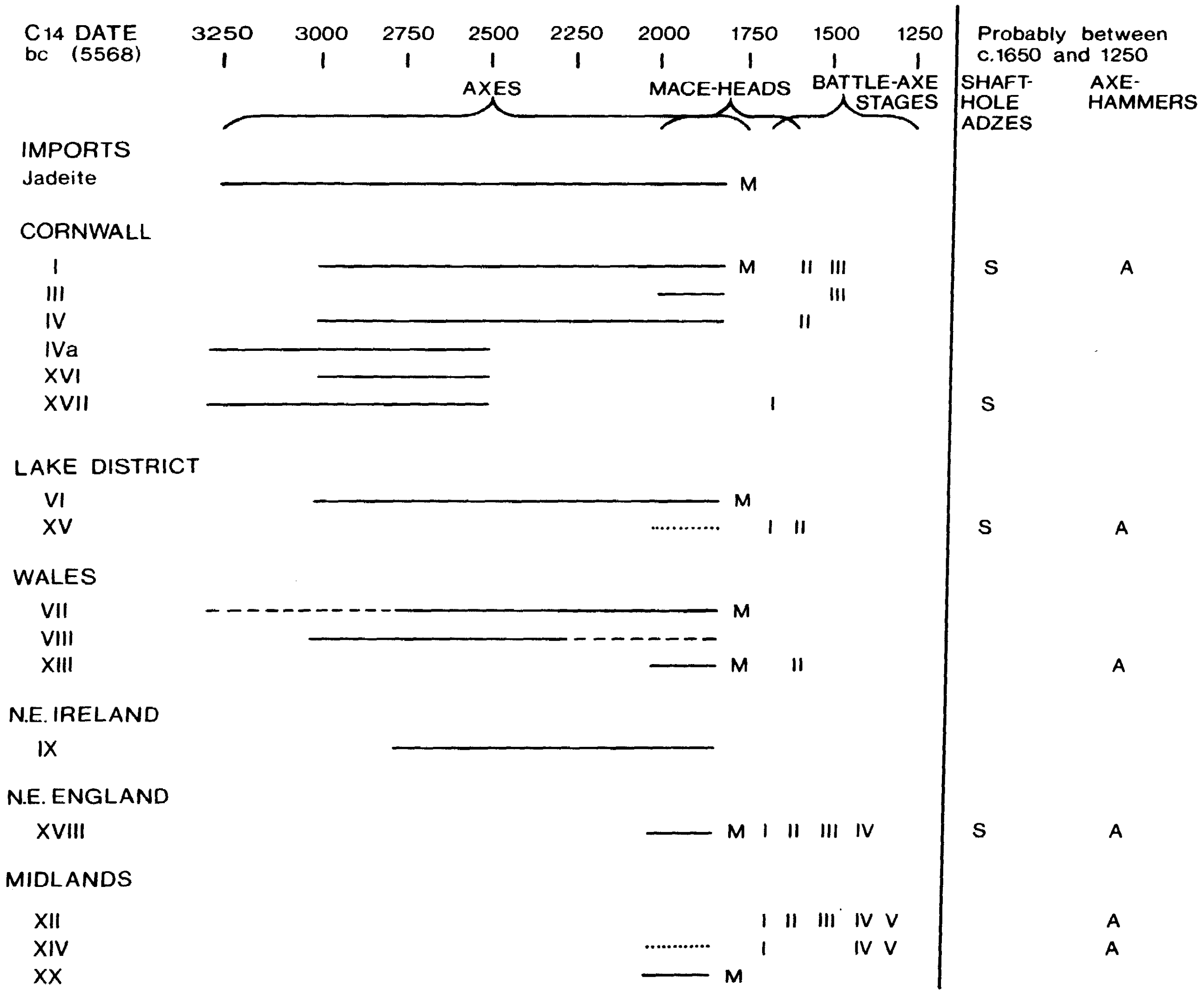
The paper has three main sections. A preliminary discussion of the evidence relied upon for the dating of axes and of shafthole implements as types is followed by a consideration of the radiocarbon determinations obtained from axe factories. In the third section attention is directed to the chronology of imports and of those implements ascribed to selected petrological groups and to the range of products represented in each instance. Most of the background information for the latter section is derived from regional surveys (Evens *et al* 1962; Kelly 1964; Keen & Radley 1971; Clough & Green 1972; Evens *et al* 1972; Cummins & Moore 1973; Moore & Cummins 1974), from papers concerned with the petrology and products of specific groups (Shotton *et al* 1951; Shotton 1959) and from papers dealing with specific implement types (Roe 1966; 1968). The records of the implement petrology survey for south-west England have been drawn upon for some unpublished information. Uncalibrated radiocarbon dates are cited throughout this paper.

I The dating of implement types

Axes

It is suggested in Figure 1 that axes made of igneous and metamorphic rocks were being manufactured in the British Isles over a period of at least 1500 radiocarbon years, from *c* 3250 BC to *c* 1750 BC. The diagram is divided into 250-year intervals because the imprecise nature of the evidence does not permit finer distinctions. Much of that which has had to be called into play as 'evidence' is indirect, inferential, or of dubious reliability. In many cases conclusions have been based upon single radiocarbon determinations; although such 'evidence' has here been taken at face value, the degree of uncertainty involved in this process needs to be borne in mind. Problems that are perhaps less immediately obvious arise in connection with the actual relationship between the samples of organic material that have provided the determinations and the axes that they purport to date. The association may be loose, as in cases of superficial, but apparently significant, juxtapositions to dated features; or it may be open to doubt because of the possibility that residual material may have been introduced, by accident or by intent, into later contexts.

Here it has been assumed that surface finds probably relate to the main period of activity on the site in question; hence, for example, the proposed extension of date for Group I axes on the strength of the presence of unstratified examples at Carn Brea (for details, *see* Section III). On intensively occupied sites artefacts deriving from an early phase may be incorporated in deposits belonging to a later one. The possibility of perceiving such anachronisms depends upon informed observation during excavations, as in the case of the Group VI axe fragments from Abingdon, or on the existence of enough other information to indicate a deviation from the normal pattern, as argued below in connection with the Group XVII axes from Maiden Castle. Because of the symbolic significance that has been attached to axes from the earliest times (cf votive or foundation deposits in late 4th and early 3rd millennium structures, represented by a jadeite axe beside the Sweet Track in the Somerset Levels and by a Group VI axe at the Class I henge monument at Llandegai), they are liable to be introduced, when functionally obsolete, into Bronze Age or later constructions (cf Jope 1952, 35; J F S Stone, in Richardson 1951, 162–3). Two additional examples of this practice, both potentially misleading if considered in isolation, have come to light in recent years. One involves a Group IX axe in a context dated to the 9th century BC (Lynn 1974), the other a Group XX axe from a deposit of the 11th (or possibly 8th) century BC (Bradley & Ellison 1975, 87); further particulars will be found in Section III. Unrecognized examples of this practice, or of chance survival on occupied sites, may have led to misinterpretations in these pages. The problem is of course especially acute and difficult to resolve when an attempt is to be made to define a lower limit to the period of axe production.



Axes :

——— Apparent minimum period of currency

- - - - - - - - **Possible** extension. evidence uncertain

…………… Few identified. none datable

M Mace-head(s)

S Shaft -hole adze (s)

A Axe-hammer(s)

'Diagrammatic representation of the chronology and range of products of selected imports and petrological groups. Dates for axes are indicated to the nearest 250 year intervals

Cessation of demand for stone axes must have been a gradual and uneven process, dependent upon the rate at which metal axes became available to individual communities. As Burgess (1976, ii-iii) has pointed out, it is now evident that the initial industrial stages of metal working overlapped entirely with the traditional 'Late Neolithic' *(c* 2200-1700 BC) and therefore with the final phase of stone axe production, as attested by the pattern of associations with 'Late Neolithic' ceramics and structures noted for axes of various groups in Section III. A pattern of recurrent associations, which seems to offer a suitable *terminus ad quem,* is to be found in a number of settlements in Cornwall and Northern Ireland which appear to stand at, or just beyond, the point of transition to the Early Bronze Age as defined in terms of ceramic sequence. Although Mercer (1970, 36) postulated a production date around 1500 BC for two ungrouped axes associated with the field system of Phase I at the Stannon Down settlement in Cornwall, the ceramic evidence suggests contemporaneity with the Phase II house and a Group Ia axe at Site XV, Gwithian (Megaw 1976, 36, 65). The presence of a few

Beaker sherds on the latter site, and the Beaker-derived attributes of the earliest Bronze Age (pre-Trevisker) pottery there and at Stannon Down, permit correlation with the three or four Cordoned Urn settlements in Northern Ireland which have produced Group IX axes (ApSimon 1969, 49). In one of these, at Downpatrick, a few Beaker sherds were again recovered from a house which contained a stone (Group IX) axe; the marked degree of Beaker influence on Cordoned Urns has been pointed out by ApSimon (1969, 49) and Megaw (1976, 61). If it can be accepted that these finds do conform to a pattern, it is perhaps immaterial whether the axes are to be interpreted individually as residual or as testimonies to magical or practical use. In the present state of knowledge they provide the firmest available indication that the production of stone axes had ceased by, or soon after, the end of the first quarter of the 2nd millennium. Another critical marker is afforded by the flanged bronze axe from the ditch of the Mount Pleasant henge monument, which lay immediately above a sample yielding the date of 1778 BC ±59 (BM–646) (Burleigh *et al* 1972, 398).

Shafthole implements

The following discussion is intended to provide a framework for, and to be read in conjunction with, Roe's contribution to this volume and her previous papers on the typology and associations of mace heads (Roe 1968) and of battle axes (Roe 1966). Attention will be directed to new evidence bearing on the absolute dating of these two classes of implement, the only members of the series with reliable associations. Shafthole adzes and axe hammers, nearly always casual finds or from uncertain contexts, are assumed to have been broadly synchronous with battle axes. In view of the diffuse nature of the apparent associations of pebble hammers (Roe, this volume), the dating of this class is clearly not a topic that can be discussed with profit in the present paper.

Mace heads

The ovoid, pestle, and cushion varieties. The suggestion that stone mace heads may derive from antler prototypes (Roe 1968, 159–62) seems to be supported by the circumstance that the earliest well-dated mace head of any kind is a crown antler example; it comes from the Neolithic II level at Northton, Isle of Harris, dated 2461 BC ±79 (BM–705), where the ceramic associations include both Hebridean and Unstan wares (Simpson 1976, 222). The question of the circumstances and timing of the translation from antler to stone was examined in detail by Roe (1968) in her study of ovoid and pestle mace heads, the only varieties then known from datable contexts. Metrical analyses indicated close similarity in the positions and dimensions of the shaftholes in both battle axes and mace heads; although the mace heads were found to occur consistently in non-Beaker contexts, and the relatively few associations of the typologically early battle axes were found just as consistently with developed Beakers, neither class of implement could be shown to have priority. It therefore seemed reasonable to suggest that the technique of drilling straight holes through stone might have been introduced by the makers of battle axes (Roe 1968, 169).

New evidence permits a tentative re-assessment of mace head/battle axe relationships. During the recent excavations at the Grooved Ware settlement at Skara Brae, Orkney, a fragment of a stone mace head of the cushion variety was recovered from near the top of the latest midden, a layer for which two radiocarbon dates have been obtained: 2070 BC ±110 (Birm–434) and 1881 BC ±110 (Birm–433). The mace head fragment is illustrated by Roe (this volume, Fig 9, 1) and the context of the find by D V Clarke (1976, Fig 13, 4). Part of a pestle mace head, unstratified, was already known from Skara Brae, and a fragmentary example of the ovoid variety seems to have come from a late deposit at the contemporary settlement of Rinyo, Rousay (Roe 1968, 153–4).

The single date that can be related directly to early battle axes is that of 1564 BC ±120 (BM–441), obtained from a cache of carbonized grain found at the base of the ash fill in one of the walls of House 1, Ness of Gruting, Shetland. In addition to a Stage I battle axe from the ash fill itself, a second example, together with one of Stage II, came from the floor of the house (Calder 1956, 353, 392; Roe 1966, 222). The three Stage I battle axes from Beaker graves in Wiltshire and Yorkshire are associated with vessels of Clarke's Southern British Beaker series (Clarke 1970, Appendix 6, Beakers 1103, 1119, 1296; Roe 1966, Appendix I, battle axes 235, 224, 261). Clarke's tentative chronology for Southern British Beakers placed them between *c* 1600 BC and *c* 1500 BC. Lanting and van der Waals (1972, 27, 40, 44) have subsequently assigned such Beakers to Step 6 in their revision of Clarke's scheme and dated them from *c* 1700 BC to *c* 1550 BC. The radiocarbon dates for Step 6 Beakers now available are in broad agreement with the latter estimate. A determination of 1850 BC ±150 (BM–133), obtained from a domestic site at Fifty Farm, Isleham, Suffolk, was interpreted by Clarke (1970, 223) as providing a *terminus post quem* for Late Southern Beakers, and that of 1570 BC ±150 (BM–77) as a *terminus ante quem* for a Final Southern Beaker domestic site at Wattisfield in the same county. Six dates relating to Beaker domestic refuse dumped in the ditch of the Class I henge monument at Gorsey Bigbury, Somerset, indicate a mean age of 1736 BC ±77 for vessels that are mostly attributable to Step 6 (ApSimon *et al* 1976, 178–80). The date of 1550 BC ±150 (BM–75) from the upper fill of the ditch of the causewayed enclosure at Windmill Hill, Wiltshire, loosely associated with Developed Southern Beaker sherds, may be compared with that of 1610 BC ±120 (BM–285) from Hearth V in the fill of the north ditch at Durrington Walls, associated with typologically late Beaker sherds and correlated stratigraphically with a horizon in the south ditch which produced a similar piece (Burleigh *et al* 1972, 401–2). Finally, a determination of 1473 BC ±62 (Birm–84) comes from a grave at Ysgwennant, Llansilin (formerly in Denbighshire), which contained Developed Southern Beakers (Clarke 1970, Appendix 6, Beakers 1854–5).

Consequently it is now possible to suggest that some of the ovoid, pestle, and cushion mace heads may antedate at least those battle axes that have so far been found in datable contexts. That some of them continued in use side by side with Stage I/II battle axes is indicated by the association of an Orkney pestle mace head with a Yorkshire Vase Food Vessel at Doune (formerly in Perthshire) (Roe 1968, 155).

The Bush Barrow and Largs groups. The associations of mace heads with centrally placed shaftholes, discussed by Roe (this volume), suggest that these may be somewhat later than the other varieties. The most closely dated examples are the two from Bush Barrow and Towthorpe (Roe, this volume, Fig 10, D, A), each associated with bronze daggers of Bush Barrow type. In his recent discussion of the 'Bush Barrow group' of

Early Bronze Age graves, Burgess (1974, 189-90) has proposed a starting date as early as the 19th century BC, ie before *c* 1650 BC in terms of radiocarbon years based on the 5568 half-life. Other mace heads of the Bush Barrow and Largs varieties, found with Collared or Cordoned Urns, may be placed within the broad limits offered by radiocarbon determinations for such urns, from *c* 1650 BC to *c* 1250 BC (for a list of relevant dates, *see* Burgess 1974, 225–7). The comparative rarity of these mace heads in grave-groups, and the nature of such associations as there are with metal artefacts, may, however, suggest that they belong to the earlier part of this period.

As shown in Fig 1, mace heads may have appeared early in the first quarter of the 2nd millennium BC, overlapping with the final phase of stone axe production. They may have fallen out of fashion sometime during the third quarter of that millennium, when there was perhaps a shorter phase of overlap with battle axes.

Battle axes

It must be emphasized that the regular chronological sequence of battle-axe typological stages shown in Fig 1 is purely a device of convenience, adopted in order to display in diagrammatic form the existing information about specimens made of grouped rocks and the stages of battle axe development which they represent in the scheme set forth by Roe (1966), now simplified to Early, Intermediate, and Developed (Roe, this volume, Figs 1, 2). The overall sequence is not in doubt; the other grave-goods found with Stage I battle axes are clearly earlier than those found with Stage V battle axes, but allowance must be made for a degree of overlapping between one stage and the next.

As will be evident from the previous discussion of the absolute dating of Stage I battle axes, radiocarbon determinations do not yet offer a closely defined point for their introduction. The evidence does, however, permit the suggestion that this may have occurred early in the 17th century BC. Information about the end of the series is more satisfactory. The grave-group from Hove in which a Stage V battle axe (Roe 1966, Appendix I, battle axe 207) was associated with a Camerton-Snowshill dagger, is dated 1239 BC ±46 (BM–682) and so carries with it the Stage V battle axe (Roe 1966, Appendix I, battle axe 75) from the grave at Snowshill which contained a dagger of the same type. The date is consistent with other evidence indicating an abrupt end for the Early Bronze Age and the apparently simultaneous cessation of demand for battle axes around the middle of the 13th century BC (Burgess 1974, 194). Thus it appears that the British battle axe series, beginning with the simple Stage I form , and displaying thereafter a range of typologically evolving, regionally specialized variants (Roe 1966, 205–12), was spread over a period of the order of four radiocarbon centuries.

Shafthole adzes and axe hammers

As shown in Fig 1, most of the identified rock sources that were exploited for the manufacture of battle axes were also used to make shafthole adzes (Roe, this volume, Fig 13) or axe hammers (Roe, this volume, Figs 7, 8), or both. This petrological link is interpreted, for want of better evidence, as an indication that the three classes of implement were being produced concurrently and that shafthole adzes and axe hammers date from *c* 1650 BC to *c* 1250 BC.

II Axe factories

Amongst the several categories of evidence that may contribute to the dating of stone implements, that obtained from working sites is likely to be the most reliable. But unless an extensive series of radiocarbon dates can be obtained, as from the factory near Plussulien in Brittany (Le Roux 1971; this volume), the resulting information is necessarily limited in scope, as is the case with the three working sites that have so far produced radiocarbon dates in Britain.

The two determinations obtained for a chipping floor on Thunacar Knott, near Pike o' Stickle in Cumbria, 2730 BC ±135 (BM–281) and 2524 BC ±52 (BM–676), indicate that axes of Group VI (Langdale) rock were being made there around the middle of the 3rd millennium BC (Clough 1973). As suggested by Clough, and discussed further in Section III of this paper, activity at this particular site probably correlates with the period of most intensive exploitation in the Langdale area rather than with its beginning or end.

Waste from the manufacture of axes of Group XXIV rock at Creag na Caillich, Killin, in central Scotland, is dated by means of deposits of peat lying immediately beneath and above it; the respective results were 2510 BC ±90 (UB–371) and 2250 BC ±90 (UB–372) (MacKie 1972, 415). In the absence of further information about the products, associations, and distribution of this group, the significance of these dates is difficult to assess.

Finally, a hearth set in the silted-up hollow of the workings on Mynydd Rhiw, north-west Wales, and dated within the 12th century BC provides a *terminus ante quem* for the cessation of extraction of Group XXI rock (Houlder 1961, 141).

III Imported and 'grouped' artefacts

Imports

Jade. No other artefact to be discussed is so precisely and securely dated as the splendid jade axe found beside the Sweet Track in the Somerset Levels (Coles *et al* 1974). Eight radiocarbon determinations date the apparently deliberate act of deposition around 3200 BC. Five other jade axes have been recovered from less closely defined Neolithic contexts. A fragment from High Peak, Devon, and two axes from Hambledon Hill, Dorset, are surface finds from earlier Neolithic sites; the relevant radiocarbon dates will be found in Table I. Another fragment, again a surface find, was loosely associated within a restricted area at the top of Ebbor Gorge, Somerset, with a Group VII axe and other artefacts suggestive of occupation. A date within the latter half of the 3rd millennium would seem appropriate in the light of the evidence, discussed below, for the time of dispersal of Group VII axes in southern England. A very small fragment from the paving in the outer compartment of a chambered tomb, Cairnholy I, in south-west Scotland (Piggott & Powell 1949, 137) appears to have been contemporary with Beaker sherds and other pottery of later Neolithic aspect, probably datable around 2000 BC. Two further artefacts are likely to belong within the first quarter of the 2nd millennium. One is a small chisel-like object which accompanied a cremation under a round barrow at Brownstone Farm, Kingswear, Devon (Rogers 1947; Evens *et al* 1972, 254); its dimensions are such as to allow the possibility that it may represent a reworked axe. This is not the case with the cushion mace head

Table I Distribution of stone axes on earlier Neolithic sites in south-west England

	Cornish Groups					Other Groups			Other
	I	IV	IVa	XVI	XVII	VI	VIII	Jade	rocks
Hembury	-	-	4	-	1	-	-	-	11
Carn Brea	4	2	-	19	1	-	-	-	20
Hazard Hill	-	1	1	2	2	1	-	-	8
High Peak	-	1	-	-	-	-	-	1	2
Hambledon Hill (1974-5 excavations)	-	1	-	2	-	1	1	2	5
South Cadbury	-	-	1	-	-	-	-	-	-
Maiden Castle	-	1	4	1	2	-	-	-	6

Particulars of radiocarbon dates

Hembury (Devon)	BM-138: 3330 BC ± 150: burnt layer in ditch BM-130: 3150 BC ± 150: charcoal from ditch bottom BM-137: 3240 BC ± 150: occupation site Groups IVa and XVII appear to be securely dated here.
Carn Brea (Cornwall)	BM-825: 3049 BC ± 64: burnt structure covered by enclosure wall BM-824: 2747 BC ± 60: collapse of enclosure wall Some axes, in derived positions, could be earlier than BM-825.
Hazard Hill (Devon)	BM-149: 2970 BC ± 150: charcoal from pit BM-150: 2750 BC ± 150: charcoal from occupation level Axes unstratified, except for those of Group XVII.
High Peak (Devon)	BM-214: 2860 BC ± 150: charcoal from pit Jade axe unstratified.
Hambledon Hill (Dorset)	NPL-76: 2790 BC ± 90: charcoal from bottom of ditch Probably provides a *terminus post quem* for all except two ungrouped axes.
South Cadbury (Somerset)	I-5972: 2755 BC ± 115: hazel-nut shells from Pit 154 I-5970: 2510 BC ± 120: antler from same pit Dates provide a probable context for, but are not directly associated with, the Group IVa axe.
Maiden Castle (Dorset)	Ceramic associations indicate contemporaneity with the other sites.

with unfinished perforation from Bottisham, Cambridgeshire (Clough & Green, 1972, Fig 13, CAM 55), which is clearly too thick to derive from a normal jade axe.

Group X (Sélédin, Plussulien, Côtes-du-Nord). All four of the axes found in England are without associations. The factory was in production before the end of the 4th millennium and dispersal to sites on the coast of Brittany had begun by the first quarter of the 3rd millennium (Le Roux 1971).

Cornwall

Since axes ascribed to several of the Cornish groups frequently occur together on Neolithic sites in south-west England, and since radiocarbon determinations obtained from these sites constitute the main source of dating evidence for most of these groups, the relevant information is assembled in Table I. The table also demonstrates the repetitive pattern of associations between axes of Groups IV, IVa, XVI and XVII as well as the anomaly presented by the occurrence of Group I axes at one site only.

Group I. Axes of this group have hitherto seemed to represent a late phase of production in Cornwall. Associations with Grooved Ware in Wessex and Essex and with ceremonial monuments in Wiltshire (Evens *et al* 1972, 253) point consistently to a date around 2000 BC for distribution outside Cornwall and, prior to the recent excavations at Carn Brea, Group I axes had not been reported from earlier contexts. Four axes of this group are now known from Carn Brea, where indications of a late Neolithic presence are minimal. Although none of them was securely stratified within the occupation levels, it is difficult to find a context for them other than that provided by the main period of Neolithic activity on the site, ie within the first quarter of the 3rd millennium. The circumstance that Carn Brea lies within a short distance (about 20km) of the presumed source of Group I rock in the Mount's Bay area may suggest one possible explanation of the apparent anomaly. Group I axes, much less numerous in Cornwall than elsewhere (Evens *et al* 1972, Fig 1; Cummins, this volume, Fig 7a), may at first have been produced on a small scale and distributed within the immediate vicinity of the source; the major dispersal to distant areas may reflect a subsequent expansive phase of production. Alternative explanations may seem equally possible, but at least the validity of this one can be put to the test in the light of further discoveries.

In view of the Grooved Ware connections of several Group I axes, it may be significant that eight mace heads of the ovoid and Thames pestle varieties, as well as an unperforated pestle-shaped object, probably an unfinished mace head, have been ascribed to the group. Their distribution pattern conforms to that of the bulk of Group I axes, as does that of three shafthole adzes; none of these comes from Cornwall. Two battle axes (representing Stages II and III) and one axe hammer are all, on the other hand, from Cornwall.

Group III Two axe fragments from Stonehenge are the only ones in context; a late 3rd/early 2nd millennium date may therefore be suggested for this numerically small group. Two battle axes are known, both of Stage III.

Group IV. The presence of axes of this group at Carn Brea, Hazard Hill, High Peak, Hambledon Hill, and Maiden Castle is taken as evidence that production is likely to have begun during the first quarter of the 3rd millennium. A fragment from Floor 15 at Grimes Graves, Norfolk, suggests that Group IV axes may have continued in use until the end of the 3rd or the beginning of the 2nd millennium. The single shafthole implement is a Stage II battle axe.

Group IVa. The group comprises fifteen axes; of these ten come from four Neolithic sites (Hembury, Hazard Hill, South Cadbury, and Maiden Castle); the other five are casual finds from Devon, Dorset, and Somerset. The presence of four examples at Hembury indicates that the axes were already in circulation during the last quarter of the 4th millennium; the restricted distribution and range of dated contexts suggests that production had probably ceased by the middle of the 3rd.

Group XVI. Most of the axes are recorded from Cornwall, with a thin scatter extending to East Anglia and the north Midlands. Group XVI is not represented at Hembury; roughouts and finished axes to the number of nineteen at Carn Brea (in the immediate vicinity of the presumed source in the parish of Camborne) suggest that production was under way by *c* 3000 BC. No examples have so far been recovered from contexts that need be later than *c* 2500 BC *(see* Table I).

Group XVII. Seven of the eleven recorded axes come from Hembury, Cam Brea, Hazard Hill, and Maiden Castle; the remaining four are casual finds from Cornwall, Devon, and Dorset. A period of production and use parallel to that of Group IVa seems to be indicated, although the evidence from Maiden Castle is perhaps ambiguous. One of the Group XVII axes from that site was found in a pit together with Beaker sherds, and was thought by the excavator to be derived (Wheeler 1943, 166); the other came from a layer with a mixed ceramic content. In view of the other associations it seems unlikely that axe production extended over a long period; on the other hand, 2nd millennium exploitation is attested by a Stage I battle axe and a shafthole adze. It should, however, be noted that two sources of Group XVII rock have been identified (Evens *et al* 1962, 223) so that there need not necessarily be a connection between the earlier and the later use.

The Lake District

Group VI. The radiocarbon dates obtained from the chipping floor on Thunacar Knott (Clough 1973) have been mentioned in Section II, where it was suggested that they indicate that activity on this particular site, sometime between *c* 2800 BC and *c* 2500 BC, may be correlated with the time of maximum expansion of the Langdale industry. There is some evidence, indirect or ambiguous and more persuasive in combination than in detail, that seems to support the assumption that exploitation had begun before the first quarter of the 3rd millennium.

Sediments in small lakes around the known working sites attest to episodes of small-scale and temporary interference with the natural environment from *c* 3700 BC, followed by more extensive forest clearance beginning around 3100 BC and reaching a peak around 2500 BC (Pennington 1970; 1975). The latter is confidently attributed to the presence of Neolithic settlers and, in an area devoid of alternative sources of material suitable for axe manufacture, would seem to imply synchronous and gradually intensifying exploitation of the Langdale rock. Despite the absence of artefactual confirmation, it seems possible that the transient earlier episodes might relate to the time of initial discovery of the desirable properties of the rock and its use to meet local needs. It may be significant that parallel and contemporary phenomena at Ballyscullion in Northern Ireland, also unaccompanied by archaeological material, can be correlated with the earliest Neolithic presence at Ballynagilly (A G Smith 1975, 64). In view of the hints, discussed below, that widespread dispersal of Group VI axes may already have been taking place around 3000 BC, it seems reasonable to postulate a preliminary phase of discovery and development.

At Williamson's Moss, Eskmeals, a coastal site in Cumbria, an axe rough-out has been recovered from a position indicative of association with oakwood clearance, here taking place not long after the elm decline (ie, after *c* 3100 BC) (Pennington 1975, 84). The earliest of several dates relating to another coastal site at Ehenside Tarn, 3014 BC ±300 (C–462), cannot be related directly to any of the artefacts recovered (which suggest that axe finishing was one of the activities represented) and therefore cannot be used as evidence, though it no longer seems as unlikely as once it did (Piggott 1954, 296). Fell (1964, 41) has suggested that the date may reflect an initial phase of local use, prior to the 'export' phase.

Flakes and fragments of Group VI axes recorded from sites with early dates in parts of Britain remote from the Lake District afford clues to the beginning of this phase. One was associated with a Neolithic house at Fengate, Peterborough, Cambridgeshire, for which there are two radiocarbon dates: 3010 BC ±64 (GaK–4196) and 2445 BC ±50 (GaK–4197)(Pryor 1974, 12, 38). In the present state of knowledge, either determination would seem appropriate for the house and its contents. At Llandegai, in North Wales, a Group VI axe, deposited as a votive offering in a primary position in the Class I henge monument, is dated 2790 BC ±150 (NPL–220) (Houlder 1976, 59). Dr Alasdair Whittle has kindly supplied information about the context of the only Group VI axe fragment from the causewayed enclosure at Abingdon, Oxfordshire, of which the stratified position is known; it was found in the upper fill of the inner ditch during the 1963-4 excavations. Observations made during these excavations suggest that this ditch had been recut and had then silted up gradually; material from the earlier phase of activity may therefore have been redeposited in the top of the fill. A radiocarbon determination for the layer which contained the fragment gave the results 2510 BC ±140 (BM–355); others obtained for underlying layers range from 3110 BC ±130 (BM–331) to 2500 BC ±145 (BM–354). It is therefore possible that the axe fragment may relate to the late

4th/early 3rd millennium activity to which some of the radiocarbon dates seem to attest. Single flakes from Group VI axes, both surface finds, come from the Neolithic sites at Hambledon Hill, Dorset, and Hazard Hill, Devon *(see* Table I). Here again, the circumstances are suggestive but inconclusive. Finally, the presence amongst the ungrouped axe fragments from Carn Brea, Cornwall, of an example made of a tuff similar to, but not identical with, Group VI rock lends substance to the idea that axes of Lake District origin were in circulation by at least the first quarter of the 3rd millennium.

The latest certain associations for Group VI axes appear to be with Beakers. A battered fragment from Chew Park, Somerset, came from a pit which also contained a cremation, sherds of typologically early Beakers, a barbed and tanged arrowhead, and other Beaker flintwork (information from A M ApSimon, entered on the petrological record card). Other fragments are recorded from Beaker domestic sites in the parish of Hockwold-cum-Wilton, Norfolk (Clough & Green 1972, 137–40). The majority are surface finds; one, from a stratified position, was associated with Beaker sherds and 'others resembling food-vessel types'. Beakers from these sites, as listed by Clarke (1970, Appendix 6, Beakers 553–8), include examples of developed forms; a date round the end of the first quarter of the 2nd millennium would seem appropriate.

The existence of three cushion mace heads made of Group VI rock (Cummins & Moore 1973, Fig 5, 326; Evens *et al* 1972, Fig 5, Berk 55; Stanley 1976, 6, illus) and of a perforated disc (Evens *et al* 1972, Fig 5, Wilt 305) attests to a final phase, contemporary with or overlapping the tail-end of axe manufacture, when a limited number of new types was produced. In view of its petrological affinities, it seems reasonable to attribute the perforated disc to a late Neolithic context, on analogy with a similar artefact from Ronaldsway, Isle of Man (Piggott 1954, Fig 61, 3).

Group XV. Axes ascribed to this group are few in number and no associations are recorded for published examples. Shafthole implements, which include battle axes of Stages I and II, axe hammers, and shafthole adzes, seem to constitute the main output.

Wales

Group VII. At Llandegai, close to the source on Graig Lwyd, fragments of Group VII axes were recovered from a pit adjacent to, and believed to be contemporary with, a house dated 3290 BC ±150 (NPL–223) (Houlder 1976, 58, 60–1). On the basis of the information at present available, Fig 1 indicates a provisional starting date for the Graig Lwyd industry at 3250 BC. The Llandegai evidence may indicate a phase of initial exploitation to meet local needs. The period of widespread dispersal cannot yet be placed much earlier than *c* 2750 BC. An axe from the Swaffham Engine Drain, Swaffham Pryor, Cambridgeshire, can be dated around 2700 BC by its position relative to that of the onset of Fen Clay formation (Clark 1965, 72). Another, from Shapwick Heath in the Somerset Levels, may have been deposited 150 years earlier or later than the date of 2580 BC ± 130 (Q-430) obtained from a peat sample near the find-spot (Dewar & Godwin 1963, 26). Three associated finds in Wiltshire (Evens *et al* 1972, 253), two of them with Grooved Ware, indicate that Group VII axes continued in use until the first quarter of the 2nd millennium. The circumstance that the single shafthole implement recorded is part of an ovoid mace head of Roe's Maesmore group suggests that production ceased at that time.

Group VIII. The occurrence of flakes ascribed to this source (believed to lie in south-west Wales) in a Mesolithic context at Trwyn Du, Aberffraw, Anglesey (Ireland & Lynch 1973) receives enhanced significance from the presence of a chip of Group XXI rock (from north Wales) at the same site. Discussion of the wider implications of these finds would be premature before further information becomes available. The earliest known polished axe of Group VIII is from Coygan Camp (Wainwright 1967, Appendix 2), where it was found close to a pit containing Neolithic pottery dated 3050 BC ±90 (NPL–132). At Llandegai a roughed-out block of this rock, used as an axe polisher and accompanying a cremation, came from a position in the Class I henge which suggests its contemporaneity with the Group VI axe mentioned above and the date of 2790 BC ±150 (NPL–220) (Houlder 1976, 59). A fragment from Hambledon Hill, Dorset, is less securely dated, since it came from a slot, apparently the earlier of two such features, cut into the fill of a ditch segment (information kindly supplied by Roger Mercer). Thus, although a determination from charcoal recovered from the bottom of a ditch at this site *(see* Table I) is similar to that noted above from Llandegai, the piece may post-date the material from the ditch bottom by an interval of, as yet, indeterminate length. The presence at Carn Brea of an axe of ungrouped tuff, probably originating in south Wales, indicates that axes from that area were already in circulation in the earlier part of the 3rd millennium. A complete axe from Downton, Wiltshire, came from the base of a deposit which yielded sherds of Peterborough ware as well as a few undecorated rims (Rahtz & ApSimon 1962, 140). The stratification suggests that the axe was contemporary with the earlier, Ebbsfleet, style of Peterborough ware and might therefore be dated within the second half of the 3rd millennium. However, the presence of a stylistically late (Fengate) sherd at a slightly higher level opens the possibility that the axe could be somewhat later. Fig 1 therefore indicates a tentative extension into the first quarter of the 2nd millennium. No shafthole implements have been recorded.

Group XIII. The preselite of Carn Meini and Cerrig Marchogion in south-west Wales, best known in connection with the 'bluestones' of Stonehenge, seems not to have been extensively utilized for portable artefacts. In the opinion of the writer, none of the objects of preselite from Stonehenge that Evens *et al* (1962, 250) listed as possible axe fragments is entirely convincing. Another fragment, from the upper fill of a ditch at Windmill Hill, Wiltshire, is also difficult to interpret as part of an axe (I F Smith 1965, 114). Of the few remaining genuine axes so far recorded, the only one found in context is from Maiden Castle, Dorset, It was not published by Wheeler (1943) and the information in Stone and Wallis (1951, 128) that it came from a 'non-Neolithic level' is presumably derived from a label accompanying the find. Other products include an ovoid mace head, three Stage II battle axes, and half a dozen axe hammers.

North-east Ireland

Group IX. Although the sources of porcellanite (at Tievebulliagh and Rathlin Island, Co Antrim) lie outside the formal scope of this paper, the circumstance that Group IX axes are recorded in quantity in Scotland

(Ritchie 1968, 123–6) and that their distribution extends to parts of England as remote as Kent and Dorset indicates the importance of this traffic amongst the Neolithic communities of Britain. An attempt must therefore be made to provide a chronological framework for this activity.

Examples made of porcellanite have not yet been identified amongst axes from 4th millennium contexts in Ireland (Liversage 1968, 95–6; Smith & Collins 1971, 22; Mitchell 1972; ApSimon 1976, 20). An early 3rd millennium date may be implied by flakes from Group IX axes associated with pottery in the Dunmurry style at Langford Lodge, Co Antrim (Case 1969a, 10–11) ; Case's suggestion now receives some support from the dates of 2980 BC ±80 (UB–534) and 3095 BC ±95 (UB–535) recently obtained for this style of pottery at Ballybriest ('Carnanbane'), but the life-span of the style remains uncertain. Other associations for Group IX axes within Ireland, though numerous, are not closely datable (Jope 1952, 45; Herity & Eogan 1977, 36–46). The earliest radiocarbon-dated context is that at Goodland, Co Antrim (Case 1969b), for which there is a determination of 2625 BC ±135 (UB–320E) and a *terminus ante quem* of 2200 BC ±200 (D–46). In Scotland , Group IX axes are loosely associated with two Neolithic settlements (Ritchie 1968, 124); a further fragment was recovered from the excavated site at Eilean an Tighe, North Uist (Scott 1951, 36), in an Unstan ware context. This association permits a tentative extrapolation to the Neolithic II level at Northton, Isle of Harris, dated 2461 BC ±79 (BM–705) (Simpson 1976, 222) and to the more remote Knap of Howar in Orkney, where dates range from *c* 2800 BC to *c* 2400 BC (Renfrew *et al* 1976, Fig 2). All the Group IX axes from England appear to be casual finds.

The occurrence of Group IX axes on three or four Cordoned Urn settlements in Northern Ireland (ApSimon 1969, 49, 53) has been noted in Section I, where it was suggested that the apparently recurrent pattern of associations might be taken to represent the final phase of stone axe production. The best documented of the Irish sites is the settlement at Downpatrick, Co Down, where a broken axe had been used as a packing stone in a posthole of House A (Pollock & Waterman 1964, 35). Dates of 1845 BC ±75 (UB–472) and 1625 BC ±70 (UB–471) were obtained for the lower occupation level; a few Beaker sherds (not recognized as such by the excavators, but cf Megaw 1976, 61) came from this level.

If the radiocarbon date, 865 BC ±50 (UB–599) gives a true indication of the age of a ring-cairn enclosing cremations at Camkenny, Co Tyrone (Lynn 1974), the presence therein of a Group IX axe would seem best explained in terms of the reuse of an obsolete implement for the sake of the magical properties attributed to it.

North-east England

Group XVIII. Published sources indicate that about 40 axes have been ascribed to this group, but only one appears to have come from any sort of archaeological context, and that not a particularly illuminating one: it was a surface find from the causewayed enclosure on Windmill Hill, where most of the stratified stone axes came from the upper fill in the ditches. On this insubstantial evidence a token period of currency for group XVIII axes around 2000 BC has been indicated on Fig 1. The majority of products recorded for this group comprise shafthole implements which include a few mace heads (eg Roe, this volume, Fig 9, a, c) and shafthole adzes; more numerous are battle axes (of Stages I-IV) and axe hammers. The main period of exploitation is therefore likely to have been after *c* 1650 BC.

The Midlands

Group XII. Products are confined exclusively to battle axes (Stages I-V) and axe hammers. This source was apparently first discovered and worked *c* 1650 BC and continued in use throughout the Early Bronze Age.

Group XIV. As only one axe has so far been ascribed to this Group, and as products are otherwise confined to battle axes (Stages I, IV-V) and axe hammers, it appears that, like that of Group XII, the industry represented was essentially of Early Bronze Age date.

Group XX. Only 3 of approximately 50 recorded axes come from Neolithic contexts, Two of these, formerly classified as tuff, have recently been transferred to this group: a complete axe from the house site at Ronaldsway, Isle of Man, and a fragment from the upper fill of a ditch in the causewayed enclosure on Windmill Hill. The third is a surface find from the latter site. These associations, together with the existence of a few mace heads (cf Roe, this volume, Fig 9, b, e, f), but no other shafthole implements, suggest that exploitation was in progress during the late 3rd and early 2nd millennia.

A Group XX axe from the Bronze Age enclosure on Rams Hill (Bradley & Ellison 1975, 87) was found in a significant position, at an entrance, and had been incorporated in a deposit dated 1050 BC ±90 (HAR–231) and 740 BC ±70 (HAR–230). Tool marks attributed to an axe of this type were observed in a section of the contemporary palisade trench. It is easier to believe that a chance-found axe head that was ultimately to serve as a foundation deposit had first been utilized, unhafted, to trim the side of the trench, perhaps in the hope that some of its virtue would be transferred to the proposed structure, than to accept the apparent implication that stone axes were still being made or regularly used in the Middle Bronze Age.

Some implications

Despite its sparsity, and the unsatisfactory nature of much of it, the information assembled does at least help to bring into focus some aspects of the history of stone implement manufacture. One of the most obvious is the great length of time, at least 1500 radiocarbon years in some instances, over which artefacts ascribed to petrological groups or 'factories' can be traced. It has been possible to isolate within this continuum a number of 'factories' which seem to have been active for relatively short periods. Notable amongst these are the 'factories' represented by the numerically small Cornish Groups IVa and XVII, and perhaps the larger Group XVI, which came into production at an early date and seem to have been abandoned by the middle of the 3rd millennium. At the lower end of the timescale are Groups III, XIII, XVIII, and XX, which come into sight only towards the close of the millennium, perhaps in response to increased demand; their period of stone axe production would therefore have run entirely alongside the earlier stages of the development of metal axes *(see* Section I).

Other 'factories' seem to have started early and remained active until the end. For Groups I, VI, and VII it may be possible to discern two phases of activity; an initial phase when axes were made for use by communities in the vicinity of the sources, followed by a longer phase of intensified exploitation, perhaps primarily for 'export'. The evidence for the first phase is tenuous but plausible if it can be assumed that sources of raw material are more likely to have been discovered by settlers than by prospectors engaged in a deliberate search for exploitable commodities. The second phase, well attested by the widespread distribution of the axes of all these groups, might testify to a reorganization of the basis of production during the 3rd millennium.

The existence of mace heads ascribed to Groups VI, VII, and XX suggests that attempts were sometimes made, even with intractable rocks, to meet the demand for a new type of artefact; but the very small numbers of mace heads that were actually produced, and the apparent absence of battle axes and axe hammers, indicate that those particular attempts were soon abandoned. Some 'factories', exploiting more easily perforated rocks, made the change over from axes to shafthole implements with varying degrees of success. The apparent petering out of Group I after a relatively prolific phase of mace head production may reflect local social or economic changes or, possibly, exhaustion of the source of supply; Group XVIII, on the other hand, attained maximum productivity in the Early Bronze Age. The Midlands Groups XII and XIV represent the discovery and exploitation of new rock sources for the sole purpose of manufacturing battle axes and axe hammers.

The most interesting implications are of course those relating to the social and economic aspects of stone implement production about which least can be said. Ethnographic analogy suggests that individual lineages or communities are likely to have held proprietary rights over individual sources of raw material. The circumstance that some sources were exploited over many centuries may provide additional testimony to the essential continuity and stability of life in the Neolithic period and the Early Bronze Age. The evidence can be placed alongside that for the persistence of ceramic styles (I F Smith 1974, 106–8, now supplemented by Green 1976, 22) and that for the persistence of some forms of burial rite (Burgess & Shennan 1976) through changes in ceramic fashion and major technological innovations.

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Thanks are expressed to Fiona Roe for helpful discussions about shafthole implements; to Frances Lynch for drawing attention to the Trwyn Du finds; to Roger Mercer for details of his Carn Brea and Hambledon Hill excavations; to Alasdair Whittle for details of the stratification at Abingdon; and to Bill Cummins for information about unpublished petrological records.

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Typology of stone implements with shaftholes

F E S Roe

Abstract

The five types of shafthole implement that are successively described are battle axes, axe hammers, mace heads, shafthole adzes, and pebble hammers. Axe hammers tend to be larger versions of certain varieties of battle axe; otherwise the five types can be seen as separate entities. Within two of these entities, the battle axe and mace head, quite extensive ranges of interrelated shapes can be described. Axe hammers generally follow the earlier, less elaborate forms of battle axe, while adzes and pebble hammers are more restricted in morphology.

Only battle axes and mace heads have satisfactory associations, and these tend to suggest two separate traditions, with the battle axes linked to Early Bronze Age pottery and metalwork, while the mace heads tend towards connections with the Grooved Ware tradition, and a few only, from a limited group, have Early Bronze Age associations.

Distributions for each of the five types of shafthole implement, while covering the whole of Britain, tend to focus on individual areas. The distributions of axe hammers made of Groups XII, XIV, XV, and XVIII show a tendency towards regional groupings for the implements made of each of these materials.

Increasing availability of petrological determinations makes more meaningful comparisons between all five types of shafthole implement possible. Groups XII and XIV were used almost exclusively for battle axes and axe hammers. Group XVIII was used for all varieties of implements, including axes, and Group XV was used especially for axe hammers and adzes. The mace heads stand out as being different, with a preference for more traditionally Neolithic materials, also used for axes, such as Groups I, VI, and VII, together with XIII and XX. Continued work on petrology in the north of England will expand the picture, and be particularly relevant for the large numbers of axe hammers from this area.

More detailed treatment of the implements discussed in this paper will become available with the publication, in *British Archaeological Reports,* of catalogues and drawings, together with a revised statement of progress in petrological work. A volume is now in preparation.

The five categories of shafthole implement discussed in this paper were all outlined some 80 years ago by Evans (1897, 183). Little alteration need be made to the general distinctions he drew then between the implements now known as battle axes, axe hammers, mace heads, shafthole adzes, and pebble hammers. It is merely unfortunate that, in the case of the axe hammers and shafthole adzes, the two classes that have the least satisfactory associations, little further published work exists. Now that increasing numbers of petrological determinations are becoming available, work on these is more meaningful, and one aim of the present paper is to make a start at increasing our understanding of these two little known categories of implement. They are best studied in conjunction with battle axes and mace heads, both of which have good associations, and are also now well recorded from the petrological point of view.

Battle axes

Battle axes can be studied in some detail, taking all the minor morphological differences into account (Roe 1966). On the other hand, one can simplify the scheme into nothing more than Early, Intermediate, and Developed, and this kind of assessment seems more appropriate for a brief survey.

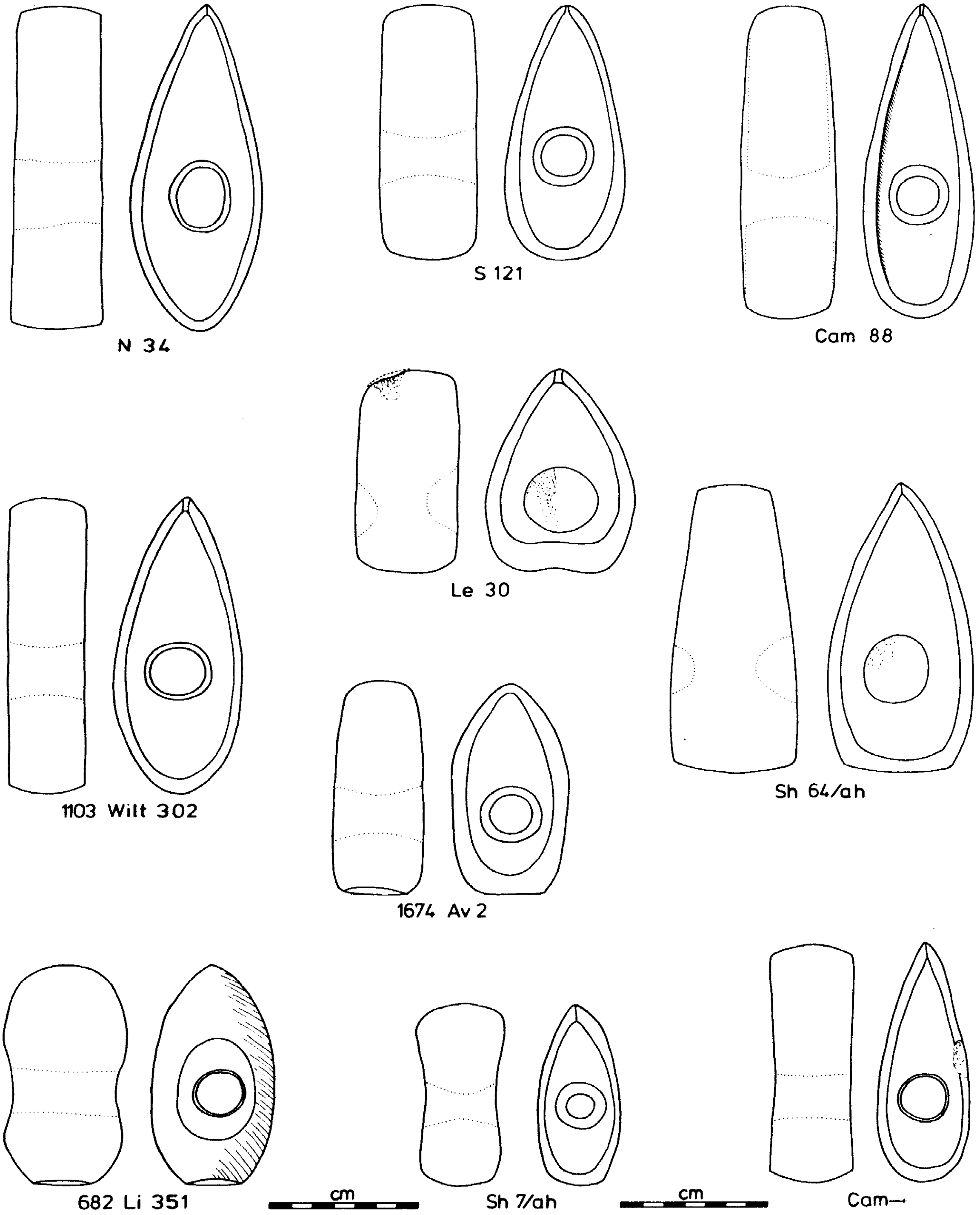
The earliest known battle axe associations in Britain are with Beakers (Smith, this volume). Figure 1 shows Early battle axes, which can be correlated chronologically both with Beakers of the Long-Necked or Southern variety, and also with Food Vessels. Finely made Group XVIII battle axes are characteristic (N 34, S 121, Cam 88), and for one of these (S 121) there is an unconfirmed association with a Long-Necked Beaker (information kindly supplied by Norwich Castle Museum). One need only look at the profile view of a battle axe (by convention the left-hand side) for a simple typological assessment. Convex, non-expanded examples are likely to be Early. They may have the greatest depth towards the butt end, as shown most clearly by Sh 64/ah; other examples, all of which belong to the Woodhenge group (Roe 1966, 205), are N 34, S 121, Cam 88, Le 30, and Av 2.

Not all battle axes are finely made, and some of the Early Group XII examples are inclined to be large and crudely shaped (eg Sh 64/ah). An unfinished Group XIV battle axe (Le 30) already looks a failure. This material was in fact little used, while the Group XV greywacke was restricted to Early forms only (Av 2, Li 351). One of these (Li 351) shows the beginnings of a concave form, Stage II in a more detailed typology, as found among Intermediate battle axes.

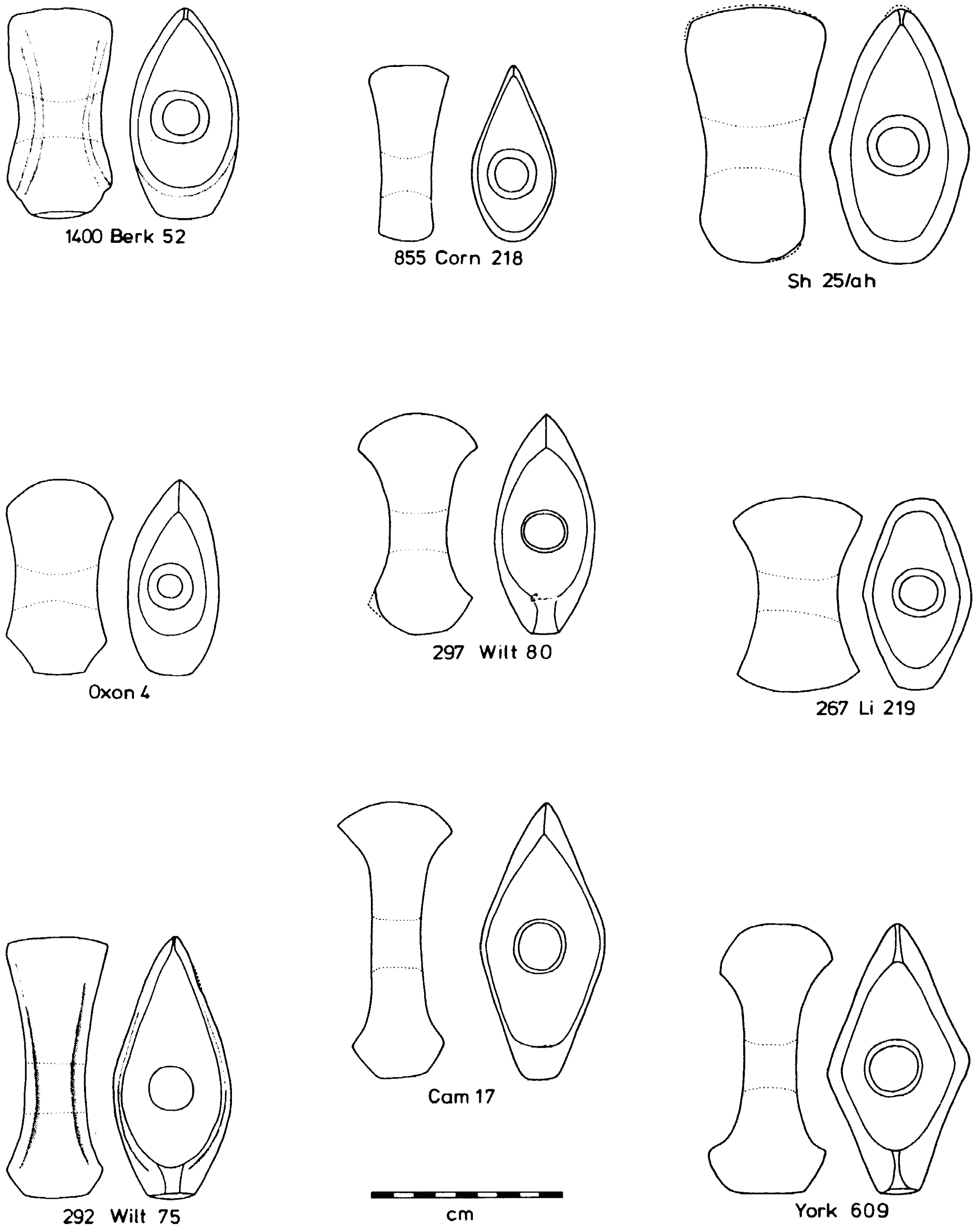
Three Group XIII battle axes have been recorded, all very slightly concave, carefully made, and remarkably alike (Wilt 302). The two Group XXIII battle axes, however, deviate from this pattern. One of them, from Carno, Montgomery (Grimes 1951, Fig 55, 1) has unusual decoration, in the form of a groove round the top and bottom surfaces. Such ornament, not paralleled among British finds, can be seen on battle axes from the Netherlands, as for instance one from a barrow at Laaghalerveld (Lanting 1973, 234, Fig 8).

Groups XII and XVIII were both used for battle axes of increased concavity. Two Early examples, with slightly expanded ends (Stage II), are shown on Fig 1 (Sh 7/ah, Cam–).

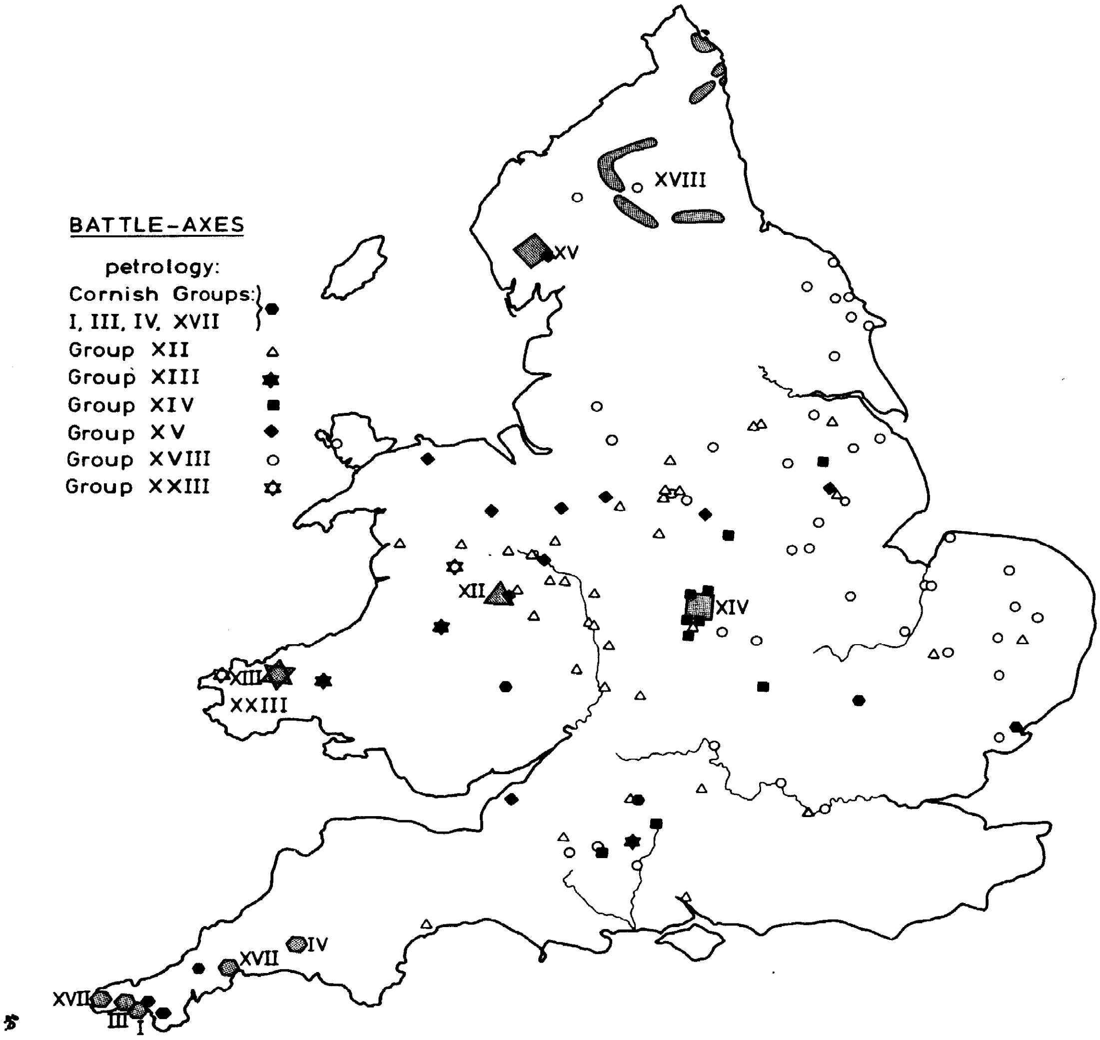
Fig 2 shows battle axes that are all concave in profile, with Intermediate forms at the top and middle, leading to Developed forms at the bottom. In this final, sophisticated form, the battle-axe becomes long and slender, with comparatively widely expanded ends. Typical associations for these include ogival daggers and cinerary urns. Such Developed forms have been named Southern Variants, by contrast with the relatively short, thick Northern Variants that comprise the Developed battle axe form in Scotland, with related versions in Ireland. There is no petrological information for these at the moment.



1 Early battle axes. N 34, Tottenhill, Group XVIII. S 121, Stowmarket area (?), Group XVIII. Cam 88, Downham, Group XVIII. Le 30, Sutton Cheney, Group XIV. Wilt 302, Wilsford G 54, Group XIII. Av 2, Yatton, Group XV. Sh 64/ah. More, Group XII. Li 351, Branston and Mere, Group XV. Sh 7/ah. Morfe, Group XII. Cam–, Newark, Group XVIII. Scale $^{1}/_{3}$



2 Intermediate and developed battle axes. Berk 52, Cookham, Group XVIII. Corn 218, Sithney, Group I. Sh 25/ah, Montford Bridge, Group XII. Oxon 4, North Hinksey, Group XVIII. Wilt 80, Codford St Peter, Group XIV. Li 219, Brigg (?), Group XII. Wilt 75. Kilmington G 1 (Stourton), Group XVIII. Cam 17, Chippenham, Group XII. York 609, Doncaster, Group XII. Scale $^1/_3$



3 Battle axe petrology. The positions of the various sources for grouped rocks are shown approximately only

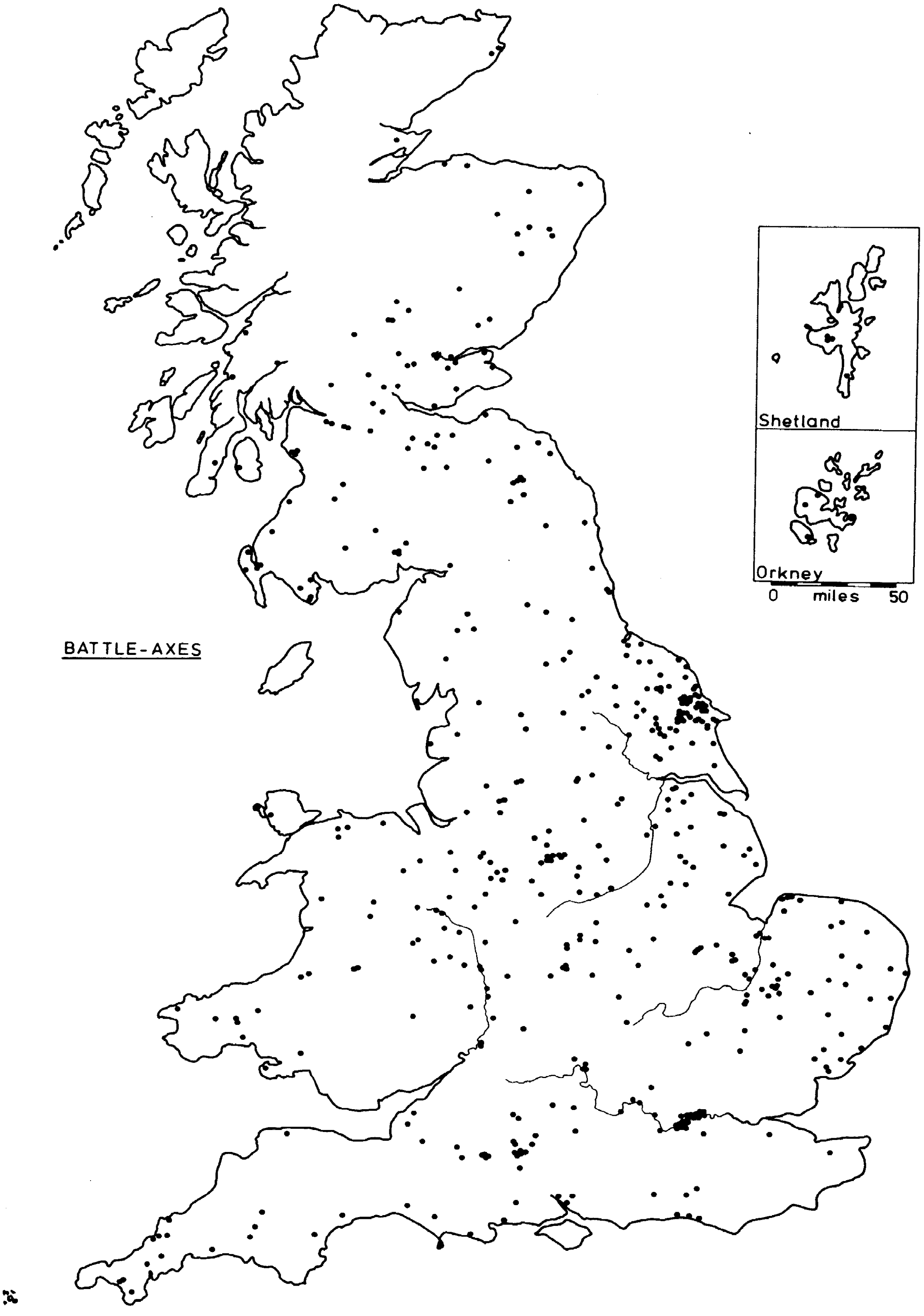
Group XII picrite was especially used for the more evolved English battle-axe forms (Fig 2, Sh 25/ah, Li 219, Cam 17, York 609). Only one complete later example of Group XIV camptonite has been recorded (Wilt 80). Cornish materials were not much used for battle axes, and then only for Early and Intermediate forms (Corn 218). The second Group XXIII battle axe, from Llanrhian, Pembrokeshire, is an Intermediate form (Stage V, see Grimes 1951, Fig 55, 5), and can be compared with the example shown from Sithney (Corn 218). Group XVIII continued to be used (Fig 2, Berk 52, Oxon 4, Wilt 75), though less extensively than it was for the Early battle axes.

The geographical aspect of battle axe petrology is shown in Fig 3. Cornish materials, especially Group I, were traded as far east as Essex. Groups XIII, XIV, and XV were all little used. Group XII, by contrast, was much used and widely distributed, as was Group XVIII, with a find from as far west as Anglesey. Battle axes made from most of the identified materials included here are known from Wessex.

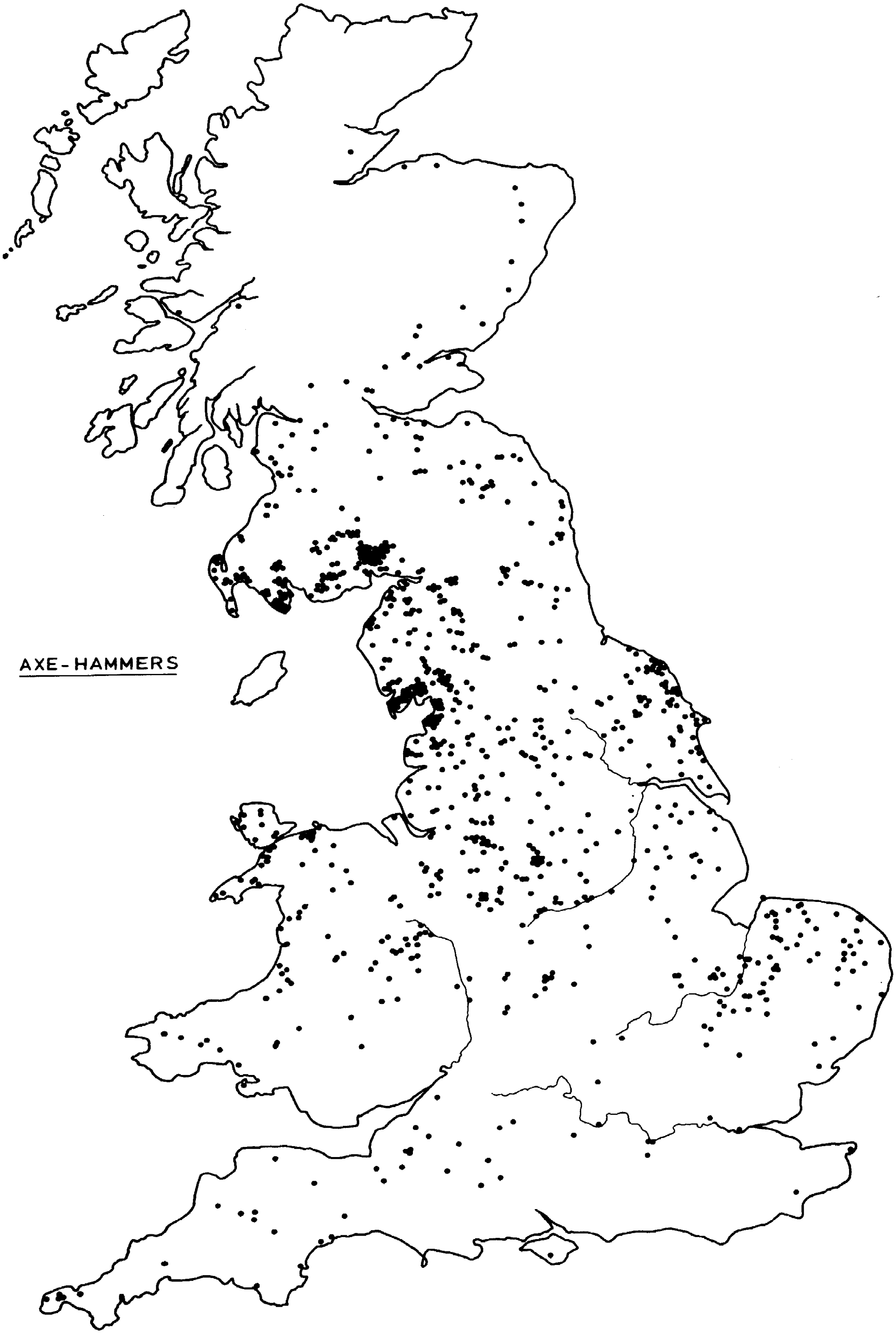
Little petrological work has as yet been carried out in the north of England, and the coverage for other areas tends to be uneven (Cummins, this volume, Fig 1). For this reason it is useful to compare the petrological map with a total distribution for battle axes (Fig 4). It is perhaps a fairly traditional distribution pattern for Early Bronze Age Britain, though more finds from the Wessex area might have been expected. The cultural centre, if such it can be called, for battle axes, is in Yorkshire, and comparisons can be made with the distributions in this area of Food Vessels (Simpson 1968, Figs 47, 48) and Primary Series Urns (Longworth 1961, 275, Fig 8).

Axe hammers

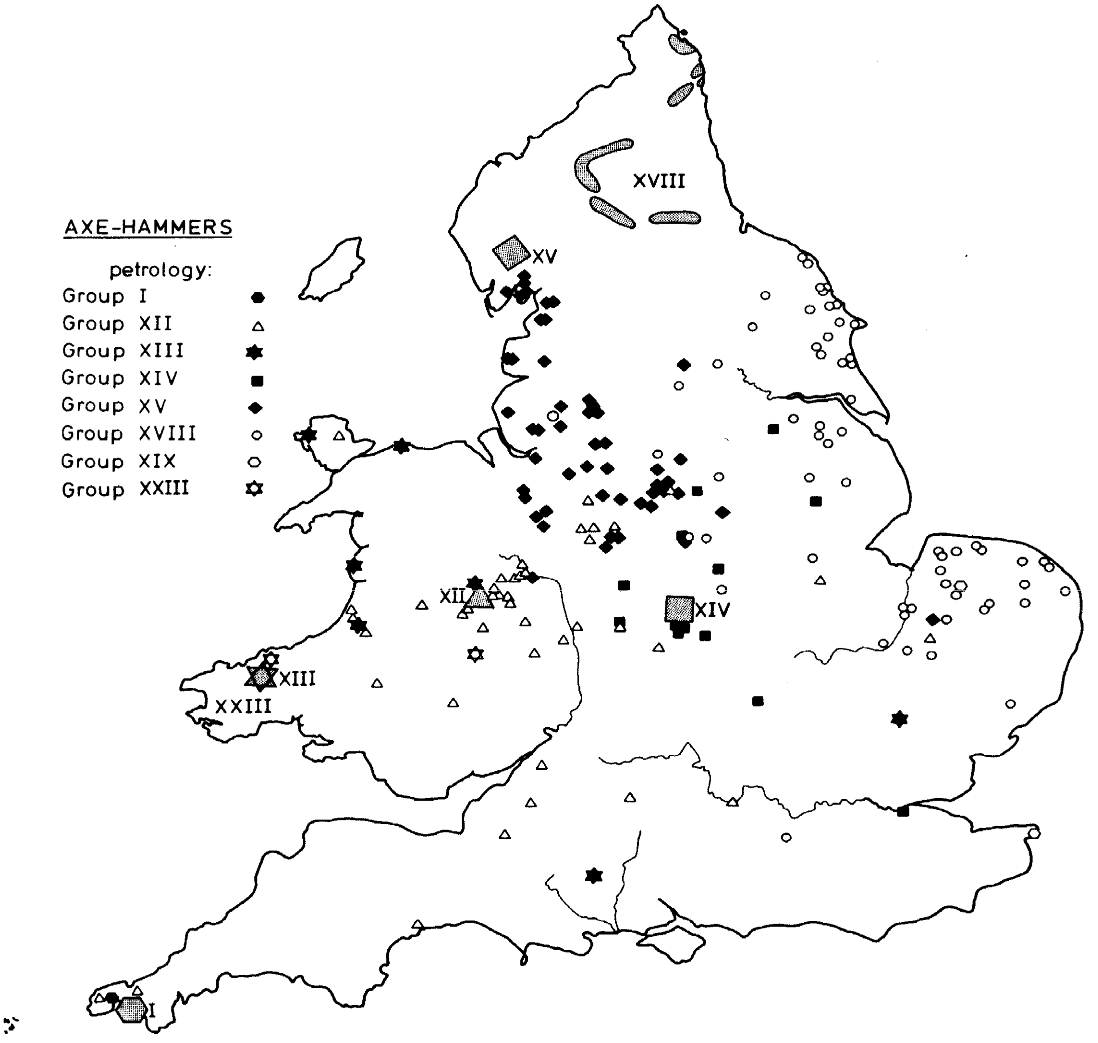
Turning next to the overall distribution of axe hammers (Fig 5), an immediate contrast can be seen, both in the quantity of finds, and in the areas in which they are concentrated. Around 950 axe hammers have been recorded to date, as opposed to some 550 battle axes and 435 mace heads. Although the distribution shows a



4 Battle axe distribution



5 Axe hammer distribution



6 Axe hammer petrology

fair number of finds from East Anglia and Yorkshire, the real emphasis is quite different, being concentrated in western Britain, especially Lancashire, Cumbria, and south-west Scotland. There is a concentration centred on the town of Dumfries, which was evidently an area of particular importance. Unfortunately the material used for these Scottish axe hammers is as yet unknown.

Not many axe hammers from northern England have been sectioned at the time of writing. There are some 94 unsliced axe hammers from Yorkshire alone, a fact that needs to be remembered when considering the map for axe hammer petrology (Fig 6). Three materials, Groups XII, XV, and XVIII, were particularly used for axe hammers, and each has a restricted distribution. Axe hammers are heavy, and there may have been some unwillingness to trade them over long distances. Group XVIII axe hammers are found in the eastern half of England, with just one example recorded so far in Lancashire. Those made from Group XII picrite and Group XV greywacke occur in the west. Group XIV camptonite is found in a limited area in the Midlands, with an outlier from the Thames. A northward extension of Group XV and XVIII finds into areas where axe hammers are most abundant seems likely. Meanwhile, it is interesting to reflect whether these regional groupings of finds could possibly indicate meaningful groupings of population.

Axe hammers have been defined as being altogether larger and more crudely shaped than battle axes (Roe 1966, 199–203). They can be divided into two main classes, Class I containing those that are basically convex in profile, while Class II includes those that are concave. Some axe hammers are inevitably too irregular in outline for a clearcut distinction to be made.

Fig 7 shows convex axe hammers, and covers the small variation found in these implements. If one needs to go into greater detail, they can be assessed according to the position of the greatest depth. Thus Class Ia axe hammers have the greatest depth near the butt end (N 63, La 41, Db 187), corresponding to battle axes of the Woodhenge group; Class Ib axe hammers are thickest near the blade end (York 307, E 29), corresponding to some of the Stage II battle axes that are convex rather than concave in outline. Less commonly found are axe hammers with the greatest depth in the area of the shafthole, and these have been designated Class I a/b. Minor variations found among all Class I axe hammers include dished surfaces (La 41, E 29), and oval shaftholes (Db 187), features that also occur on battle axes (Roe 1966, 213).

Such convex axe hammers are especially to be found among the Group XV and XVIII examples. Fig 7 also includes one of the Group XIII axe hammers (E 29). Of the two Group XXIII axe hammers so far known, only half (a dished blade) survives of the one from Kington, Herefordshire, while the other, from Teifiside, Cardiganshire, is a further Class I example.

Fig 8 shows the second axe hammer class, those that are concave and expanded, corresponding to Intermediate battle axes. Only some 18% of axe hammers are in fact concave, and in some cases the difference between these and the convex examples is not clearly apparent (Li 272). Only two variations are found. The greatest depth may be at the butt end (Class IIa, Sh 20/ah), or, and this is more usual, at the blade end (Class IIb, Li 272, Sh 17/ah, Sh 35/ah, La 12).

Such differences may seem to be of little interest. However, it can be shown that the majority of Group XII and Group XIV axe hammers are of the concave variety. Group XV, represented on Fig 8 by a large specimen (La 12), is divided between the two classes, while the Group XVIII axe hammers are mainly convex, as also are the numerous finds from south-west Scotland Roe 1967). It is among these axe hammers from Dumfriesshire and Galloway that decoration with grooved or fluted lines is mainly to be found (Roe 1967). Thus the regional groupings shown in the petrological distribution are borne out to some extent by the way in which the different axe hammer classes are distributed.

There are a few associated finds for axe hammers, and they are, without exception, unsatisfactory. For instance, a few are known to come from barrows, but they are old finds, and the records never make it clear whether they were in fact deposited with burials, or merely incorporated in the mound material. One therefore has to use analogies with battle axes to assess the probable chronological range of axe hammers.

Mace heads

For mace heads, some associations are available that indicate cultural groupings, mainly with Grooved Ware. The evidence has already been published, together with descriptions of Ovoid and Pestle mace heads (Roe 1968); what is now needed is to link further kinds of mace head with the existing scheme.

Three morphological extremes are illustrated on Fig 9. At the top there is an egg-shaped mace head (a); at bottom left, an Orkney Pestle mace head (k); and at bottom right, two Cushion mace heads (1, m). All three are members of an interrelated series.

Ovoid A or egg-shaped mace heads are short and thick (Fig 9, a). These grade into Ovoid B, which are thinner (Fig 9, b, c), and Ovoid C, which are more slender still (Fig 9, e). Pestle mace heads are clearly pestle ended (Fig 9, d, f, g, k), and have their greatest depth near to the top end of the implement. These divide into Thames Pestles (Fig 9, d, f, g), with straight or nearly straight sides, as seen in plan, and Orkney Pestles with concave sides (Fig 9, k). One of these is known to be associated with a Food Vessel (Anderson 1883, 453).

Cushion mace heads have already been described (Gibson 1944), but it remains to show how they relate to other kinds of mace head. In brief, it is necessary first to return to the Ovoid C mace head (Fig 9, e). If this is made in a more slender form, with a reduction especially in depth relative to length, the result is a Proto-Cushion mace head (Fig 9, h, i, j). This variety is not numerically important, but it can be shown metrically to belong to an intermediate position between the Ovoid and Cushion varieties (Roe 1969, 345). The Cushion mace head (Fig 9, 1, m) is a longer and relatively more slender form than the Proto-Cushion mace head.

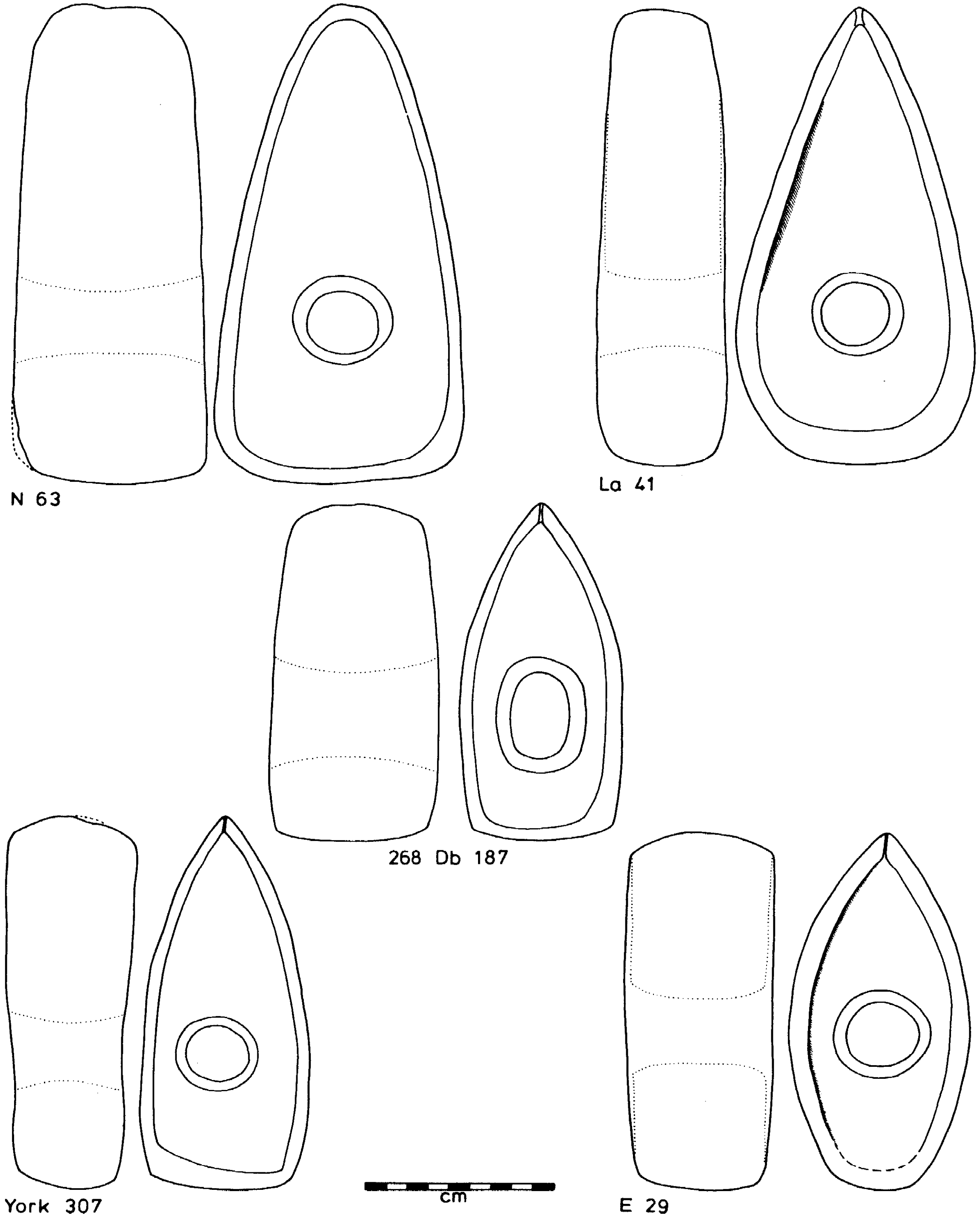
Cushion mace heads are often carefully shaped and well made; possibly they could be regarded as the most sophisticated variety of mace head, reminiscent of the Southern Variants in the battle axe series. Cushion mace heads have previously lacked associations, so it is satisfactory to be able to record a small fragment from Skara Brae (Fig 9, 1; Smith, this volume).

A different kind of mace head, a variety with a central and more or less straight bored shafthole, is shown on Fig 10. Such mace heads are not very common, but two kinds can be distinguished, those that are flat ended, and those that are not. The latter variety (Fig 10, C, D, E, G) includes the Bush Barrow mace head (D) (Annable & Simpson 1964, 45, No 175), and one which was found in a Collared Urn near Scarborough (G) (Allies 1844, 461).

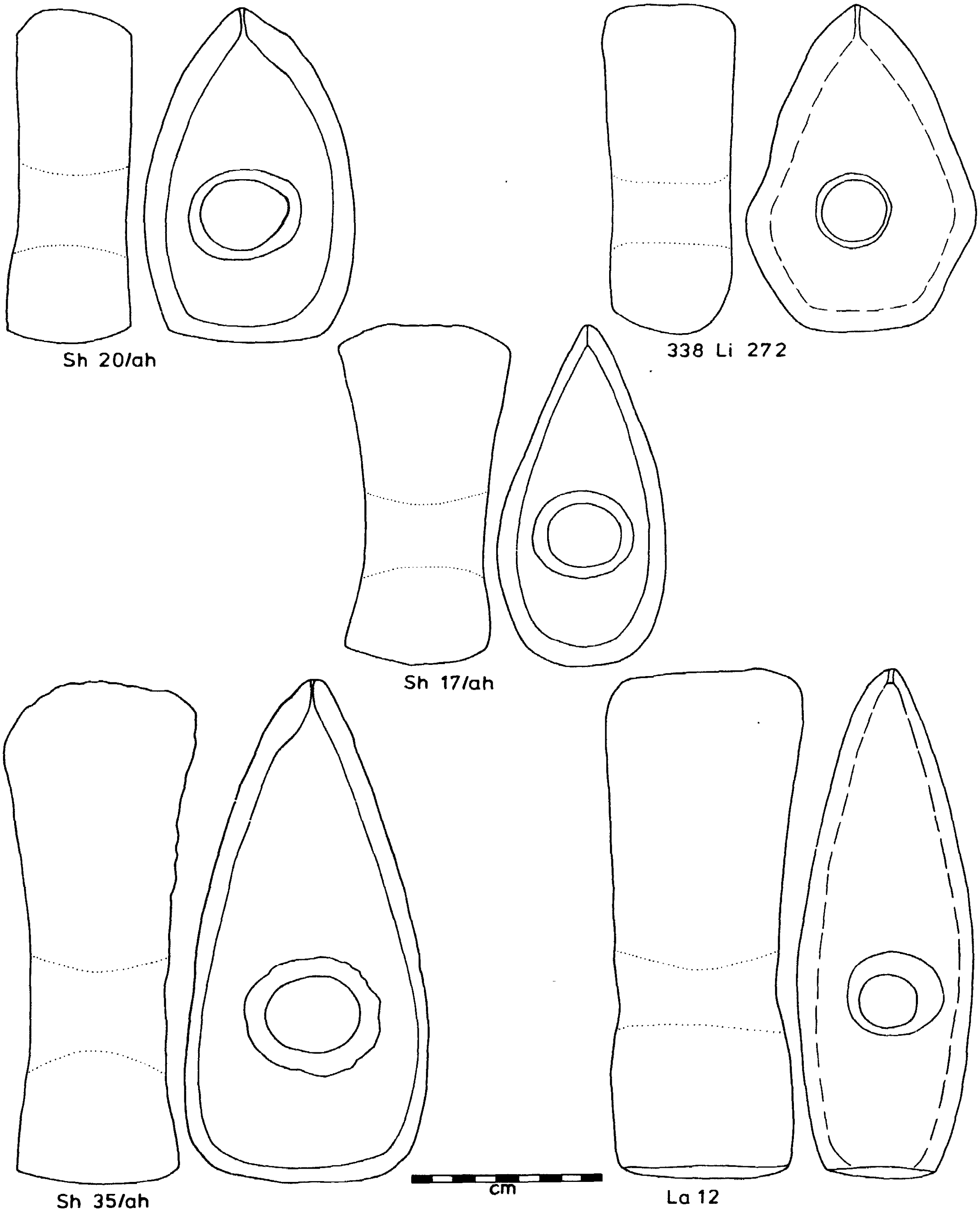
The flat-ended mace heads (Fig 10, A, B, F) have been named the Largs group, after a find (B) associated with a Tripartite Collared Urn in a cremation cemetery (Monro 1910, 242). Cambusbarron, near Stirling, is another cremation site, where a mace head (F) was found with a Cordoned Urn (Anderson 1883, 453). The specimen from Towthorpe (A) was associated with a bronze dagger comparable to those of the Bush Barrow variety (Mortimer 1905, 6).

The distribution pattern of mace heads is again different from those that have preceded it (Fig 11). Emphasis is on the Highlands and Islands, more particularly Orkney, where further unlocated examples have not been shown on the map. Shetland and the Hebrides are also included in the distribution and Aberdeenshire is an important area. So also is the Thames in the London region, where a number of flint Ovoid mace heads have been found (Roe 1971).

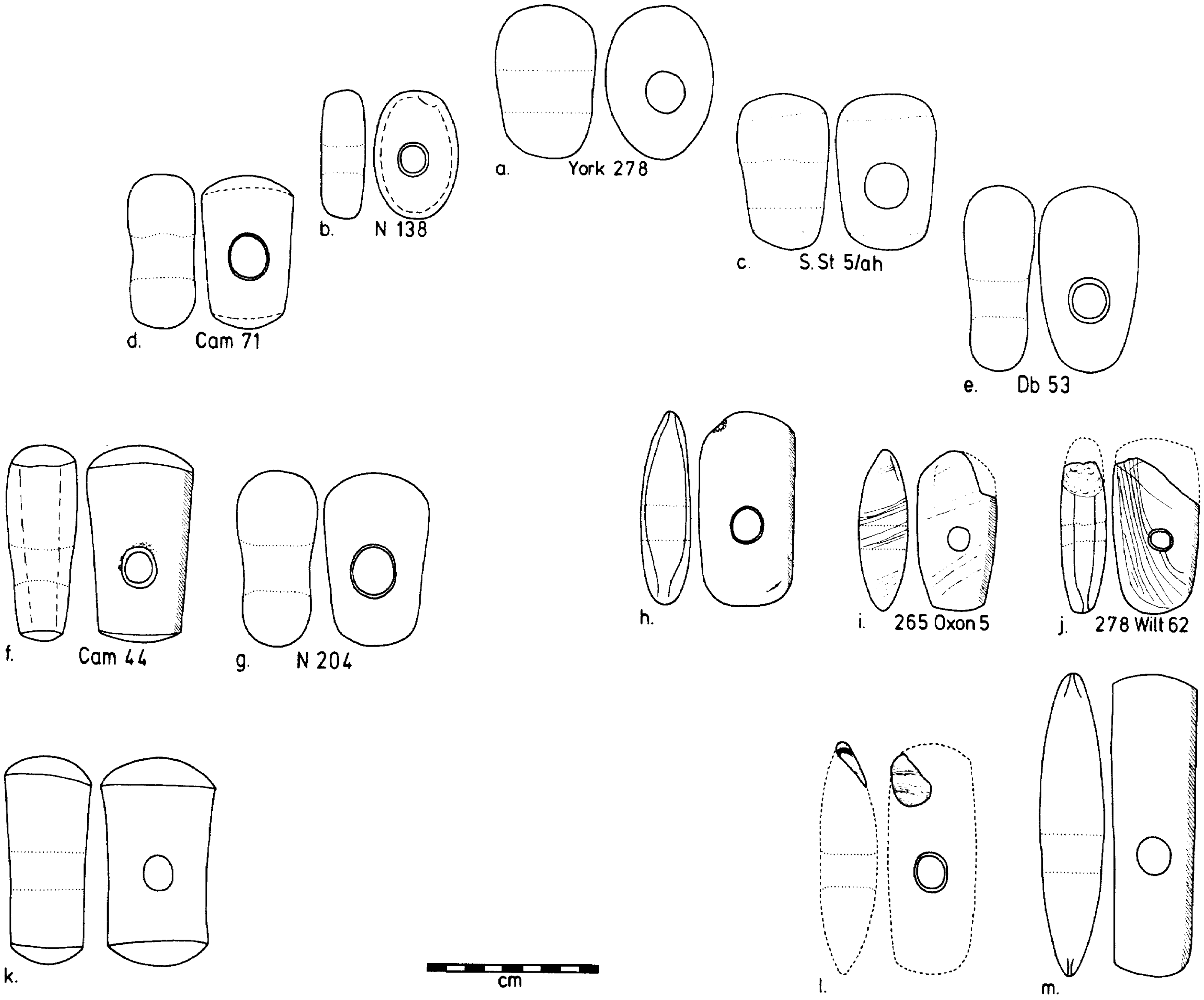
The petrology of mace heads is also different from that of battle axes and axe hammers. Groups XII, XIV, and XV are absent, and instead are found Groups VI, VII, and XX, while the main grouped material used was Group I greenstone. The north-eastward spread of Group I mace heads from the source area in Cornwall compares with the spread of axes made of the same material (Cummins, this volume, Fig 7). All three of the Group VI mace heads known at present are of the Cushion variety; the findspots are Great Hale in Lincolnshire and the River Thames near Windsor and at Hammersmith. Two further Cushion mace heads are thought possibly to have been made of riebeckite felsite from Shetland (Ritchie 1968, 132); they are both Scottish finds, from a cairn in Fife and Lewis in the Hebrides. Limited use was made of Groups XIII, XVIII, and XXIII, but banded rocks, and others that were visually attractive, were popular, and even jade was used for a Cushion mace head with an unfinished shafthole (Clough & Green 1972, Fig 13, Cam 55).



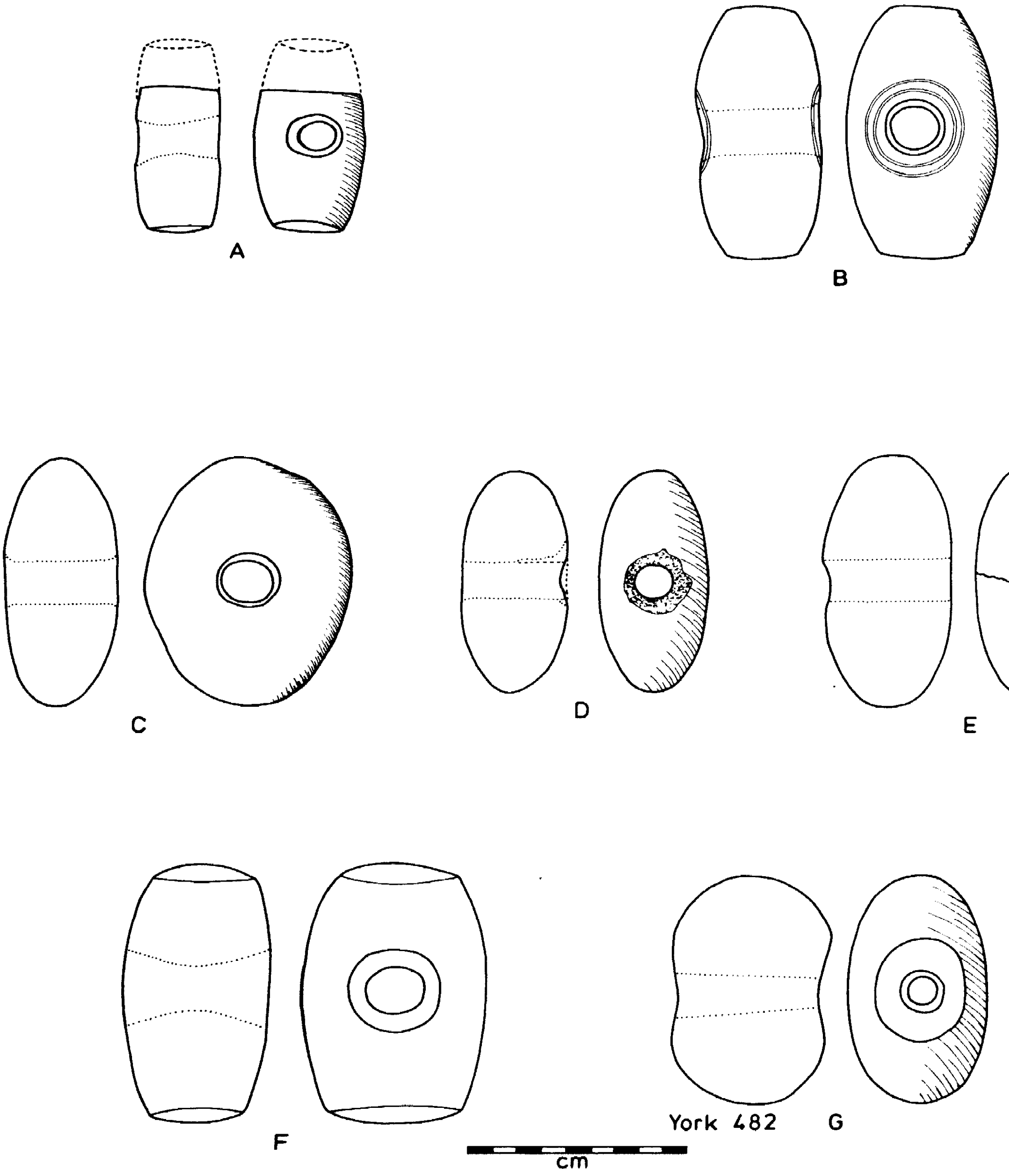
7 Class I axe hammers. N 63, Frettenham, Group XVIII. La 41, Lancaster, Group XV. Db 187, Whitwell, Group XVIII. York 307, Sherburn, Group XVIII. E 29, Thaxted, Group XIII. Scale $^1/_3$



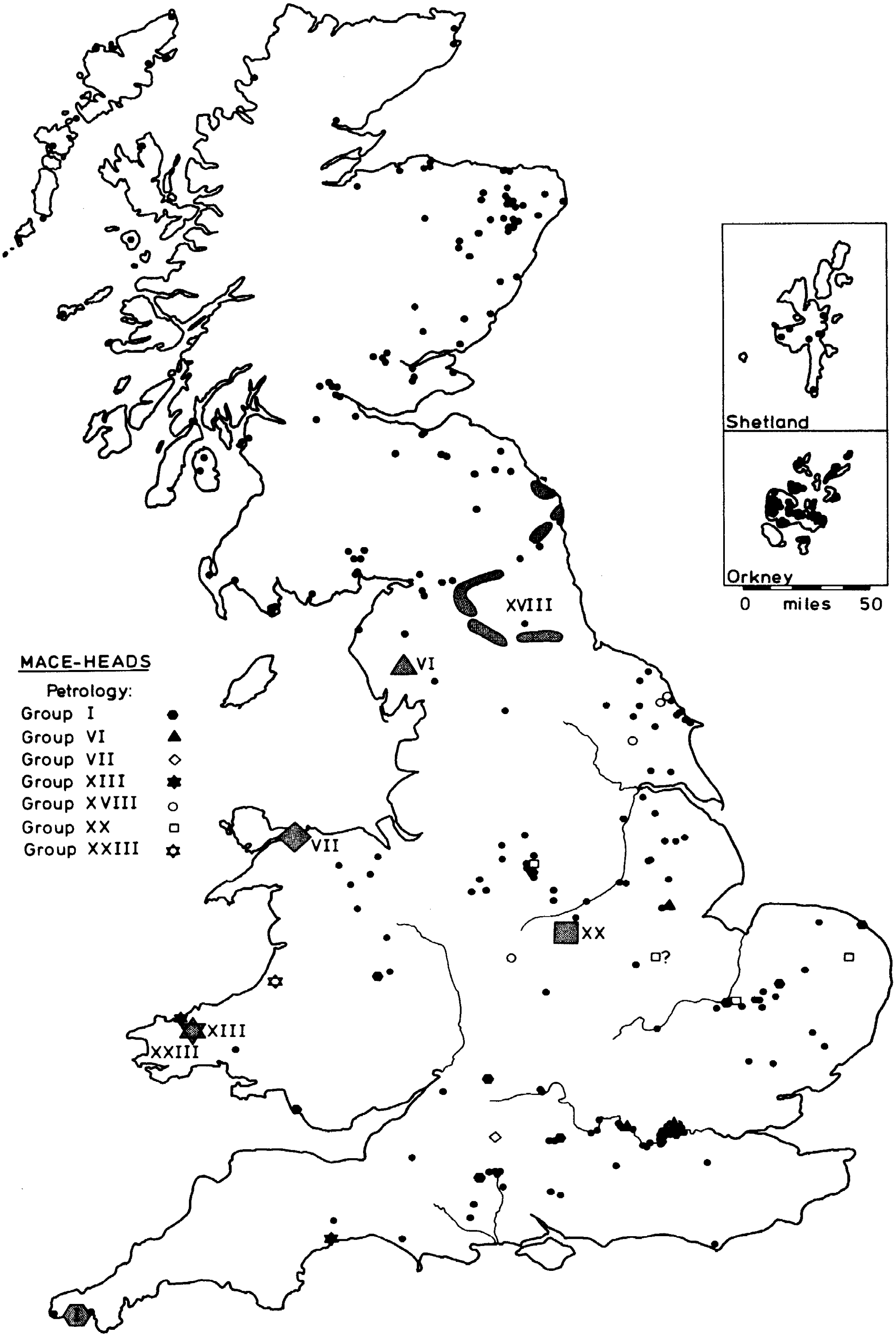
8 class II axe hammers. Sh 20/ah, Wrentnall, Group XII Li 272, Dunston Fen, Group XIV. Sh 17/ah, Little Ryton, Group XII. Sh 35/ah, Hardwick, Group XII. La 12, Lowton, Group XV. Scale $^{1}/_{3}$



9 Ovoid, Pestle, and Cushion mace heads. a Garrowby Wold, C 69, Group XVIII. b Colney, Group XX. c Sutton Coldfield, Group XVIII. d Burwell, Group I. e Beeley Moor, Group XX. f Soham, Group XX. g Bacton, Group I. h Birkhill (Proc Soc Antiq Scot, 21, 1886–7, 265). i Dorchester (Atkinson et al 1951, 116, no 149). j Winterbourne Stoke (Annable & Simpson 1964, 36 no 19). k Stove Bay, Sanday, Orkney. l Skara Brae. m Fife, possibly Group XXII Scale $\frac{1}{3}$



10 Mace heads with centrally placed shaftholes. A Towthorpe. B Largs. C Bank of *Rye, near Ryton (unpublished, Yorkshire Museum 1027–1948). D Bush Barrow. E Heatherbank, Westray, Orkney (Proc Soc Antiq Scot, 42, 1907–8, 9). F Cambusbarron. G Wheatcroft, Scarborough, Group XVIII. Scale 1/3*



11 Mace head distribution and petrology

Shafthole adzes

Turning to another type of shafthole implement, the adze, another distribution pattern becomes apparent (Fig 12). There are no obvious concentrations of find-spots. There is a broad scatter of finds from south-eastern England, especially along the south coast. There are no petrological determinations for these yet, but some are known to have been made of quartzite.

The petrology of shafthole adzes is interesting for the materials which were not used. Groups VI, VII, XII, XIII, and XIV are excluded. Instead, use was made of Groups XV and XVIII, both of which were traded over considerable distances. The nearest parallel seems to be with axe hammers, the makers of which favoured these two materials.

Shafthole adzes, which were first noticed by Curwen (1928), are relatively uncommon, and some 265 examples only have been recorded at the time of writing. They tend to be about twice as long as they are broad (Fig 13), with an hour-glass shafthole in or near a central position. One or both ends of the adze are narrowed to form a blade, though this never gives the impression of being capable of cutting.

This is a simple type of tool, capable only of slight modification. Some shafthole adzes have a more or less symmetrical outline (Li 246, Cam 34) and this form is typical of those from southern England (Sx 60, Sx 73). Other shafthole adzes are narrower at one end (N 131, Wa l/ah, E 18), especially the Group XV specimens, and for these the term 'narrow butt' has been used in the Appendix. Less common are nearly circular, disc-like types, which perhaps should not be included in the general category of adzes.

As with axe hammers, associations for these adzes are less than conclusive, but half of one was found in the upper levels of the outer ditch at Windmill Hill (I F Smith 1965, 114, No 34, Fig 51, S 10).

Pebble hammers

The last type of shafthole implement to be considered in this paper is the pebble hammer, of which some 710 have currently been listed. These cannot truly be said to have a typology, being unadapted pebbles save for the shaftholes, which are always centrally placed. They are waisted, and characteristically are worn smooth in the centre. Another feature of pebble hammers is that they often appear battered at the ends. The term 'pebble hammer' seems preferable to that of 'mace', since they differ from the mace heads so far discussed in being unmodified in shape, having hour-glass holes, and showing signs of use.

Some 70 instances in which pebble hammers were found in some sort of context have been recorded, but these tend to be anything but satisfactory for dating purposes. The pebble hammers shown on Fig 14 have no diagnostic features that differentiate them typologically, but they come from sites of different periods.

The Mesolithic associations (Fig 14, a) are best known (Rankine 1949), and a fresh review of this aspect is being undertaken (Mellars & Reinhardt, forthcoming). There seems little doubt that some pebble hammers at least have an early date.

Other finds of pebble hammers, which could conceivably have belonged originally to Mesolithic cultures, come from Neolithic sites, such as Durrington Walls (Fig 14, b; Crawford 1929, 50) and Hurst Fen (Fig 14, c; Clark *et al* 1960, 227). It seems that we must become accustomed to the idea that pebble hammers outlasted the Mesolithic period, though lack of closed finds still makes this interpretation uncertain.

Some pebble hammers could be either Neolithic or Bronze Age in date, such as those from Windmill Hill; Fig 14 (d) shows one of two fragments from the ditch of a barrow on the site, while (f) was a loose find (I F Smith 1965, 124). A small pebble hammer from a barrow at Rudston (Fig 14, e) could be contemporary either with Beaker and Food Vessel burials, or with earlier occupation material from the body of the mound (Greenwell 1878, 248). Another example comes from a habitation site at Ulrome in Holderness (Fig 14, g), where the finds seem to belong to two periods (R A Smith 1911). The East Ayton pebble hammer (Fig 14, h) may belong with a Bronze Age burial, one of a series of similar finds, all from Yorkshire (Roe & Radley 1968, 173).

Three quartzite pebble hammers come from rather later contexts. One is from the Roman fort of Segontium in Caernarvon (Fig 14, i; Grimes 1951, 165, No 308) another comes from South Cadbury (Fig 14, j), while a third is from a pit at an Iron Age site at Fifield Bavant in Wiltshire (Fig 14, k; Clay 1924, 477). All these three may or may not actually be earlier in date than their contexts would suggest.

All the pebble hammers recorded to date have been mapped (Fig 15) and this serves to show that pebble hammers were not used solely in the south of England, where most of the Mesolithic associations are known. But if pebble hammers are to be regarded as multi-period implements, the map has little validity for representing any one cultural aspect or period. It may only show the areas where quartzite pebbles are most easily to be found.

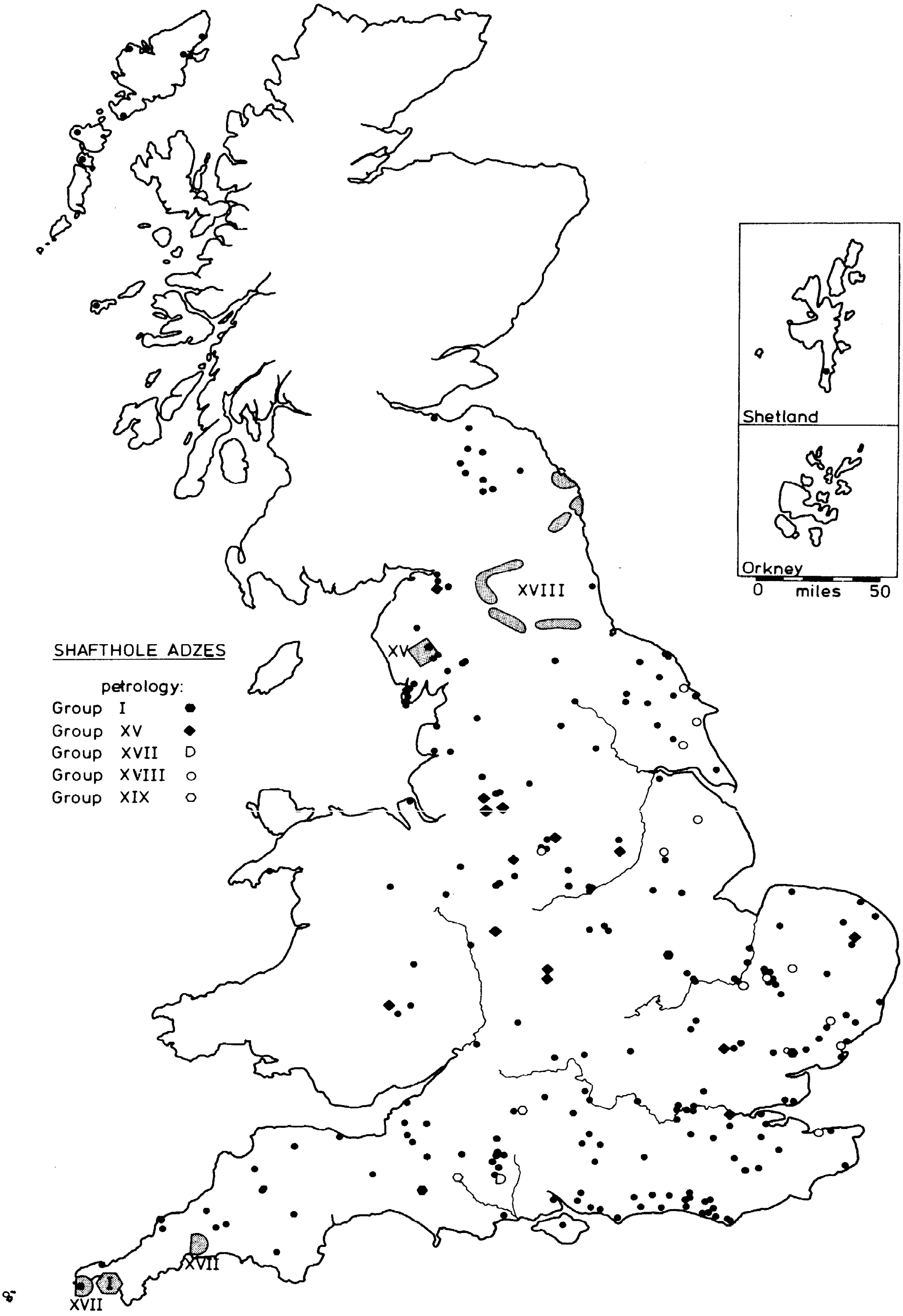
The majority of pebble hammers do seem to be made of quartzite. However, Groups VII, XIII, XV, XVIII, XIX, and XX were also used (Fig 14, 1, m, n). Half of the grouped implements are made from Group XV greywacke, and are distributed down the western side of England. The petrology then gives an indication that some of the pebble hammers at least are likely to be contemporary with other shafthole implements.

This paper includes a great many maps, although dealing with a subject that is basically concerned with typology. This was intentional, in the hope of demonstrating something of the different distribution patterns for different classes of implement. It seems possible that, as more petrological results become available and can be plotted in this way, we may begin to see rather more of the different population groupings that must have been in existence during the period in question. Thus we can get away from typology, and think more in terms of people.

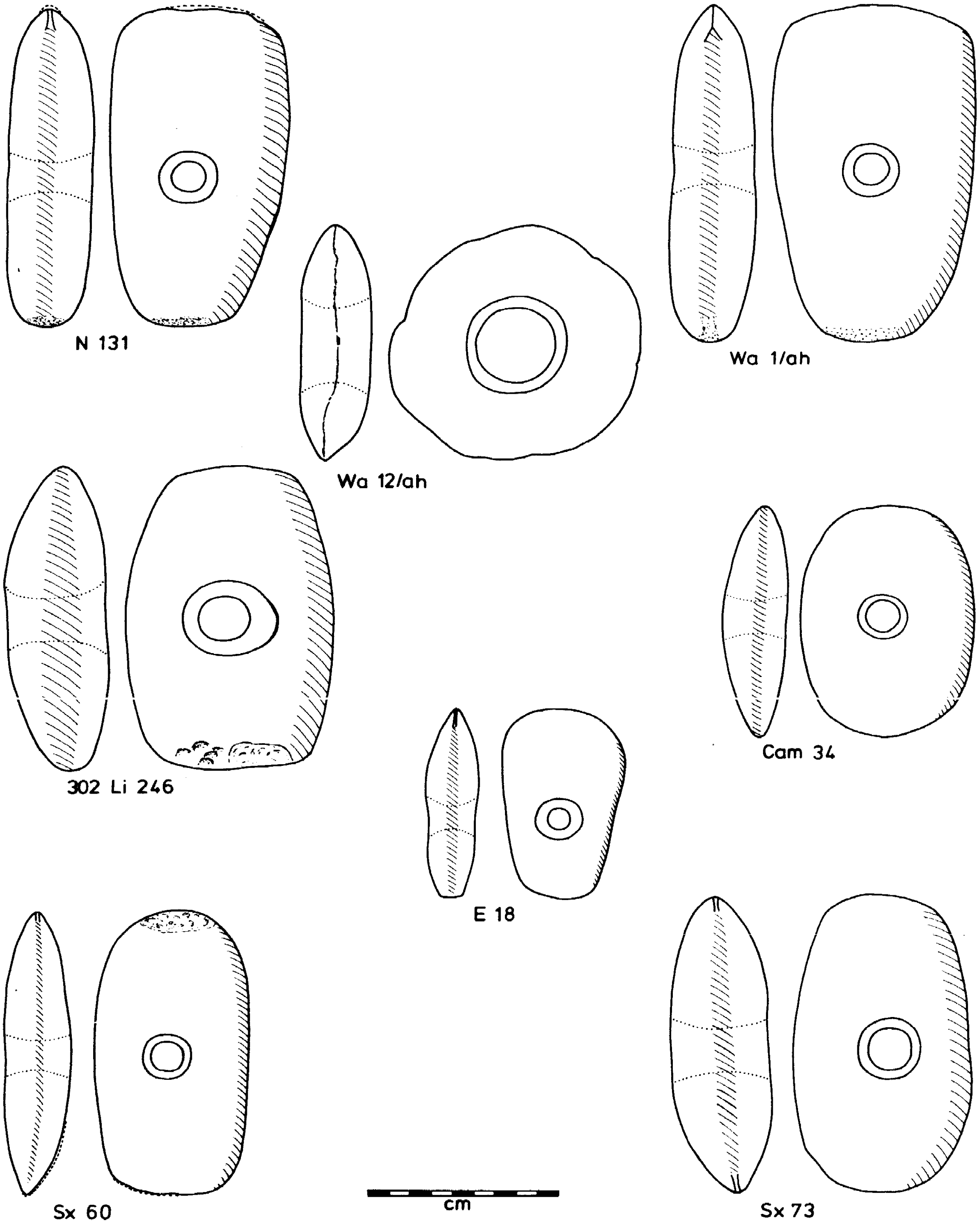
In conclusion, the petrological determinations used for this paper are entirely the work of other people. I should like to express appreciation of their efforts and achievements, and also their cooperation and kindness, which have led to the combination of material presented here.

Acknowledgements

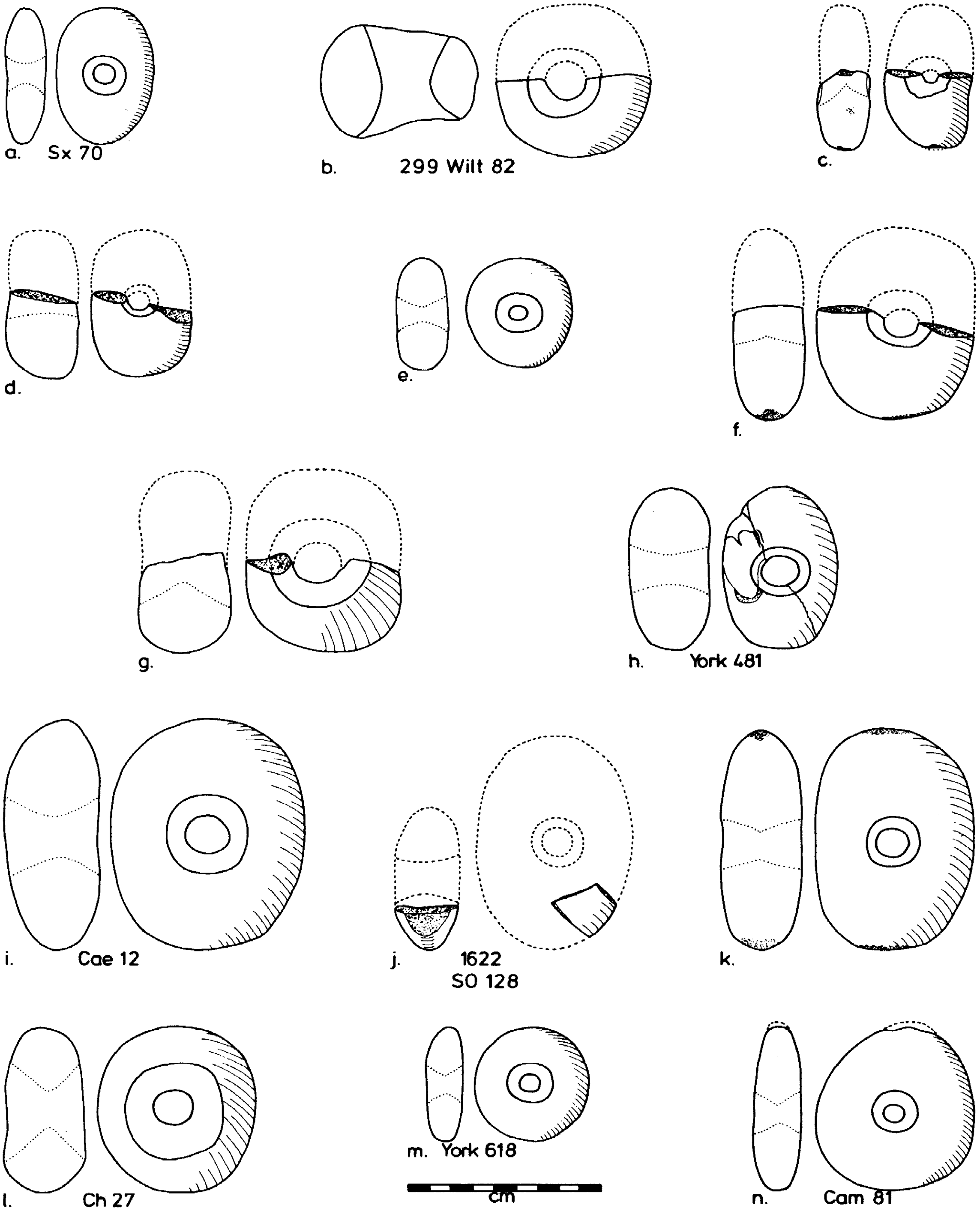
To thank everyone who has contributed in some way to this paper would necessitate another Appendix. Many will also have contributed towards other papers in this volume. Among those to whom I am especially grateful are: A M Burchard, D V Clarke, T H McK Clough, W A Cummins, Miss B Green, H S Green, A Gregory, E E Harrison, D B Kelly, Jeffrey & Brenda May, C N Moore, Dr P Phillips, Miss E Pirie, D J Robinson, D A Roe, Dr I F Smith, and A G Woodcock.



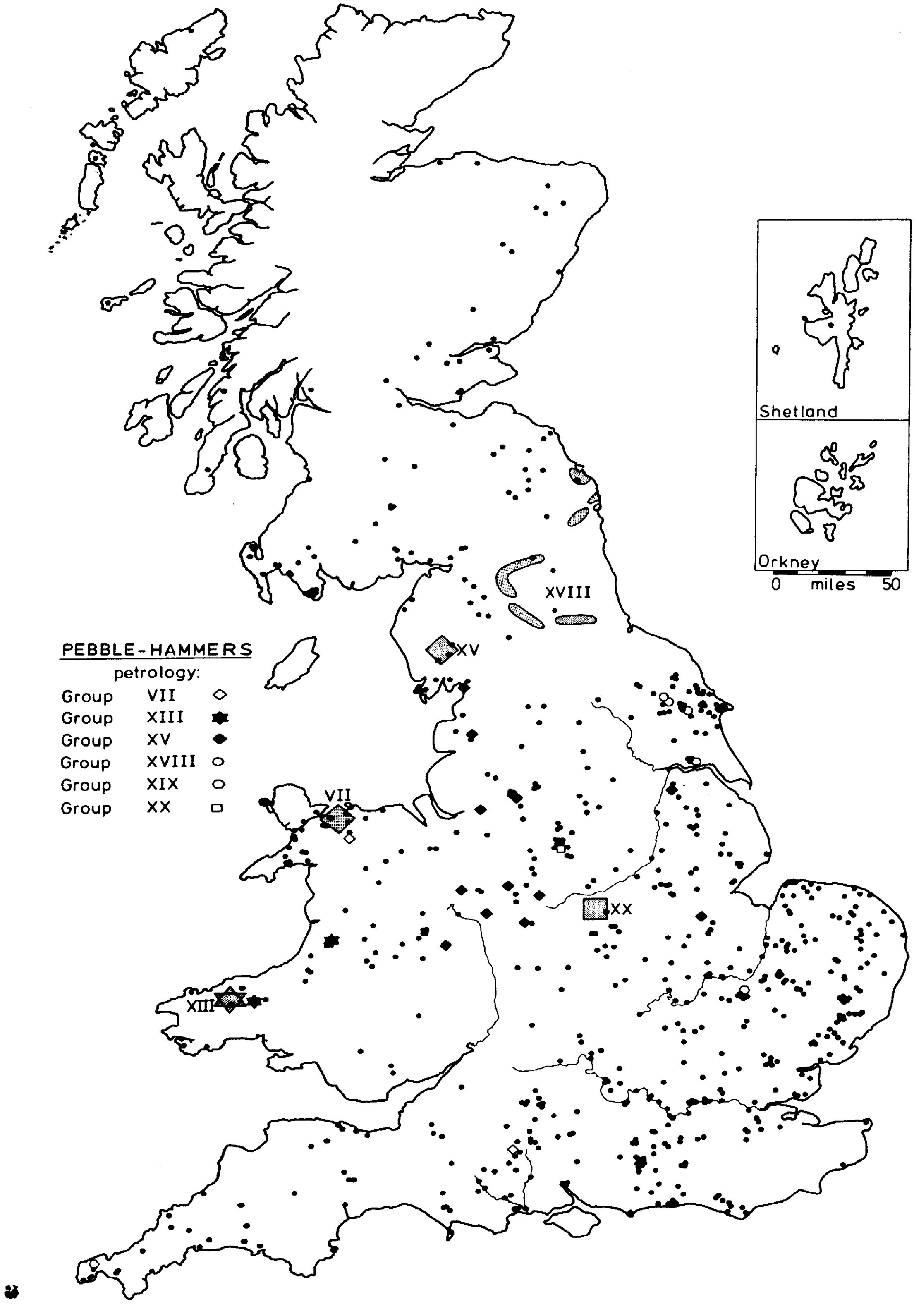
12 Shafthole adze distribution and petrology



13 shafthole adzes. N 131, Norwich, Group XV. Wa 1/ah, Warwick, Group XV. Wa 12/ah, Kenilworth, Group XV. Li 246, Harmston, Group XVI.... Cam 34, Wicken Fen, Group XVIII. E 18, Layer Breton, Group I. Sx 60, Firle. Sx 73, near Lewes. Scale 1/3



14 Pebble hammers. a Washington. b Durrington Walls. c Hurst Fen. d, f Windmill Hill. e Rudston. g Ulrome. h East Ayton. i Segontium. j South Cadbury. k Fifield Bavant. l Appleton, Group XV m Settrington. Group XVIII. n Fen Ditton, Group XIX. Scale 1/3



15 Pebble hammer distribution and petrology

Appendix: Catalogue of shafthole implements made of grouped rocks

Battle axes (shown on map, Fig 3)

Serial No	County No	Location	Stage	Petrological Report
Group I				
782	Corn 179	Probus	III	Evens *et al* 1972
855	Corn 218	Sithney	III	*ibid*
	He 9/ah	Vowchurch	II	–
Group III				
870	Ht 3	Ashwell	III	Evens *et al 1962*
4	Wilt 4	Avebury	frag (?)	Keiller *et al* 1941, Fig 2
Group IV				
	E2	Great Oakley Hall	I	Clough & Green 1972
Group XII				
1329	Berk 50	Lambourn	V (S)	Evens *et al 1972*
	CAM 17	Chippenham	V (S)	Clough & Green 1972
1545	Devn 123	Yettington	I	Evens *et al* 1972
	Db 124	Tideswell	IV	Moore & Cummins 1974, Fig 7
	Db 125	Carder Low	III	Moore & Cummins 1974
	Db 126	Parcelly Hay	III	*ibid,* Fig 7
1502	Glos 94	Snowshill	V (S)	Evens *et al* 1972
538	Hamp 51	Southampton	II	Stone & Wallis 1951, Fig 8
	He 3/ah	Mathon	V (S)	Shotton *et al* 1951, Fig 1
267	Li 219	Brigg (?)	IV	Cummins & Moore 1973, Fig 9
322	Li 263	Nocton	III	*ibid*
	N41	Stole	½ V (S)	Clough & Green 1972
	Sh 3/ah	Bromfield	III	Shotton *et al* 1951, Fig 1
	Sh 7/ah	Morfe	II	*ibid*
	Sh 9/ah	Moreton Corbet	II	*ibid*
	Sh 15/ah	Much Wenlock (?)	I	*ibid*
	Sh 16/ah	Frodesley	II	*ibid*
	Sh 25/ah	Montford Bridge	III	*ibid*
	Sh 64/ah	More	I	this paper, Fig 1
1513	SO 109	Holwell	III	Evens *et al* 1972
	S St 10/ah	Dove Valley	(?)	–
	N St 19/ah	Hanley	I	–
		Throwley	IV	–
	SY 9	Chertsey	III	–
	Wa 16/ah	Coventry	½ II	–
295	Wilt 78	Windmill Hill	III	Stone & Wallis 1951, Fig 8
298	Wilt 81	Shrewton G 27	V	*ibid*
	Wo 9/ah	Bewdley	V (S)	Shotton *et al* 1951, Fig 1
	Wo 11/ah	Ribbesford	IV (S)	*ibid*
	Wo 14/ah	Bromsgrove	V (S)	–
	Wo 17/ah	Bredon Hill	½ II	–
	Y 592	Armthorpe	IV (S)	–
	Y 609	Doncaster	V (S)	this paper, Fig 2
	ME6	Dolgelly	II	–
	ME9	Merioneth, probably	II	–
	MO4	Garthbeibio	IV	–
	MO 36	Uppington	III	–
	Wales 6	Shrops or Mont, probably	V (S)	–
Group XIII				
1103	Wilt 302	Wilsford G 54	II	Evens *et al* 1972
	CAR 23	Trelech a'r Bettws	II	
	RA 4	Llansantffraid-cwmdeuddwr	II	
Group XIV				
	Db 7	Long Eaton	I	Moore & Cummins 1974, Fig 7
	Le 30	Sutton Cheney	I	Moore & Cummins 1974
305	Li 249	Hackthorn	½ III	Cummins & Moore 1973, Fig 9
822	Np 73	Potterspury	½ II	
	Wa 3/ah	Coventry	½ IV	Shotton 1959
	Wa 17/ah	Stoneleigh	½ IV	
	Wa 22/ah	Coventry	II	
	Wa 24/ah	Mancetter	frag	
297	Wilt 80	Codford St Peter G 5	V	Evens *et al* 1972
1059	Wilt 299	Collingbourne Kingston G 6	frag	*ibid*

Serial No	County No	Location	Stage	Petrological Report
Group XV				
1674	AV2	Yatton	I	this paper, Fig 1
	Ch 5	Norbury/Bickley	II	–
	Db 206	Belper	I	Moore & Cummins 1974, Fig 7
	La 48	Wray	I	–
682	Li 351	Branston and Mere	II	this paper, Fig 1
	Sh 62/ah	Shrewsbury	II	–
	Sh 63/ah	Lydham	II	–
	N St 12/ah	Betley	II	–
	DEN 13	Llanelian-yn-Rhôs	½	*Bull Board Celtic Stud,* 22, 1966–8, 204
	DEN 14	Llansantffraid Glynceiriog	½	*Tr Denbigh Hist Soc,* 18, 1969
Group XVII				
853	Corn 216	Burnow-in-Cury	I	Evens *et al* 1972
Group XVIII				
1400	Berk 52	Cookham	II	*ibid*
	CAM 88	Downham	I	Clough & Green 1972, Fig 11
	CAM–	Newark	II	this paper, Fig 1
1045	Cumb 12	Plumpton Wall	frag	Evens *et al* 1962
	Db 8	Hartington	½ II	Moore & Cummins 1974
	Db 26	Aldwark	frag III	*ibid*
981	Durh 1	near Heathery Burn	frag	Evens *et al* 1962
	E 41	Frating	I	Clough & Green 1972
	La 32	Breightmet	II	–
	La 64	Northenden	(?)	–
821	Le 48	Branston	IV	–
120	Li 118	Roxby cum Risby	½ IV	Cummins & Moore 1973
190	Li 168	Ancaster	½	*ibid*
304	Li 248	Grainsby	½ II	*ibid*
343	Li 276	Scunthorpe	III	*ibid*
378	Li 310	Ropsley	I	*ibid,* Fig 11
849	Li 397	Welton-le-Marsh	(?)	–
953	Li 426	Southrey	II	–
	Middx	Thames Ditton	I	Celoria 1974, 90
	N 34	Tottenhill	I	Clough & Green 1972
	N 52	Wymondham	I	*ibid*
	N 83	Hunstanton (Holme)	½ II	*ibid*
	N 85	North Lopham	½ IV	*ibid*
	N 97	Tasburgh	II	*ibid,* Fig 11
	N 108	Norfolk	II	Clough & Green 1972
	N 137	Tottenhill	I	*ibid,* P1 XI
	N 194	Sparham	II	–
728	Np 38	Harpole	I	–
451	Not 76	South Leverton	IV	Cummins & Moore 1973, Fig 11
	Oxon 4	North Hinksey	II	this paper, Fig 2
	S 17	Icklingham	½ II	Clough & Green 1972
	S 121	Stowmarket area (?)	I	this paper, Fig 1
	Wa 11/ah	Lower Hillmorton	I	–
292	Wilt 75	Kilmington G 1	IV (S)	Evens *et al 1972*
304	Wilt 86	Upton Novell G 2a	III	*ibid*
886	Wilt 231	Old Sarum	½ III(S)	*ibid*
1554	Wilt 383	Bulford Down G 27	I	*ibid*
627	Y 15	Bridlington	½ I or II	Keen & Radley 1971, Fig 6
	Y 207	Wold Newton	½ III(S)	*ibid,* Fig 7
	Y 308	near Pickering	III (S)	Keen & Radley 1971
	Y 309	near Pickering	½ IV (S)	*ibid*
	Y 350	Sheffield	II	*ibid*
	Y 425	Cayton	II	–
	Y 495	Dalton Holme	½ V (S)	–
	Y	near Robin Hood's Bay	½ III (S)	–
	AN 13	Bodedern	III	–
Group XXIII				
	MO3	Carno	II	Shotton 1972
	P 11	Llanrhian	V	*ibid*

Axe hammers (shown on map, Fig 6)

Serial No	County No	Location	Class	Petrological Report
Group I				
516	Corn 38	Madron	½ Ia	Stone & Wallis 1951, Fig 6
Group XII				
1297	Berk 44	Caversham	Ia/b	Evens *et al 1972*
515	Corn 37	Gwinear	IIb	*ibid*
789	Corn 186	St-Just-in-Penwith	IIb	*ibid*
	Db 107	Stanton Moor	IIa	Moore & Cummins, 1974, Fig 7
615	Devn 27a	Otterton	Ib	Stone & Wallis 1951, Fig 8
1245	GLOS 53	Cromhall	IIa	Evens *et al* 1972
	He 2/ah	Pembridge	IIb	Shotton *et al* 1951, Fig 1
673	Li 348	Langtoft	IIb (?)	–
	Sh 1/ah	Shrewsbury	Ib	Shotton *et al* 1951, Fig 1
	Sh 4/ah	Bitterley	Ib	*ibid*
	Sh 17/ah	Little Ryton	IIb	*ibid*
	Sh 18/ah	Netley	IIa	*ibid*
	Sh 20/ah	Wrentnall	IIa	*ibid*
	Sh 21/ah	Minton	IIb	*ibid*
	Sh 22/ah	Acton Scott	IIb	*ibid*
	Sh 35/ah	Hardwick	IIb	*ibid*
	Sh 38/ah	Wentnor	IIb	*ibid*
	Sh 40/ah	Condover	Ia	*ibid*
	Sh 41/ah	Bettws-y-Crwyn	Ib	–
	Sh 52/ah	Hockleton, probably	IIb	Shotton *et al* 1951, Fig 1
	Sh 75/ah	More	(?)	–
889	SOMT 38	Keynsham	IIb	Evens *et al 1972*
1316	SOMT 93	Ebbor	frag	*ibid*
	N St 16/ah	Talke	Ia	–
	S St ll/ah	Broughton	IIb	–
	S St 17/ah	Swynnerton	½	–
	S St 27/ah	Chebsey	IIa	–
	St	Forsbrook	IIb	–
	S 73	Lakenheath	Ia/b	Clough & Green 1972
	Wa 18/ah	Budbrooke	IIb (?)	–
968	Wilt 246	Ogbourne St George	Ib	Evens *et al* 1972
	Wo 6/ah	Abberley	IIb	Shotton *et al* 1951, Fig 1
	Wo 12/ah	Kidderminster	Ib	*ibid*
	Wo 15/ah	Stirchley	IIb	–
	AN 45	Llandyfrydog	IIb	–
	BR 11	Llanfihangel Cwmdû	(?)	–
	BR 12	Breconshire	IIb	–
	CA 10	Glan Ystwyth	IIb	–
	CA 26	Lledrod, Upper	Ia/b	–
	CA	Llanbadarn-y-Creuddyn	IIb	*Bull Board Celtic Stud,* **22,** 1966–8, 203, Fig 4
	CAR 3	Llandovery	IIa	–
	MO 27	Llanidloes	IIa	–
	RA 6	Radnor, probably	IIb	–
	RA 11	Beguildy	Ia	–
	RA 24	Stanage Park	IIb	Shotton *et al* 1951, Fig 1
	RA 34 (not on map)	Harpton and Wolfpits	IIa	*Trans Radnor Soc,* **46,** 1976, 81, Fig 3
Group XIII				
	E 29	Thaxted	Ib	Clough & Green 1972
	Sh 6l/ah	Wotherton	Ia	–
434	Wilt 133	Fifield Bavant	IIb	Stone & Wallis 1951, Fig 7
	AN 10	Llanfaethlu	Ia	–
	CAE 51	Llandudno	½-	–
	CA 25	Lledrod, Upper	½ -	–
	ME 8	Llangelynin	Ia	–
Group XIV				
	Bucks	Loughton	½ IIb	Roe 1974, Fig 1
	Db 204	Clay Cross	(?)	Moore & Cummins 1974
	Db 227	Derby, Littleover	IIb	–
	Essex	Tilbury Docks	IIb	Celoria 1974, 91
	Hamp 94	Ropley (?)	IIb	–
	Le 12	Barrow-on-Soar	IIb	Moore & Cummins 1974, Fig 7

Serial No	County No	Location	Class	Petrological Report
256	Li 211	Epworth	IIa	Cummins & Moore 1973, Fig 9
338	Li 272	Dunston Fen	IIb	this paper, Fig 8
	S St 25/ah	Tamworth	Ib	–
	Wa 4/ah	Walsgrave-upon-Sowe	IIb (?)	Shotton 1959
	Wa 5/ah	Foleshill	IIb	*ibid*
	Wa 10/ah	Lower Hillmorton	IIa	*ibid*
	Wa 15/ah	Coventry	½	*ibid*
	Wo 13/ah	King's Heath	IIb	*ibid*
Group XV				
	Ch 3	Pinsley Green	IIa	–
	Ch 13	Coddington	(?)	–
	Ch 22	Beeston Castle	IIb	–
	Ch 23	Frodsham	IIb	–
	Ch 28	Brinnington	Ia	–
	Ch 29	Middlewich, R Croco	(?)	–
	Ch 42	Gatley	Ib	–
	Ch 43	Macclesfield	IIa	–
	Ch 44	Chelford	IIa	–
	Db 60	Allenton	IIa	Moore & Cummins 1974
	Db 61	Barley Dale	Ib	*ibid*
	Db 106	Stanton Moor	Ib	*ibid,* Fig 7
	Db 108	Harthill Moor	Ib	Moore & Cummins 1974
	Db 110	Taddington	IIb	*ibid*
	Db	Stanton Moor	IIb	–
	Db	Winster	Ib	–
	Db	Derbyshire	Ib	–
	La 4	Blackford Bridge	IIb	–
	La 5	Radcliffe	Ia	–
	La 6	Blackpool	Ib	–
	La 7	Blackpool	(?)	–
	La 8	Eccleston	Ib	–
	La 9	St Helens	IIb	–
	La 12	Lowton	IIb	this paper, Fig 8
	La 33	Holcombe	Ia	–
	La 36	Blackrod	IIb	–
	La 37	Aynsome, Cartmel	Ia	–
	La 38	Allithwaite	Ib	–
	La 41	Lancaster	Ia	this paper, Fig 7
	La 42	Lancaster	IIb	–
	La 43	Lancaster	Ia	–
	La 44	Borwick	IIa	–
	La 45	Ayside, Cartmel	IIa	–
	La 47	Yealand, Mossdale	IIa	–
	La 50	Rusland	Ia	–
	La 52	Altcar	(?)	–
	La 55	Barton	IIb	–
	La 56	Bury	(?)	–
	La	Ulverston	(?)	Fell 1974, 5
817	Li 390	Spalding (?)	(?)	–
	N 53	Feltwell	frag	Clough & Green 1972
	Not 85	Newstead	Ib	–
	Sh 39/ah	Wroxeter	½	Shotton 1959
	Sh 70/ah	Calverhall	Ib	–
	Sh 72/ah	Whitchurch (?)	IIb	–
	N St 13/ah	Biddulph	IIa	–
	N St 14/ah	Cauldon	Ia	–
	N St 15/ah	near Leek	Ia/b	–
	N St 18/ah	Swinscoe	II	–
	S St 2/ah	Hopton	Ia	Shotton 1959
	S St 12/ah	Chartley	irregular	*ibid*
	S St 15/ah	Chartley	Ib	*ibid*
	Y 521	Adel	(?)	–
	Y 669	Totley	½	–
Group XVIII				
	CAM 1	Isleham	IIb	Clough & Green 1972
	CAM 24	Stretham Fen	Ib	*ibid*
	Db 55	Sinfin, Derby	IIb	Moore & Cummins 1974
	Db 120	Longeaton	Ia	*ibid*

Serial No	County No	Location	Class	Petrological Report
268	Db 187	Whitwell, Burnt Leys	Ia	*ibid*
	Db	Ashopton	Ia	–
	La 66	Bickershaw/Abram	(?)	–
	Le 16	Leicester	Ib	Moore & Cummins 1974
258	Li 213	Swallow	Ia	Cummins & Moore 1973
262	Li 217	Bigby	Ib	*ibid*
295	Li 239	Baumber	IIa	*ibid*
297	Li 241	Stainfield	IIa	*ibid,* Fig 11
298	Li 242	Sudbrook	Ia	Cummins & Moore 1973
300	Li 244	Lincolnshire (?)	(?)	*ibid*
301	Li 245	Lincolnshire	IIb	*ibid*
373	Li 305	Scunthorpe	Ia	*ibid*
376	Li 308	North Kelsey	Ib	*ibid*
954	Li	Holton-le-Moor	IIb	–
	N 35	near Docking	Ia/b	Clough & Green 1972
	N 36	near Docking	Ib	*ibid*
	N 63	Frettenham	Ia	*ibid*
	N 64	Fordham	Ib	*ibid,* Fig 11
	N 66	Great Massingham	Ia	Clough & Green 1972
	N 67	West Dereham	Ib	*ibid,* Fig 11
	N 68	'Downham Market'	Ia	Clough & Green 1972
	N 89	Hackford	Ia	*ibid*
	N 93	Binham	Ia	*ibid*
	N 94	Hingham	Ia	*ibid*
	N 95	Necton/Holme Hale	IIa	*ibid*
	N 96	Edingthorpe	½ Ib	*ibid,* Fig 13
	N 99	Paston	Ia	Clough & Green 1972
	N 100	Eaton, Norwich	I a/b	*ibid*
	N 102	North Creake	Ib (?)	*ibid*
	N 103	Alby-cum-Thwaite	Ia	*ibid*
	N 104	Southery/Brandon Creek	I a/b	*ibid*
	N 105	Warham St Mary	(?)	*ibid,* Fig 11
	N 129	Ickburgh	Ib	Clough & Green 1972
	N 186	Rollesby	Ia	–
	N 201	Castle Acre	Ia	–
	S 33	Icklingham	Ia	Clough & Green 1972
	S 88	Kesgrave	Ia	–
686	Sy 3	Ripley	Ia	Evens *et al* 1962
	Wa 9/ah	Coventry (?)	Ib	–
	Y 171	Rigg Hall	IIb	Keen & Radley 1971, Fig 6
	Y 218	Burstwick	IIa	*ibid*
	Y 307	Sherburn	Ib	Keen & Radley 1971
	Y 372	Moreley	(?)	–
	Y 377	Whitby	(?)	–
	Y 378	Yorkshire (?)	(?)	–
	Y 380	Sheriff Hutton	(?)	–
	Y 388	Stutton-with-Hazlewood	(?)	–
	Y 415	Lowthorpe	IIb	–
	Y 418	Hutton Cranswick	Ib	–
	Y 419	Atwick	Ib	–
	Y 420	Farndale	½	–
	Y 421	Sewerby	Ia	–
	Y 422	Seaton, Catfoss	(?)	–
	Y 434	Scalby Beck	½	–
	Y 490	Scalby	IIa	–
	Y 491	Ruston	Ib	–
	Y 515	Scalby	IIb	–
	Y 516	East Ayton	Ia	–
	Y 665	Sunderlandwick	IIa	–
	Y 666	Hornsea	IIa (?)	–
	Y	Speeton	Ib	–
Group XIX				
	Kent 22	Ramsgate	Ib	–
	N 101	Wendling	Ib	Clough & Green 1972, Fig 9
Group XXIII				
	CA 2	Teifiside	Ia	Shotton 1972
	He 1/ah	Kington	½	*ibid*

Mace heads (shown on map, Fig 11)

Serial No	County No	Location	Group	Petrological Report
Group I				
241	Berk 10	Cold Ash	Thames Pestle	Evens *et al* 1972
	CAM 71	Burwell	Thames Pestle	Clough & Green 1972, Fig 9
	Db 27	Aldwark	½ Ovoid	Moore & Cummins 1974, Fig 3
1470	GLOS 85	Rendcomb	½ Thames Pestle	Evens *et al* 1972
242	N 28	Santon Warren W	frag, Thames Pestle	Stone & Wallis 1951, Fig 6
	N 204	Bacton	Thames Pestle	this paper, Fig 9
	Sh 55/ah	Purlogue	½ Ovoid (? C)	Roe 1968, 155
717	Wilt 206	Deptford	½ Thames Pestle (?)	Evens *et al* 1972
	GL 87	Porthcawl	Orkney Pestle	*Bull Board Celtic Stud,* **24,** 1970–2, 98, Fig 5
Group VI				
1423	Berk 55	near Windsor	Cushion	Evens *et al* 1972, Fig 5
326	Li 267	Great Hale	½ Cushion	Cummins & Moore 1973, Fig 5
	–	Thames, Hammersmith	cushion	Stanley 1976, 6, illus
Group VII				
1	Wilt 1	Windmill Hill	frag, Maesmore	Evens *et al* 1972
Group XIII				
88	Devn 1	Sidmouth	½ Ovoid C or pebble hammer	Stone & Wallis 1951, Fig 7
	PE	Newport	Thames pestle	Roe 1968, Fig 33, 3
Group XVIII				
	S St 5/ah	Sutton Coldfield	Ovoid B	this paper, Fig 9
	Y 278	Garrowby 69	Ovoid A	Keen & Radley 1971
	Y 445	Hutton Buscel	½ Ovoid	–
	Y 482	Wheatcroft	Bush Barrow	this paper, Fig 10G
Group XX				
	CAM 44	Soham district	Thames pestle	Clough & Green 1972, Fig 12
930	CAM	Bamack	frag, possibly of Thames pestle	–
	Db 53	Beeley Moor	Ovoid C	Moore & Cummins 1974
	N 138	Colney area	Ovoid B (?)	Clough & Green 1972, Fig 12
Group XXII				
(These identifications have not been confirmed, and so the mace heads are not included on the map)				
	–	Cairn, Fife	Cushion	this paper, Fig 9m
	–	Knock, Lewis	Cushion	Gibson 1944, Pl 1
Group XXIII				
	CA 11	Lower Lledrod	Ovoid (?)	Shotton 1972

Shafthole adzes (shown on map, Fig 12)

Group I				
1454	Dors 112	Halstock	damaged	Evens *et al* 1972
	E 18	Layer Breton	narrow butt	Clough & Green 1972, Fig 9
	Np 62	Polebrook/Ashton	symmetrical	–
Group XV				
	Ch 25	Stockport	narrow butt	–
	Ch 41	Timperley	half	–
	Cumb	Dalston, Greenhead	narrow butt	–
	Db 226	Edensor	damaged	–
	He 8/ah	cusop	symmetrical	–
	Ht 25	Bishop's Stortford	narrow butt	–
	Kent 8	Dartford Heath	narrow butt	–
	La 14	Irlam	disc	–
	N 131	Norwich, Cedar Rd	narrow butt	Clough & Green 1972, Fig 10
211	Not 35	Kneesall	narrow butt	Cummins & Moore 1973, Fig 9
	N St 7/ah	Cheddleton	narrow butt	–
	S St 4/ah	Wolverhampton	half	Shotton 1959
	Wa l/ah	Warwick	narrow butt	*ibid*
	Wa 12/ah	Kenilworth	disc	*ibid*
Group XVII				
1618	Dors 122	Alderholt	nearly symmetrical	
Group XVIII				
	CAM 34	Wicken Fen	symmetrical	Clough & Green 1972
	Db 40	Middleton and S	nearly symmetrical	Moore & Cummins 1974

Serial No	County No	Location	Class	Petrological Report
	E 14	Dovercourt	nearly symmetrical	Clough & Green 1972
	Kent 23	Swalecliffe	symmetrical	*Archaeol Cantiana,* **79,** 1964 (1965), 224
302	Li 246	Harmston	nearly symmetrical	Cummins & Moore 1973
377	Li 309	Ludford	nearly symmetrical	Cummins & Moore 1973, Fig 11
	N 112	Thetford	half	Clough & Green 1972
	N 184	Norfolk	half	–
	S 46	Mildenhall	symmetrical	Clough & Green 1972, Fig 11
	S 50	Westerfield	nearly symmetrical	*ibid*
	Y 145	Tickton	narrow butt	Keen & Radley 1971, Fig 7
	Y 413	Yorkshire Wolds	symmetrical	–
	Y 501	Seamer	narrow butt	–
	Y 663	Barmston	narrow butt	–
Group XIX				
195	Dors 29	Marnhull	(part)	Evens *et al* 1972
368	Wilt 99	West Kennet	(Part)	*ibid,* Fig 6

Pebble hammers (shown on map, Fig 15)

Group VII				
283	Wilt 66	Groveley or Wylye	unfinished hole, half only	Evens *et al* 1962
	DEN 36	Llanrwst		–
Group XIII				
	CA 21	Ponterwyd		–
	CAR 28	Cilrhedyn East		*Bull Board Celtic Stud,* **14,** 1950–2, 85
Group XV				
	Ch 27	Appleton		this paper, Fig 141
	La 31	Silverdale	(? or mace head)	–
	La 63	Manchester		–
	La 69	Inglewhite		–
353	Li 285	Bottesford		Cummins & Moore 1973, Fig 9
785	Li 377	Baston	(? or mace head)	–
	Sh 31/ah	Hopton Castle		–
	Sh 56/ah	Stanton-upon-Hine		–
	Sh 65/ah	Shifnal?		–
	S St 7/ah	Admaston		–
	S St 18/ah	Bloxwich		–
	S St 28/ah	Chebsey		–
Group XVIII				
	Y 147	Ryton	possibly worn adze	Keen & Radley 1971, Fig 7
	Y 503	Willerby	half	–
	Y 618	Settrington		this paper, Fig 14m
	Y 619	Fimber	half	–
Group XIX				
	CAM 81	Fen Ditton		Clough & Green 1972, Fig 9
540	Corn 50	Zennor		Evens *et al* 1962, Fig 6
Group XX				
	Db 192	Elton		Moore & Cummins 1974

Miscellaneous

Group XII				
1196	Corn 250	Gwithian, XV, layer 5	fragment, axe hammer or battle-axe(?)	Evens *et al* 1972
Group XVIII				
398	Wilt 115	Tisbury. Castle Rings	half small axe hammer or battle-axe(?)	*ibid*
	Y 349	Beauchief, Sheffield	Ovoid mace head or pebble hammer(?)	Keen & Radley 1971

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Stone axes of Brittany and the Marches

C-T Le Roux

Abstract

Since the work initiated some 30 years ago by Professors Giot and Cogné, published mainly in the *Bull Soc Préhist Fr* in the 1950s, the main Breton petrological groups of stone axes have been well known. Recently, however, new data have been obtained for most of them which are summarized in the first part of this paper.

In the second part, these data are discussed in relation to the general problems of population and social organization in Neolithic Brittany; the discussion leads to quantifications of some aspects of human activity on the main site itself, the Type A Dolerite quarry at Plussulien, and more generally in the whole of western France.

Introduction

Petrological studies on Breton axes were initiated just after World War II, when Cogné and Giot (1952, 1953, 1954, 1955, 1957; Giot 1951, 1959, 1964) developed the methods pioneered in the 1930s in Great Britain. Their results still form the basis for all subsequent work.

Brittany is only the western, protruding part of the much larger Armorican massif, chiefly made of schistose Pre-Cambrian and Palaeozoic sediments often more or less strongly metamorphosed by important granitic intrusions. Moreover, numerous dykes, sills, or flows, most of them doleritic, occur chiefly in northern and central Brittany.

Flint is totally absent, except as sea pebbles which were carefully collected by prehistoric man for flaking small tools, but were never suitable for making axes. Flint axes are very rare indeed, only about 2% of the total in Finistère and barely 5% in the rest of Brittany. Their frequency increases rather abruptly near the Palaeozoic Mesozoic boundary, and reaches 90% or more in the chalky areas of the Paris basin or the Charentes, their probable source area.

As the present paper is limited to the axes made of igneous or metamorphic rocks, the figures given will not always have the same significance in different places, and this must be borne in mind in further discussion.

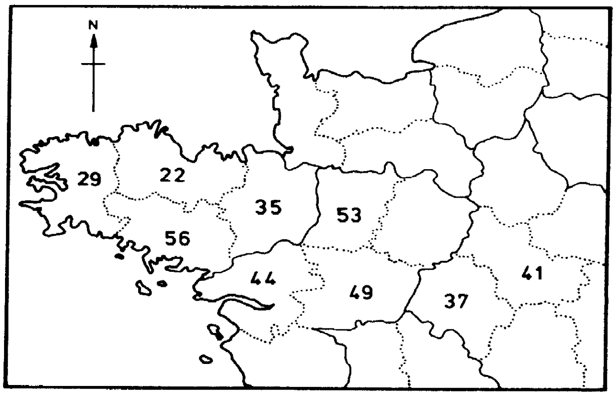
To date, nearly 5,000 axes have been examined, almost half of them from Brittany and the rest from western France. Two-thirds of them have been thin-sectioned and identified microscopically. The remainder could be accurately identified macroscopically.

The sampling technique used in Rennes for nearly fifteen years now, utilizes a small diamond-coated core-drill (available for instance from Diamant Boart, Brussels). It is mounted on a specially designed piece of equipment worked by a simple drilling machine.

The miniature core obtained is 6–10mm in diameter according to the size of the drill. Its length is, theoretically, limited only by the thickness of the sampled implement but, in practice, 20–30mm is generally sufficient and can be obtained in a few minutes. This system, which is very cheap, is moreover portable and permits one to work easily in a museum, or even in a collector's kitchen!

The sample is then sliced longitudinally into two (or three) parts on a small diamond saw (also specially designed for the purpose) and one part is ground for microscopic examination. The section obtained, of nearly 1cm^2 is quite adequate for fine-grained rocks and can be easily doubled by grinding two pieces of the sample side by side. The rest is stored for eventual future use, or as a replacement in case of accident during the preparation of the thin section.

This sampling technique leaves only a circular mark on the implement, barely larger than a *confetti,* which is, of course, quite easy to repair. Moreover, even on spectacular implements, it is often possible to find a small damaged or poorly finished area, sufficient for drilling.



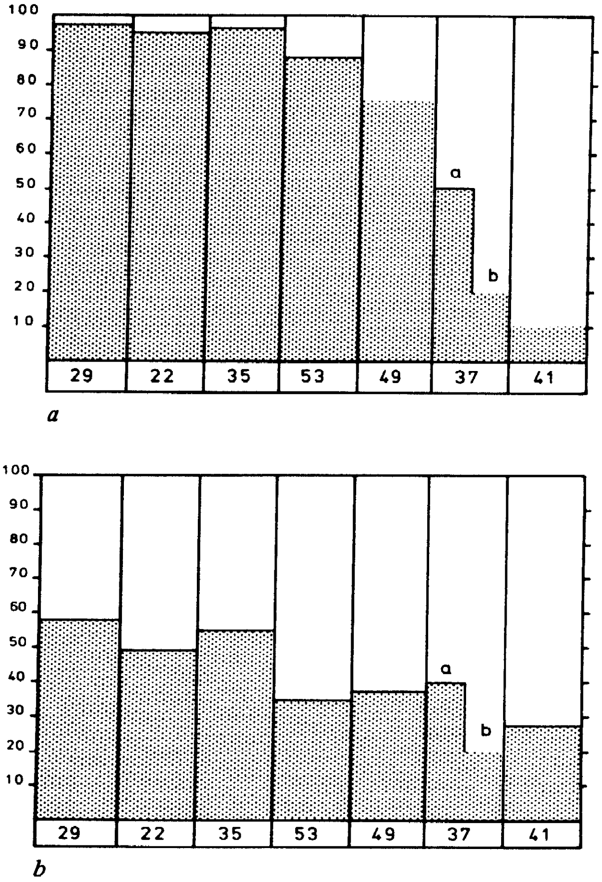
1 Map of north west France, showing the départements referred to in the tables and in Figure, 2:- 22, Côtes-du-Nord; 29, Finistère; 35, Ille-et-Vilaine; 37, Indre-et-Loire; 41, Loire-et-Cher, 44, Loire Atlantique; 49, Maine-et-Loire; 53, Mayenne; 56, Morbihan.

Table I	29 N	22	35	53
Type A	53	49	54	35
Type B	3	3	1	2
Type C	0	0	0	0
Fibrolite	27	7	5	5
Pyroxenite	2	5	11	11
Dolerites	10	18	13	28
Minor Groups	0	3	5	9
intrusive rocks	3	5	2	1
Others	2	10	3	2

Table II	29 S	56	44	44 S
Type A	59	56	48	51
Type B	12	7	5	2
Type C	3	3	5	0
Fibrolite	6	5	10	1
Pyroxenite	2	20	8	3
Dolerites	13	9	13	18
Minor groups	0	0	3	11
Intrusive rocks	3	5	5	5
Others	3	3	4	9

Table III	49	37	41
Type A	37	20	27
Type B	1	0	2
Type C	0	1	1
Fibrolite	1	5	6
Pyroxenite	10	18	15
Dolerites	17	21	21
Minor groups	23	27	8
Intrusive rocks	7	8	11
Others	5	0	7

Quantitative data on petrological groups, given as percentages of all stone axes (excluding flint) in each area:-- (I) Northern Brittany, (II) Southern Brittany, (III) Lower and Middle Loire Valley. The numbers in the column headings are 'post-code' figures for the départements shown in Figure I.



2 Graphic representation of the variation in stone axe petrology from Western Brittany to the Middle Loire countries. (a) stone axes (stippled), shown as a percentage of all axes, including flint. (b) Type A dolerite axes (stippled), shown as a percentage of all stone axes, excluding flint. The numbers at the foot of the columns are 'post-code' figures for the départements shown in Figure I. In Andre-et-Loire, 37a represents the Chinon area and 37b represents the rest of Indre-et-Loire. Closed columns represent precise countings and open columns approximate estimates.

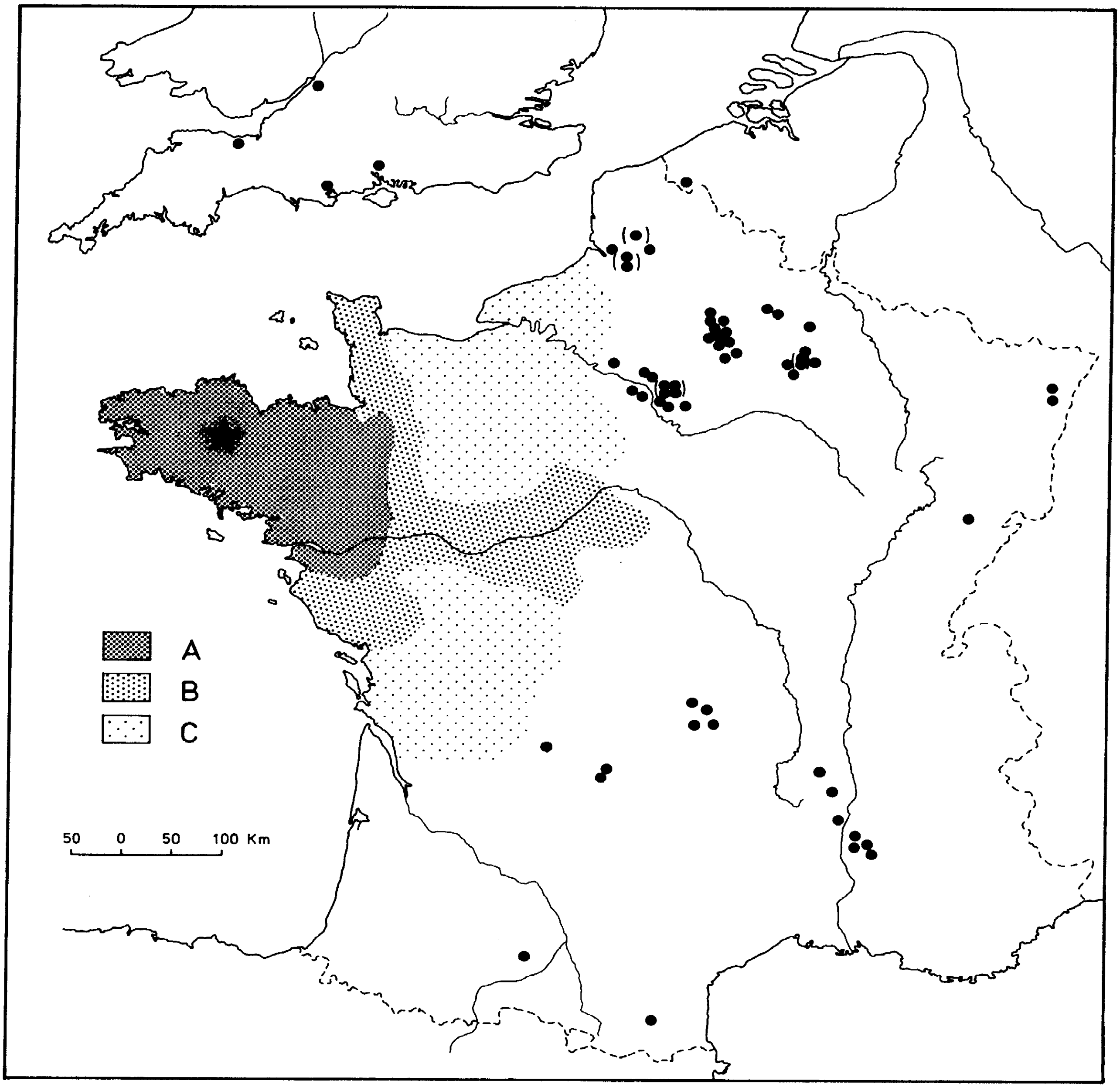
Brief review of the main Breton petrological groups and types

All the important groups discussed below were defined long ago and their descriptions have been published repeatedly. We shall therefore only review recent work on each of them.

The Type A dolerite

The rock described by Cogné and Giot (1952) as a very fine grained and strongly epidioritized dolerite forms a prolific group accounting for nearly 50% of the axes in Brittany and 30–40% in the rest of the Armorican massif. Axes of this rock are still abundant throughout north-western France, from the mouth of the Seine to the Gironde (10% or more of the non-flint axes) with a clear preferential diffusion axis along the Loire Valley, up to Orleans. Their distribution extends as far as the Pyrenees, the lower Rhone Valley, Burgundy, Alsace, and Belgium. In southern England, four finds form the British Group X (Evens *et al* 1962). These are probably an accidental export, perhaps from the Cotentin, rather than evidence for regular exchanges across the western Channel as early as Neolithic times.

The factory site, discovered in 1964 at Sélédin, near Plussulien, in the south of Côtes-du-Nord, is sited on a particularly fine-grained outcrop among the large



3 Distribution map of ape A implements. In the close-stippled area A they make up more than 40 per cent of all the stone axes studied; in area B, between 20 and 40 per cent; and in area C, between 10 and 20 per cent. Known finds beyond these areas are indicated by dots (in brackets, if the provenance is uncertain). The factory site, at Plussulien, is indicated by a star.

doleritic sills of Lower Carboniferous age in the south east of the Chateaulin basin (Nicolas & Sagon 1963). Systematic surveying and five years of excavation have revealed impressive remains of axe-making activity (Delibrias & Le Roux 1975; Le Roux 1971a, 1971b, 1973, 1975; Le Roux & Giot 1965). Roughly, the history of this site can be reconstructed as follows:

Phase I. Its discovery took place between 5200 and 5000 BP, probably by people coming along the Blavet Valley, from the main population centre of that time in the Morbihan area. The first stage of exploitation only attacked areas crushed by faulting, where separate blocks of solid rock were embedded in weathering clay. Pits were dug for block picking, generally 1–2m deep and not very different from those of many open-air flint mining sites. Heaps of refuse clay, mixed with some flakes, and small 'domestic' hearths of this period are sometimes well preserved under later accumulations.

Phase II. Rapidly, however, probably about 5000-4800 BP, these favoured places were worked out and the axe makers began to attack the massive outcrops by hammering, particularly where numerous and regular joints made the work easier. In this phase, their megalithic engineering experience also enabled them to remove huge blocks, often weighing several tons, and arrange them as anvils or benches for flaking the rough-outs at some distance from the quarrying front.

Around the main outcrop, the result is an enormous and intricate accumulation: blocks of all sizes, rejected rough-outs, thick and thin flakes, and fine hammering gravels often cemented into a solid mass by rock dust.

Phase III. About 4300–4200 BP, the use of fire for quarrying was introduced. The foot of the outcrop was strongly heated to make the joints crack, and rough preliminary breaking was probably done while the rock was still hot and brittle. Experiments (Le Roux 1971b) suggest that, before flaking, the blocks were allowed to recover their original mechanical properties by gentle cooling, perhaps in hot ashes. Axe-making techniques themselves barely changed, and the refuse of Phase III differs from that of the previous phase chiefly in the abundance of charcoal and ashes, and the reddish colour of some rock surfaces.

We have no direct evidence as to how and when the activity ceased on the site, the upper levels of refuse being poor and disturbed; but a late gallery grave at Plelauff, some 10 km from the factory, containing four Type A axes and dated to about 3650 BP, shows that production was still in progress at that time, though probably on a reduced scale. Its death was most probably a result of the increasing occurrence of bronze tools, linked with a strong cultural change, marked by the spread of the Armorican barrow culture.

During this 1500-year period, axe-making techniques changed much less than the quarrying ones described above. From the crude block to the finished axe, four steps can be clearly distinguished. First, preliminary coarse flaking with a rather heavy hammer stone gives a rough-out, which is still a fairly long way from the shape intended. A secondary trimming then leads more closely to the desired shape, the flaked axe stage. This is done with a comparatively small, rounded striker. Hammering, the third step, is very important as it gives the regular shape of the axe, but with a grained surface. Like the flaking, it is done with small rounded stones. Finally, polishing gives a smooth surface and involves the removal of very little additional rock. An important function of polishing is the accurate sharpening and shaping of the cutting edge.

It is difficult to give quantitative data for this work but some experiments made during the excavations, although very incomplete, provide some basis for estimates. First, it generally appears necessary to start from a block weighing several kilograms to produce an axe weighing a few hundred grams. If we include unusable blocks and rejected pieces, the output of axes was probably less than 1% of the rock quarried. A second point, the time involved for making an axe, can easily be overestimated. If we except quarrying, in which one day's work could easily give the material for several dozen axes, the average timing might be as follows: flaking the rough-out (including rejects): nearly 1 hour; trimming the flaked axe: approximately another hour; hammering: 2-4 hours, according to the shape and size of the piece; and polishing: 4–10 hours, depending on skill and size. On this basis a common axe could represent barely 1 day's work and the best axes perhaps 2 or 3 days'.

Actual traces of polishing are rare on the quarry site but they do exist. Several smoothed and hollowed surfaces are certainly polishing places, and others could well have vanished. It is possible that the axes were not all polished here; indeed, many common axes are barely polished at all, except on the cutting edge. But the extreme rarity of rough-outs and even flakes far from the factory area (and a few very exceptional places such as Er-Lannic, Morbihan), the evidence on the site, and the enormous loss of weight during fabrication, show that most of the axes probably left the factory at least in the unfinished hammered stage.

Typologically, the production consists chiefly of normal utilitarian axes of various sizes and shapes. Besides these, it should be remembered that nearly all the famous 'button axes' (all except three out of several hundreds so far examined) are of Type A and their distribution is nearly the same as that of the common Type A axes but less regular, with unexplained concentrations (north-east Brittany, Morbihan, Middle Loire valley, and, chiefly, south of the mouth of the Loire) separated by near 'blanks' (including the Plussulien area itself). One should also mention some miscellaneous products, such as a few battle axes and a nice beaker wrist guard.

The Type B epidiorites

These rocks, also defined by Giot and Cogné (1952), are less precisely characterized and appear rather as a family of very closely related rocks supposed to come from a series of sills in the Brioverian schists, south of the Montagnes Noires. Only very slight traces of exploitation (one single rough-out and some flakes) have been found near Glomel, in the south-west of Cotes-du-Nord, but good similarities exist between thin sections from axes and several outcrops in this area. The paucity of evidence may be explained by several factors.

Axe making was probably spread over an area of at least several square kilometres in country which is now largely arable and grassland. The rock is fibrous in texture with important development of secondary sub-acicular amphiboles. Flaking was very difficult and the rock had to be worked chiefly by hammering and grinding, which left very few permanent traces. The production was comparatively modest. Type B pieces form 5–12% of all the axes in southern Brittany, but only 1–3% in the north, and very few spread beyond the peninsula. Their distribution is mainly in the south-east of Finistère, with a coastal expansion through the Morbihan down to the mouth of the Loire.

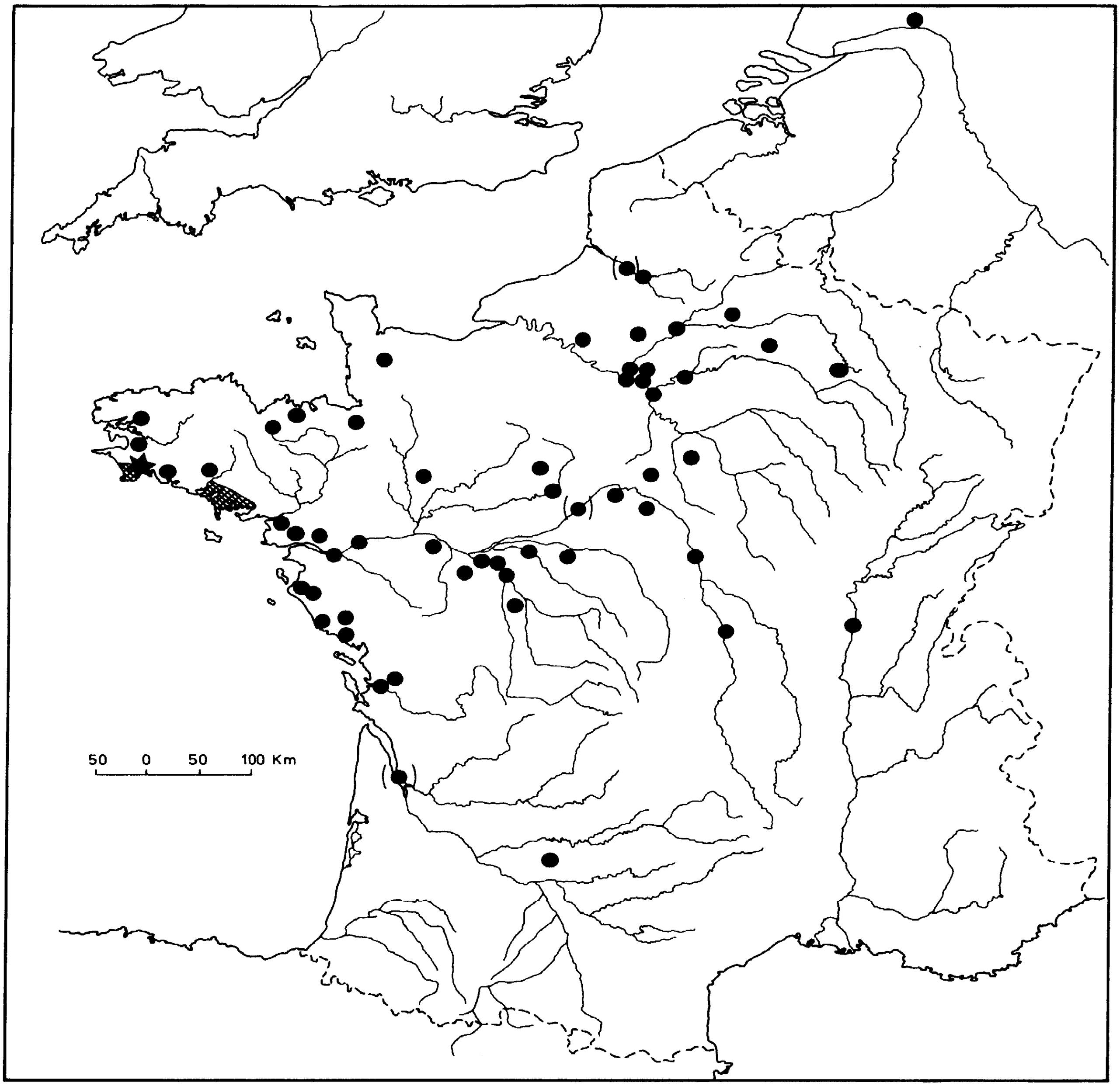
Type B axes are exclusively common implements, varied in shape and size, but rarely highly skilled products. Precise dating is still impossible for the production of these axes.

Type C hornblendite

There is little to add to the work of Cogné and Giot (1955, 1957; Giot 1959) on the specialized production of battle axes from this rock. New discoveries (nearly 100 pieces are now known) confirm their distribution in the Loire and Seine basins, up to the mouth of the Rhine and along the Atlantic coast down to the Gironde, from a strong concentration in South Finistère and littoral Morbihan.

The outcrop of this ultrabasic rock, at Pleuven near Quimper, was long ago damaged by quarries and more recently by urbanization. In spite of intensive searching, no trace of prehistoric activity has been found. Outside Brittany, most of the pieces are stray finds, often recovered during dredging or gravel quarrying in river valleys, as is true for battle axes in general.

In southern Finistère, and also to a lesser extent in Morbihan, a good series of implements, with a fair



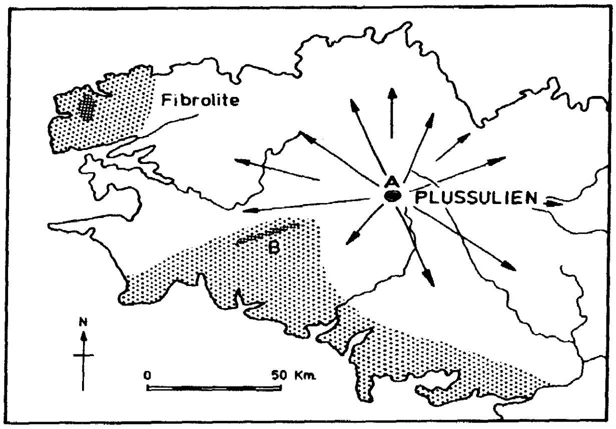
4 Distribution of Type C implements. The cross-hatched areas indicate local abundance. The source outcrop is indicated by a star.

proportion of unfinished or poor ones, has been found in megalithic graves. Moreover, in the same area, random finds of complete or broken rough-outs are common, especially in the vicinity of the quarry itself. Apart from these battle axes, three or four common stone axes, of rather poor quality, have been found in the same area of southern Finistère and western Morbihan.

Fibrolite

This is a monominerallic aggregate of fibrous sillimanite, which forms under certain metamorphic conditions. It occurs in several areas in Brittany, of which the two most important are in Morbihan and north of Brest, where it occurs as loose stones in the fields, weathered out of the surrounding rock. Hand specimens suitable for axe making could still be found a few years ago, before the onset of mineralogical piracy.

The microscopic structure is a very fine network of radiating or felty needles, which make the material very difficult to break and almost impossible to flake. It was actually worked by hammering, grinding, and sawing, traces of this being still visible on some axes (Giot 1952). In the field, very little evidence survives. The outcrop



5 Sketch map of interaction in distribution between implements of Type A. radiating from Plussulien; Type B epidiorite, in southern Finistère and Morbihan; and fibrolite, in north-west Finistère. High density areas of the last two are stippled and their source outcrops close-stippled,

area north of Brest has some quartz hammers, two hammered rough-outs, and a probable polishing stone, blown up and surviving today only as a cast in Penmarc'h museum.

Artefacts, if we exclude the very special flat axes from the Carnacean giant barrows, generally range from medium-sized axes to minute nail-shaped tools probably designed for some chisel-type hafting, though some of them have been perforated as pendants. The size of the available blocks clearly limited the possibility of their use for large tools. The hardness and tightness of the material also explains why some tools are in fact barely regularized nodules.

The distribution fits well with a shortdistance diffusion from the known outcrop areas: slight concentrations in the northeast, south-west, and south-east of Brittany, a stronger one in Morbihan, and the main 'cloud' of finds in north-western Finistère which has more than 25% of the fibrolite axes. Outside these areas they rapidly become rare (5% or less).

Fibrolite axes were certainly high-quality implements because of their good appearance, hardness, and resilience. Their surprisingly limited diffusion will be discussed below. One may also wonder why fibrolite did not compete more strongly with jadeite for parade implements. It barely did so at all, save for the special case of the grave goods of some Carnacean giant mounds.

Sodic pyroxenites (eclogite – jadeitite family)

Since the paper by Giot (1965), nothing new has appeared about the possible origins of Breton jadeitite axes. Jadeite actually occurs as a microscopic constituent of some glaucophanites on Groix island, off the Morbihan coast, but never in masses substantial enough to make an axe, even a minute one (Cogné 1960,127). On the other hand, eclogites, that is to say, garnet omphacite pyroxenites, are abundant in south-eastern Brittany, where they have recently been reexamined (Lasnier 1970; 1977; forthcoming). Lasnier recognizes a very characteristic 'atoll-like' structure of the garnets in one of the veins, passing just north of Nantes. This structure, which is highly significant because it appears only in very special conditions of crystallization, is actually found in a fair proportion of the sliced axes from western France, which suggests an Armorican origin for these and others, possibly made from less characteristic outcrops in the same area.

One should mention here the curious discovery of a large eclogite axe, in the Théodule Pass, near Zermatt in Switzerland (Sauter 1960), which revealed in thin section this precise 'atoll' structure whereas none of the known Alpine pyroxenites show it. Fending further investigation, this implement might perhaps be considered as indicating the reverse of a westwards current feeding the Armorican market from the Alpine outcrops.

If we except the very special and spectacular series of Carnacean ceremonial axes and consider only the common pyroxenite implements, Brittany generally appears rather poor (barely more than 5%), except in Morbihan. Although there is a progressive increase in northeastern Brittany and eastwards, the frequency is much less than that observable in central-eastern France for instance. Comparison with a general distribution map (as in Smith 1965) gives the same impression of an Alpine dispersion centre.

However, the possibility of unknown Breton lodes of true jadeitite remains. In addition to unknown sites on land, geological reasons lead one to think of some possible off-shore outcrop, in the same petrological district as Groix island itself, which could still have been accessible in Neolithic times, either directly or in the form of sea pebbles.

Small provisional groups

About 20 modest series ranging from 3 to 20 pieces each have so far been identified in western France. None has yet been certainly correlated with a factory site or even a precise outcrop. Their frequency is rather low in Brittany, where there is almost nothing between the large groups described above and a nebula of isolated rocks representing occasional products in a country where adequate if not ideal materials are widely distributed. These groups, still prudently considered as provisional, are much more important in the Marches and many of them are probably of east Armorican origin (Le Roux & Cordier, 1974).

Several areas are highly likely: for instance, north-western Côtes-du-Nord for a limited series of spilite; southern Mayenne and south-western Maine&-Loire for several dolerites and epidiorites; central Vendee for an important outcrop of palaeovolcanic andesite; and the north-western part of the Massif Central for a very unusual amphibolite, which has given both axes and battle axes, dispersed from the Loire valley to the Charentes.

Aspects of Neolithic Brittany illustrated by the stone axe industry

Chronology

We have seen above that the Plussulien factory produced Type A axes roughly between 5200 and 3600 BP, the first and last centuries probably being periods of slight activity. The typology of axes, which are strictly functional implements, does not vary significantly during that time. Type A axes are never found in the earliest Breton passage graves, which begin soon after 6000 BP, but they become quite common as grave goods in monuments dated to about 5000 BP, where they are often associated with typical Chassey ware (Le Roux 1971a; b).

On the other hand, fibrolite and pyroxenite, as well as some ungrouped dolerites, do seem to be present on the earliest Neolithic sites, such as simple chambered passage graves.

Type A and fibrolite are still well represented at the very end of Neolithic times (which does not seem to be true of the pyroxenites), for instance as grave goods in late gallery graves or reutilized earlier monuments. From megaliths recently excavated in the vicinity of Plussulien, we have now a series of C14 dates covering nearly the whole period of Type A axe production: 5140 BP for a V-shaped monument at Liscuis I (or perhaps for a slightly earlier occupation of the site); 4450 and 4170 BP for the utilization of a gallery grave at Liscuis II; 3680 and 3640 BP for another gallery grave at Plelauff. Thus, the previously supposed early phase, with exploitation of the factory site during periodical raids by people from coastal Morbihan, before actual settlement took place in the vicinity (Le Roux 1971a; b), was probably very short if it existed at all.

With regard to Type C battle axes, a new date must be mentioned. At La Sauzaie, near Rochefort-sur-Mer (Charente Maritime) (Pautreau 1974), a broken Type C battle axe has been found in a Peu-Richardian stratigraphy, which could be C14 dated to about 4400 BP (Gachina *et al* 1975). This would suggest the middle of that millennium for the beginning of their production, which might well have been rather short-lived: in southern Finistère, we have seen that Type C axes are often found in passage graves as intrusions, or at least late deposits, but this apparently never happens in later gallery graves, although they are common in this area.

Production and diffusion

We have seen how, at the Plussulien factory, original techniques progressively developed from a starting point directly inspired by flint mining, to quarrying a massive rock and working a hard material that was difficult to flake but was capable of withstanding hammering.

Sawing and picking of fibrolite also developed from adaptation to the nature of the material, which certainly made axes of high quality with regard to their hardness and resilience.

The demand might well have been strong but for certain natural drawbacks which limited their production. The nodules, of unpredictable size and shape, could only be collected as loose surface stones or pebbles on the shore.

Moreover, the techniques needed for working this hard and tenacious mineral were probably very time consuming compared with those in use with dolerite. Type A dolerite, on the other hand, was quite suitable for mass production. The outcrop was extensive, easily accessible, and well exposed. The rock was amenable to efficient quarrying techniques, as well as flaking, and produced tools which were sufficiently hard and resilient for common use, although they were less so than those of fibrolite.

From these two examples, and independently from the social conditions, which remain unknown, we can imagine that there was, for each group, a balance between the production and diffusion facilities, the value attached by the users to the product, and the concurrent availability of other products.

For western Brittany, fibrolite in the north-west and Type B in the south appear as the two main local competitors to Type A, providing serious local distortion to its regular 'Thünen model' diffusion pattern (Clarke 1968, 463). Eastwards, on the contrary, the concurrence appears less precise, allowing an even distribution over a large area.

In the same way, the preferential diffusion in the middle Loire area, up to 500km from the factory, is obviously explained by the long-distance communication facilities along the ligerian axis, favouring a well established and regular mass production. This can be compared with various ethnological evidence (eg Sahlins 1972).

Demography and economy

By way of conclusion, some hypothetical production estimates based on stone axe evidence in western France may be put forward.

At Plussulien, the main factory site covers nearly 10,000m² and the mass of refuse, as seen in the different trenches, may reach in places 3m thick. A reasonable mean estimate appears to be 1.5m, giving a volume of stone debris of nearly 15,000m³. Peripheral working places are almost continuous over nearly 1km², one third of this area showing an almost unbroken level of flakes in the soil, which might be estimated as equivalent to a 10–15cm dry stone layer which, with a somewhat thicker accumulation on perhaps one-tenth of the area, leads to an estimate of a further 45,000m³. On this basis, the total volume of the refuse left by axe production seems to be nearly 60,000m³.

Assuming an axe production equal to about 1% of all the rock quarried, and an average axe size of about 100cm³, this volume of waste represents the manufacture of about 6 million tools. Over 1200 years of full activity, excluding the first and last centuries of reduced output, a full year's work would have produced about 5000 axes.

From the series analyzed, we know that this production represents nearly 50% of all the Breton axes in Brittany itself and not far off 30% in a marginal zone, from the Cotentin to the Vendee. We can propose an average estimate of 40% for an area of 60,000km², having absorbed most of the Type A production. Assuming that further diffusion was quantitatively negligible, and that this proportion remained constant over time, the mean annual consumption can be estimated at about 12,000–13,000 axes.

Several elements are lacking to allow an estimate of the population to be made on this basis: the purpose of the axes (exclusively utilitarian and, if so, for what? or partly ceremonial and, if so, to what extent?), the number and quality of axe users (some or all the male adults, or also some of the women?); the average life of an axe (including loss or breakage risks and resharpening possibilities), and so on. Nevertheless, if we assume as a working hypothesis that most male adults actually used axes, and needed more or less one implement per year, these axes would represent an approximate population of 50,000 persons, accepting the coefficient of 4, which appears to be roughly acceptable in the demography of many primitive societies (Young 1971, 339).

Since the area under consideration consists of nearly 60,000km², the inferred population density would be slightly over 0.8 per km². With other bases for calculation, such as one axe user per 3 or 6 persons, or an annual axe consumption of 2 per head, the densities obtained could range from 0.4 to 1.6 per km^2. These figures fit rather well with the few published estimates for the Neolithic period in western Europe (eg Clark 1967; Harrison *et al* 1964; Randsborg 1975).

At the rate of one axe per man per day (p 52), the annual output of 5000 axes would require 5000 man-days of work. If the work was spread evenly through the year, say for 250 days, this would mean a team of some 20 men permanently employed on the site; but it could also mean a much larger number of casual workers coming in for a few days each; we have no means of telling. Even if these men did not work continuously according to our modern conceptions, they and their families had to eat. With the same coefficient of 4, these workers could represent a population of nearly 80 persons, or its equivalent if part-time activity took place. Perhaps youths and women helped at work and a lower coefficient, of 3 for instance, would be more appropriate, giving a population estimate of 60.

The proportion of such specialized work acceptable for a Neolithic community was probably rather low, perhaps about 5% or roughly the equivalent of one day's work per month, or a fortnight per year. This leads to a supporting community of 1,200 to 1,600 persons. With a density of nearly 1 per km^2, such a population could control a territory of approximately 1,500km^2, that is to say, for instance, a circle of 40–45km in diameter.

At first sight, such a territory may appear rather large for a prehistoric territorial unit. But in gently hilly country such as central Brittany, the size of the territory depends on human factors: for instance, the possibility of crossing from one part to another, or going from the centre to the edge and back again within a day's walk, and the possibility of controlling it by direct observation from a few separate vantage points,

If we draw, on a map of Brittany, such a 20km radius circle centred on the factory of Plussulien, it clearly corresponds to an actual territorial unit, including the quartzite steep hills of the Quenecan forest area in the south, the rounded granitic highlands of the Quintin-Rostrenen massif in the north and the schistose lowlands of the eastern part of the Chateaulin basin in the centre. This area is also near the springs of two important streams opening the way towards the Atlantic coast of Morbihan, the Rivers Blavet and Oust.

Archaeological evidence also appears very clear. Nearly all the megalithic concentrations observed either on the southern crests or on the granitic massif fall within this ideal circle, as well as the numerous dwelling places of the St-Nicolas-du-Pelem/Tremargat area (Le Provost *et al* 1972). In contrast, a relative blank appears beyond this area, northwards to the coastal Channel zone, southwards to the granite hills of the Landes-de-Lanvaux, with their megalithic concentrations, and eastwards and westwards similarly. To consider the Plussulien factory as primarily responsible for the nature of this evidence would be hazardous, but so important an element in Neolithic life must have left its mark in one way or another on the life style of the surrounding population.

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Adzes from Linear Pottery sites: their raw material and their provenance

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Abstract

The adzes found in three Linear Pottery sites in the Netherlands were made from amphibolitic rocks, basalts, quartzites, or siliceous shales. For the implements from a fourth site, the Linear Pottery site near Hienheim in Bavaria, only amphibolites were used. The quartzites and siliceous shales were probably of local provenance but, as neither amphibolitic rocks nor basalts occur in the vicinity of the settlements, these materials had to be imported. The source of the amphibolites is looked for in the Variscan Basement of Central Europe. The exact location of the outcrops used for the adze manufacturing has not yet been discovered. The basaltic implements offer fewer problems. Their source-areas are most likely the Siebengebirge and the Western Eifel.

The investigation to which this paper refers originally formed part of a study with a much wider scope. The aim of this larger study is to describe, as far as possible, the pattern of relations which existed between a prehistoric population (or, better, an archaeological entity) and its environment. For the attempt to describe such a pattern of relations we have chosen the settlements of the Linear Pottery Culture, ie the oldest Neolithic known in Central and Western Europe. The choice fell on this culture, because there is little disagreement about its attributes.

Due to the nature of the available data, a description of the relationship between a prehistoric settlement and its environment cannot but be a poor and mutilated one compared with a description of a recent situation. However, some aspects are amenable to investigation. One of them is the provenance of raw materials. The first results of the research concerning the raw material used for one kind of implement, the adze, are presented here.

Rocks for adzes: local or imported

The adze is one of the most characteristic attributes of the Linear Pottery Culture. It is always made from crystalline rock. Adzes of chert do not occur.

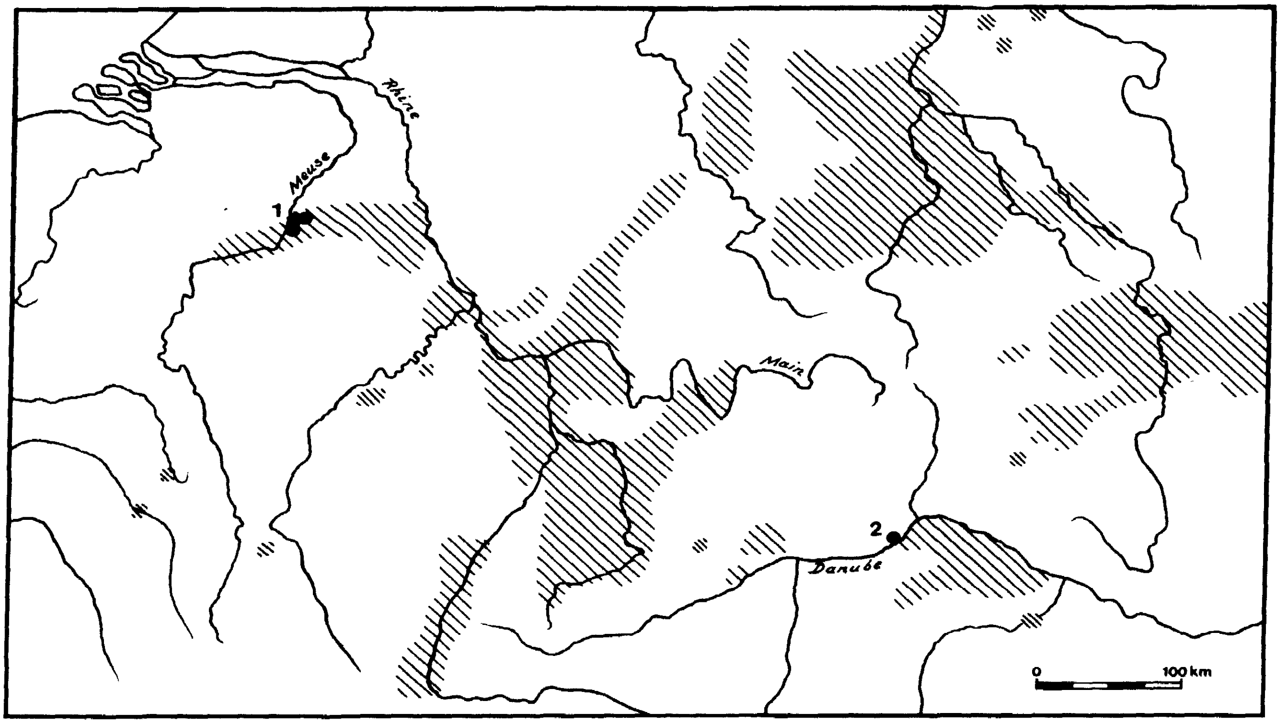
The investigation of the rocks used for the manufacture of the implements started with the adzes from four settlements: Elsloo, Stein, Sittard, and Hienheim. The first three settlements are situated in the south-eastern part of the Netherlands, the last one lies in the Landkreis Kelheim, in the West German State of Bavaria (Fig 1). The settlements were occupied in the second half of the fifth millennium BC. All four of them were excavated by Modderman. The results from the excavations at Elsloo, Stein, and Sittard have been fully published (Modderman 1958–9; 1970). A report on Hienheim is about to appear (Modderman, forthcoming).

The reason we started our research with this material is that one of us (Bakels) is attached to the same Institute as the excavator. Thus the implements were close at hand. Moreover, many adzes originate from the fillings of well-dated pits.

The adzes from the *Dutch sites* are, almost without exception, made of amphibolite, basalt, or a dark grey rock which might be described sometimes as a quartzite or, in other cases, as a siliceous black shale. The proportions in which these materials occur are represented in Fig 2.

The first question to be answered is whether the rocks could have been obtained locally or had to be imported. Outcrops of these rock types cannot be found within a six hours' walk (a day's journey) from the settlements. The only possible sources for suitable material within reach of the settlement are deposits of transported blocks and pebbles. In the case of Elsloo, Stein, and Sittard, nearby deposits of derived rock are the gravels of the River Meuse. In these gravels, quartzites which resemble the quartzites of the adzes do indeed occur. Amphibolites are very rare and consist only of small pebbles, which are too small for the manufacture of adzes. Basalts are totally absent. The conclusion is therefore drawn that the amphibolites and basalts at least must be regarded as imported materials. The quartzites and shales could be of local origin. The presence of rough-outs, exclusively of quartzite and shale, supports these conclusions.

As the adzes of amphibolite and basalt appear to be of a foreign provenance, the question arises of where they came from. Thoughts about lines of supply depend on the idea one has concerning the type of supplying. One might think of expeditions – journeys of many days – carried out by the inhabitants of the settlements under study. Or one might think of a kind of transit: implements passing from one settlement to another. In the former case, the source of the amphibolites and basalts could have been either the moraines of the Northern Netherlands or outcrops in Central Europe. The search for suitable rocks in the moraines would not have been an easy task. Moreover, we are of the opinion that the passing on of adzes is the simplest model and therefore the most likely one. In that case, only Central Europe has to be taken into consideration, because at



1 Location of the four Linear Pottery settlements. 1 Elsloo. Stein, and Sittard. 2 Hienheim. Hatched areas: Linear Pottery settlement areas (mainly after Zápotocká 1970)

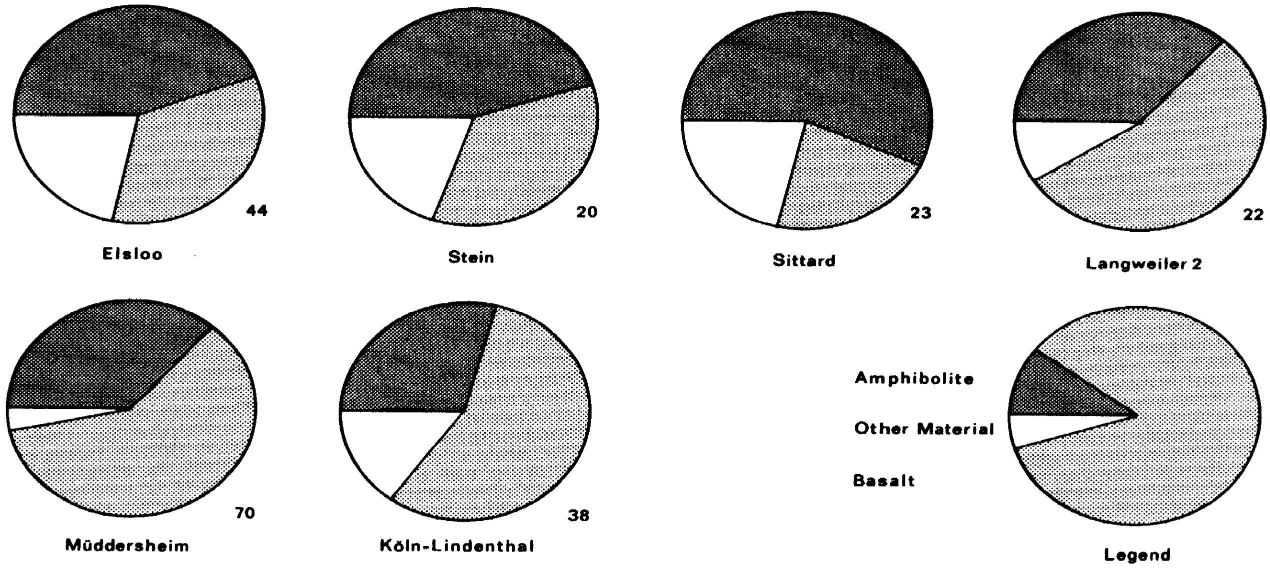
that time, people with a Mesolithic tradition lived in the region between the settlement areas of the Linear Pottery Culture and the moraines. They used no amphibolites or basalts and it is therefore unlikely that they supplied these rocks. For that reason we seek the source of the adzes somewhere east of Elsloo, Stein, and Sittard.

In the east, the Dutch settlement area adjoins a larger settlement area, now in Western Germany, that stretches as far as the Rhine. If the implements from Elsloo, Stein, and Sittard were indeed handed over from settlements in this area, it is to be expected that the adzes from these settlements would show the same kind of rocks. This appears to be true. Three assemblages of adzes have been published; the adzes from Langweiler-2, from Müddersheim, and from Köln-Lindenthal (Bakels 1973; Frechen 1965; Koch 1936). The assemblages are represented in Fig 2. (It is not clear if Koch has seen all adzes from Köln-Lindenthal. We think he has, but, as the material is at the moment inaccessible, we are not able to check this.) In these assemblages too, the group 'other materials consists mainly of dark gray quartzites and siliceous black shales; these appear to be different from site to site, which could point to local sources but need not necessarily do so. As expected, the amphibolites and basalts are comparable. The examination of thin sections from the Langweiler-2 and Müddersheim adzes show that the rocks belong to the same types as those found in the Dutch sites (examination by one of us [Arps] and by Frechen).

Since neither in Langweiler-2 nor in Müddersheim are amphibolites and basalts locally available, we have to look still farther away for the original sources. The increased ratio of basalt in the material of the German sites, compared with the Dutch sites, suggests that outcrops of basalt were less distant than those of amphibolites. This is indeed the case. The nearest sources of basalt are the volcanoes of the northern and eastern Eifel and the volcanoes of the Siebengebirge, less than 5Okm away. As is pointed out in the next section, there are petrological indications that the basalts might have been obtained from these regions.

The amphibolites must be sought in more distant regions. Frechen ascribes the rock from Müddersheim to the outcrop near Sobótka (Zobten) in Poland, and gives the same provenance for the Dutch adzes. We consider the Sobótka outcrop to be very distant and are trying to find suitable outcrops less far away.

In the settlement at *Hienheim* only amphibolites were found. There are no adzes made from other kinds of rock. The material is not found locally, that is within a day's journey around the settlement. As in the Dutch situation, the only local sources of the rock that can be considered are the gravel deposits of a large river. Hienheim is situated on a terrace of the Danube. Notwithstanding a careful search, we have not been able to find any suitable material among the pebbles in the river bed or in the terraces. The inhabitants of Hienheim must have imported their amphibolite. The rock was brought into the settlement in a less advanced state of manufacture than the amphibolite excavated in the Dutch sites because waste material was found. We think therefore of a place of extraction farther than a day's journey from the settlement but still not too far away. We have considered several outcrops east of Regensburg,



2 Rocks found among the adzes from six Linear Pottery sites situated between the Rivers Meuse and Rhine. The number to the right of each diagram indicates the number of artefacts used for the calculations

some 75km east of Hienheim, but the nearest outcrops seem to bear no resemblance to the rock used at Hienheim.

The appearance of most amphibolites from Hienheim is quite different from the appearance of those excavated in the region between the Meuse and the Rhine. They must have had a different origin. Thus, there existed no single centre of production, which supplied all Linear Pottery sites with amphibolite. There must have been several or even many places of extraction.

When we take a look at the literature concerning the Linear Pottery adzes in Central Europe and assemble the small amount of really reliable information about their raw materials, we see that adzes of amphibolite appear everywhere. We mention the surroundings of the Lower Main (near Frankfurt on the Main), Duderstadt near Hannover, Bylany in Bohemia, and Olszanica near Kraków in Poland (Meier-Arendt 1966; Ankel & Tackenberg 1961; Velimský 1969; Milisauskas 1976). The use of basalt is less common and appears to be restricted to settlements which are not too far removed from the original outcrops. This at least is a hypothesis we want to test after we have carried out more observations. Quartzites, siliceous black shales, and still other rocks are often mentioned among the raw materials. They seem to have been procured more or less locally. Perhaps quartzite and the like was considered as a third-rate material by the inhabitants of Linear Pottery sites. Basalt might have been a second-rate material. In view of the widespread use of amphibolite, we think that it was the most suitable rock for the manufacture of adzes.

There must have existed some kind of trade or exchange of amphibolites and, to a lesser extent, of basalts. It would be of interest to discover the pattern of this phenomenon. We therefore thought it worthwhile to extend the investigation beyond the original aim of determining which rocks were imported and which were not. We are now trying to locate distribution centres. This is done by a detailed description of both amphibolites and basalts.

Petrography of the adzes and their possible geological provenance

In this section two petrological aspects of the implements are discussed. First, their petrological and mineralogical properties are described and, second, their possible geological sources are indicated.

It should be emphasized here that in Central Europe no prehistoric quarries for amphibolite or basalt have yet been found. Therefore our investigations concentrate, in the first place, upon petrological correlations, ie on locating the primary and secondary geological sources.

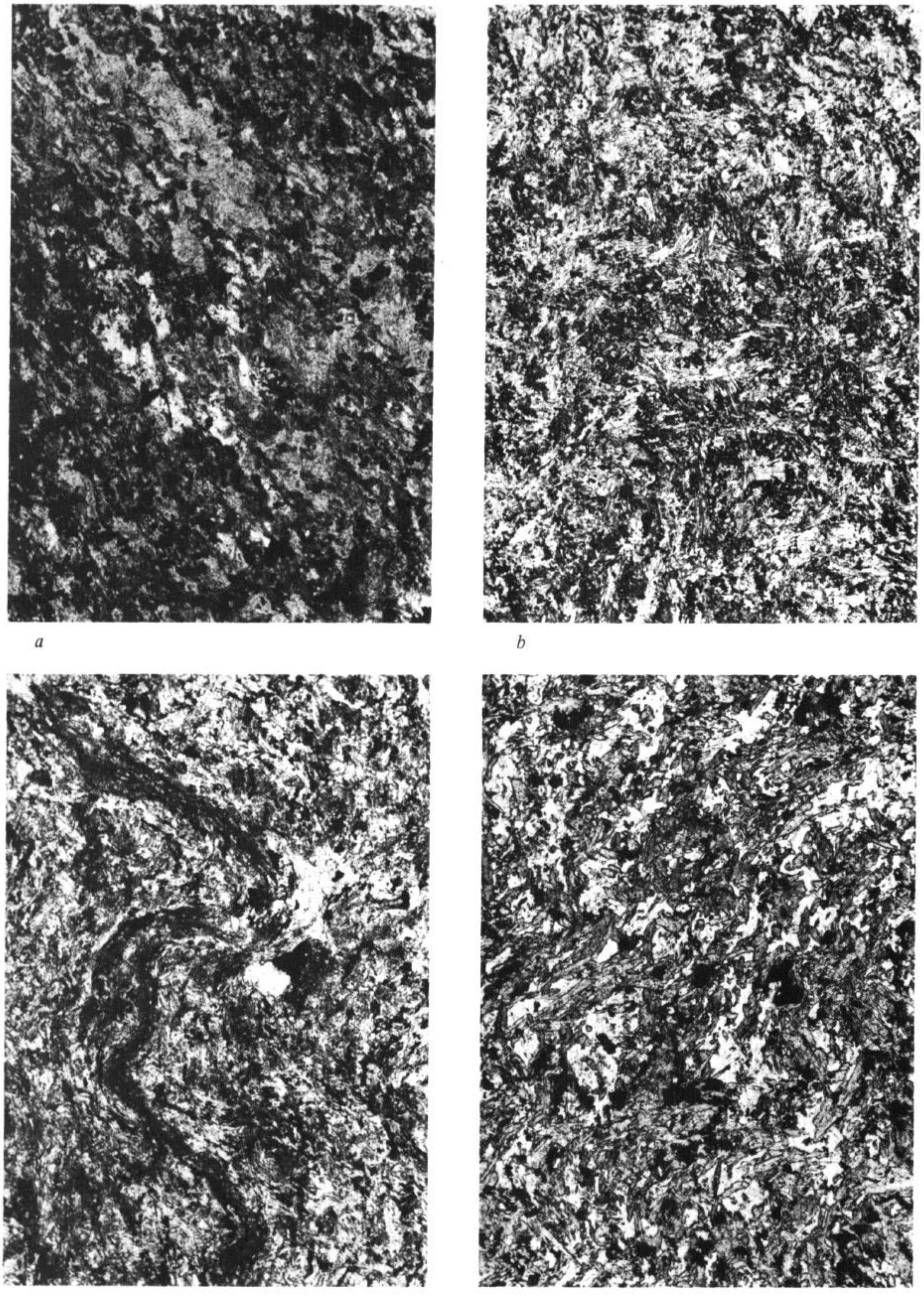
The petrological information on the artefacts has been obtained by careful surface examination, including the use of the binocular microscope, of all the material available. Thin sections for microscopic examination have been made from adze fragments and waste material.

Amphibolite artefacts

As has been mentioned in the foregoing section amphibolite artefacts are a common feature in the Linear) Pottery Culture. A more careful examination of the material enables us to distinguish macroscopically different groups within a certain assemblage.

Hienheim

The amphibolites found at Hienheim can be subdivided *macroscopically* into two main groups within which a further subdivision into smaller units is possible.



3 Photomicrographs of amphibolite artefacts. a Irregular bluish-green hornblende clusters with bushy outlines, Hienheim, Magn. 60x b Randomly oriented hornblende sheaves, Hienheim, Magn. 60x. c Very fine-grained irregularly banded actinolite amphibolite, Hienheim, Magn. 60x. d Coarser-grained amphibolite, Elsloo, Magn. 60x.

The first group consists of very fine-grained, irregularly foliated, greyish olive-green amphibolites. Due to their irregular foliation and the presence of coarser-grained leucocratic bands and cross-cutting veinlets, they display a characteristic splintery fracture. A smaller sub-group consists of very fine-grained and compact, dark-greyish varieties. The second group consists of coarser-grained, greenish, and brownish rocks. Grain size and structure of the amphibolites belonging to this group are more variable than those of the first group. Individual minerals and mineral patches or bands are often better visible.

The implements of both groups of the Hienheim assemblage may vary *microscopically* with respect to their fabric, ie grain size, state of metamorphic recrystallization, and mineral composition. The most important mineral of the amphibolites is an almost colourless to light-coloured bluish-green actinolitic hornblende. Variable amounts of ore minerals, quartz, feldspar, biotite, chlorite, epidote, and sphene, may be present as typical additional mineral constituents. The ore minerals from Central European amphibolites have been identified as being mainly ilmenite and sometimes also magnetite and pyrite (Scholz 1968). Arsenopyrite has also been found in Moravian amphibolite artefacts (Stelcl *et al* 1970).

The crystal habit of the metamorphic hornblende is characteristic and has several aspects. One may observe very fine-grained, cloudy amphibole masses with bushy outlines (Fig 3a), or better crystallized, randomly oriented, sheaf-like hornblende aggregates (Fig 3b). In German literature these amphibolites are also known as *Strahlsteinschiefer* (Bauberger *et al* 1973). In contact with the secondary quartz bands and veinlets, coarser-grained hornblende needles penetrate into the quartz. Larger hornblende metablasts may develop within the aggregates due to a more advanced metamorphic recrystallization. Those hornblendes display a deeper blue-green colour. Weak traces of a brownish hornblende may be visible in some amphibole nests.

The texture or fabric of the amphibolites is very variable. A clear pre-metamorphic, sometimes strongly undulating, banding is often present. This is accentuated by grain-size differences, string-like concentrations of ore minerals and bands of quartz grains (Fig 3c).

Elsloo, Stein, and Sittard

The amphibolites from the south-eastern Netherlands differ from the Hienheim amphibolite artefacts in that they lack the very fine-grained, light greyish-green varieties.

The amphibolite adzes differ *macroscopically* from each other in structure, grain size, and colour. The colours depend on the state of weathering, which varies from sample to sample. A few relatively fresh implements show a typical dark olive-green colour, while some strongly weathered ones are light greenish-grey. So a subdivision based on colour is unlikely to be useful.

The structure of the amphibolites is variable and provides a basis for the subdivision of the Dutch assemblages, although the lines of demarcation are less clear than in the Hienheim assemblage. Some individuals are strongly banded, while others demonstrate a more homogeneous gneissic structure or are almost unoriented. Moreover, a metablastic habit is a frequent phenomenon for hornblende (dark irregular spots) and sometimes also for plagioclase (light-coloured spots). The average grain-size is also very variable.

The coarser-grained amphibolites consist *microscopically* of easily distinguished blue-green hornblende grains (Fig 36). Larger metablastic hornblende (Fig 4a), biotite, and plagioclase are often present. Generally they are obliquely or normally oriented with respect to foliation. A resemblance between the finer-grained Dutch varieties and the second group of the Hienheim amphibolites may also be observed, with respect to the *Strahlsteinschiefer* habit.

Provenance of the amphibolites

The fine-grained amphibolites from both the Hienheim site and the sites in the south-eastern Netherlands, are low-grade metamorphic rocks carrying the mineral association: ± actinolite ± blue-green hornblende ± quartz ± plagioclase ± biotite ± chlorite ± epidote. The coarser-grained, better crystallized varieties may have reached a higher stage of metamorphism.

Fabric and mineral relations seem to indicate a progressive metamorphism of originally poorly to well-laminated mafic rocks, probably basaltic extrusions or tuffs. The traces of brownish hornblende and the large amounts of ore minerals in the amphibolites may be regarded as an indication of a (sub-) volcanic origin of the rocks (Bauberger *et al* 1973).

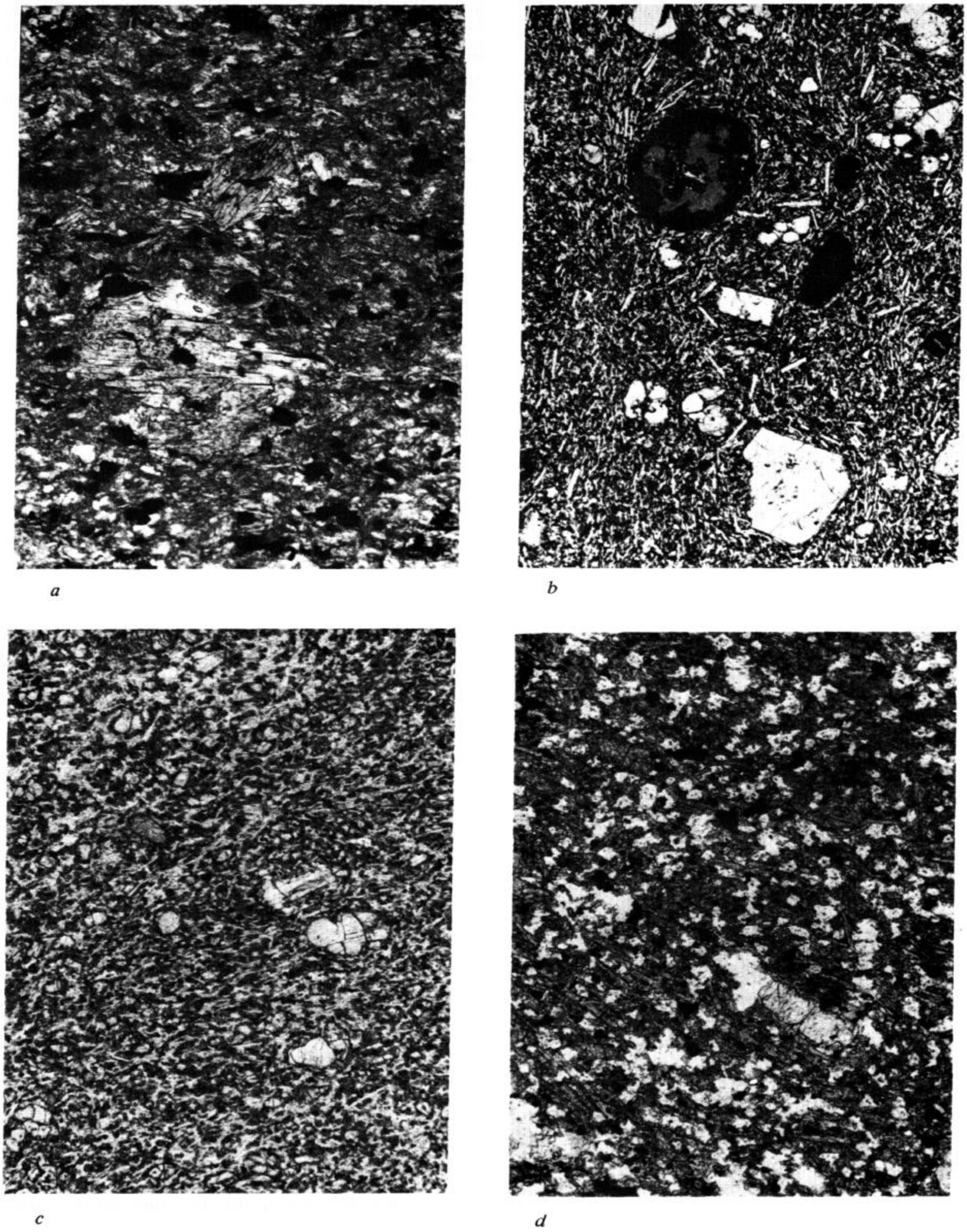
Metamorphic recrystallization, without subsequent deformation, may have converted the rocks into tough amphibolites with the characteristic fabric of unoriented hornblende clusters and rosettes, as has been described above.

No petrological indications have been found in the artefacts to suggest that the amphibolites might have been derived from higher-grade metamorphic mafic rocks. This process of retrograde metamorphic recrystallization, subsequent to a locally developed, penetrative deformation (mylonitization) has been mentioned as a possible petrogenesis of certain amphibolites (Herrmann & Schüller 1951; Bauberger *et al* 1973).

In order to locate the possible geological source-areas of the amphibolites, three geological terrains can be mentioned: first, the Precambrian Basement of Scandinavia in the north; second, the Alpine mountain range (Alps and Carpathians) in the south; and third, the Variscan Basement of Central Europe in between. Rocks from all three terrains are well known sources of artefacts in Central Europe. Scandinavian amphibolites and other rocks found among the erratics in northern Central Europe have been used for the manufacture of implements but, with respect to the sites under discussion, they can be ignored.

Although an Alpine origin of low-grade amphibolitic implements in southern European prehistoric sites cannot be excluded (Stelcl *et al* 1970), it is our opinion that the amphibolitic artefacts found in the settlements under discussion were most likely obtained from the nearest possible localities, eg from outcrops belonging to the Variscan. In Central Europe the more or less east-west trending Variscan Basement crops out in various regions, each known under separate names, such as the Ardenno-Rhenish massif, the Harz, and the Bohemian massif. Certain zones of this Palaeozoic mountain range consist of crystalline rocks within which amphibolites may be scarce or common. The Hienheim site is located near the western extremities of the Bohemian massif. Potentially attractive amphibolite outcrops must have been found in this massif (eg in the Bavarian forest, Ober-Pfalz forest, and Fichtelgebirge), but quarries have not yet been encountered.

To locate the source rocks of the amphibolites excavated in the sites of the south-eastern Netherlands is a more difficult problem because the source areas are



4 Photomicrogmphs of one amphibolite and three basalt artefacts. a Amphibolite with large blue-green hornblende metablasts, Stein, Magn. 60x. b Basalt with phenocrysts of brown hornblende (above), titan-augite (below) and olivine, and a plagioclase-rich groundmass, Elsloo, Magn. 40x. c Basalt with mainly olivine phenocrysts, few titan-augite and a groundmass rich in plagioclase laths, Stein, Magn. 40x. d Basanite, with phenocrysts of biotite-rimmed olivine and titan-augite, and equidimensional leucite in the groundmass, Elsloo, Magn. 40x.

located at least 260km away. Potential sources that must be considered and that have been mentioned in literature are the south-eastern zones of the Rheinische Schiefergebirge and the Harz, the crystalline basement rocks of the Odenwald, the Spessart, Thüringen, southern Saxony, and probably also Silesia.

The literature provides us with very little information about the origin of the amphibolites used for the production of implements belonging to the Linear Pottery Culture. Our own investigations in this respect have only just started (Arps, forthcoming). Most provenance studies that have been carried out in Central Europe focus on axes from younger cultures. It has been concluded (Bauberger *et al* 1973) that the amphibolite axes, belonging to the Chamer Gruppe and excavated in the area near Cham, about 75km north-east of Hienheim, probably have their source in the immediate neighbourhood. Herrmann and Schüller (1951) and Scholz (1968) assume a 'Saxon-Thüringian' origin of the majority of amphibolite implements found respectively in the Dobelner area (Saxony) and Thüringen. Others (Stelcl *et al* 1970) suggest a northern Moravian, geologically primary, origin for six semi-finished Neolithic artefacts excavated in southern Moravia, Czechoslovakia. Another often mentioned source area of implement amphibolites is Sobótka (formerly Zobten), and is situated in Silesia, Poland (Frechen 1965).

Basalt artefacts

Basalt implements have not been encountered in the Hienheim prehistoric sites, although basalt outcrops occur north and northeast of the area. It seems evident that for his purposes prehistoric man preferred to use amphibolite, if it was available locally.

Excavations in the south-eastern Netherlands revealed that the second largest group of the implements here are made of basalt.

Macroscopically the majority of the basalt artefacts from Elsloo, Stein, and Sittard can be divided into three main groups, with some other smaller groups and individual items. The groups differ from each other mainly in the colour of the patina and the porphyritic habit (size, mineral abundance, and composition). Within each group, the adzes may differ in grain size and also in porphyritic habit.

The adzes of the first group demonstrate a clearly porphyritic habit: black (pyroxene) and brownish (olivine) spots within a silky fine-grained, light-grey to brownish-grey groundmass. Within the groundmass very small black spots (pyroxene and magnetite) and light-coloured laths are visible. Usually the amount of pyroxene phenocrysts slightly exceeds that of olivine. The pyroxene phenocrysts, sometimes forming clusters, occur as well-developed crystals with sharp outlines; the olivines are equidimensional or prismatic. One can also recognize the presence of dark lenticular-shaped, partly altered crystal aggregates.

Microscopic investigation confirms that the phenocrysts are zoned titan-augite and colourless olivine. The lenticular-shaped bodies are partly or completely altered brown basaltic hornblende phenocrysts (Fig 4b). According to determinations by Frechen (1965), the minerals secondary to basaltic hornblende are plagioclase, augite, rhönite, and titanomagnetite. Plagioclase laths form the greater part of the groundmass; it contains in addition titanomagnetite and titan-augite. A fluidal orientation of the minerals may be visible.

The second group of adzes or fragments displays *macroscopically* a (very) fine-grained texture with smaller phenocrysts (pyroxene and olivine) than are found in the first group. The abundance and size of the phenocrysts is variable, as well as the relative amounts of pyroxene and olivine. The colour of the patina is brownish-grey and small dark spots (pyroxene, magnetite) are still clearly visible.

Microscopically this group of basalts consists of phenocrysts of olivine, titan-augite, sometimes forming clusters, and in exceptional cases plagioclase. The groundmass is variable in grain size and contains plagioclase, titan-augite, and titanomagnetite. A fluidal fabric may be present.

The third group seems to have an even weaker porphyritic habit. On closer examination with the binocular microscope, however, one finds that phenocrysts of the less visible olivine crystals are still present. The colour of the patina varies from brownish-grey to greyish-brown. From thin-section analysis (Fig 4c) it follows that besides the olivine phenocrysts, titan-augite crystals are also present although they are generally smaller in size. The groundmass contains titan-augite, titanomagnetite, and plagioclase laths. A fluidal fabric shown by the plagioclase laths is less prominent.

The other basaltic implements vary either slightly or markedly from the described main groups. Differences may be shown by the colour of the patina, the structure of the rocks, and the form and mineral composition of the phenocrysts. When the basalts are abundantly rich in olivine crystals, this is often reflected by the colour of the patina being more (spotted) brownish.

Two strongly weathered basalts demonstrate, macroscopically, a well-developed banding.

In one case a macroscopically aberrant basalt adze fragment, of which a thin-section has been studied, turned out to be a basanite. Besides olivine, which may be surrounded by biotite, the rock also contains leucite and titan-augite (Fig 4d).

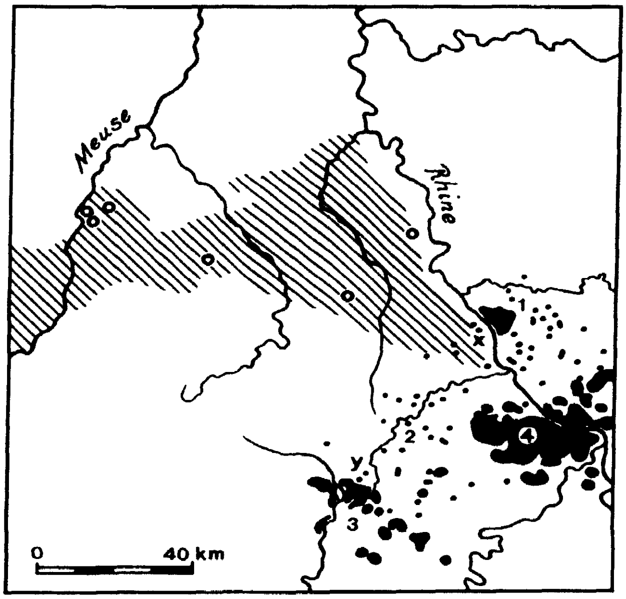
It is evident from thin-section analysis that only one of the fifteen microscopically investigated basalts was clearly foid-bearing and almost all were typically rich in plagioclase laths in the groundmass. This suggests that the foid-rich basalts were probably less attractive for making implements.

Provenance of the basalts

All the investigated basalt implements are olivine basalts. The most suitable varieties are fine-grained, compact, plagioclase-rich (groundmass), and moderately porphyritic.

The source areas of the basalts seem to be close at hand. The Dutch Linear Pottery settlements are situated in an area north-west of, and adjacent to, the volcanic regions of the Siebengebirge, the High and Western Eifel and the Laacher See Fig 5). These volcanic areas belong to the neo-volcanic province of Central Europe. The volcanic activities lasted from the Upper Cretaceous (Siebengebirge and High Eifel) to Quaternary times (Western Eifel and Laacher See) and produced alkaline volcanic rocks with alkaline olivine basalt as a major rock type (Wimmenauer 1972).

Although numerous olivine basalt bodies are cropping out in the above mentioned volcanic areas, it seems that the majority of the basaltic implements can be correlated with basalts of the Siebengebirge and the adjacent area to the west (Frechen 1965). The artefacts belonging to the first group described above are tentatively correlated with the Lyngsberg basalt (Figs 4b, 5). Other plagioclase-rich (groundmass) basalts may probably be correlated



5 Map indicating the position of the Linear Pottery settlements in relation to the volcanic areas of the Siebengebirge (1), High Eifel (2). Western Eifel (3), and Laacher See area (4). The hatched area indicates the Linear Pottery settlement area between the Rivers Meuse and Rhine. Circles give the position of the settlements mentioned in the text. These are, from west to east: Stein, Elsloo and Sittard, Langweiler-2, Müddersheim, and Koln-Lindenthal. Volcanic areas and isolated basalt outcrops are given in black. X indicates the Lyngsberg basalt outcrop, Y the Gossberg basalt outcrop

with basalts cropping out east of the Rhine in, for example, Oberkassel and Papelsberg (Frechen 1965). The exceptional basaltic adze fragment containing leucite crystals (Fig 46) has been correlated by Frechen (personal communication) with the Gossberg basalt in the Western Eifel (Fig 5).

Conclusions

At this stage of our research it is still impossible for us to locate the outcrops of the amphibolites, which were the source of the amphibolitic adzes found at Elsloo, Stein, Sittard, or Hienheim. We think that we have to look for the rocks in the Variscan Basement. Up till now we do not have a sufficiently detailed petrological knowledge of the different outcrops that are mentioned in the geological literature, so we are not able to be more precise. In the meantime, however, we have started to build up an appropriate reference collection.

The basalt implements offer less problems, because the sources seem to be obvious. From a geographical point of view the Siebengebirge and the High and Western Eifel can be the source areas. This is not contradicted by the comparative analysis of thin-sections of adzes and possible source rocks. Indeed, there exists a good correlation between the basalt of the adzes and similar rocks of the Siebengebirge and, to a lesser extent, those of the Western Eifel. Of course this resemblance is only a strong indication that these volcanic rocks may be the sources of the basalts. We know that other volcanic areas farther away, such as Westerwald, Vogelsberg, and Rhön, have basalts with similar macroscopic and microscopic properties. Still we feel that the nearest outcrops are the most likely candidates for the provenance of the raw material.

As we said in the introduction the results presented in this paper are only preliminary. The investigations are being continued.

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Typology, materials, and distribution of flint and stone axes in Yorkshire

T G Manby

Abstract

Yorkshire has the largest assemblage and most concentrated distribution of Neolithic axe finds in the British Isles. For a century and a half stone and flint axes have been collected by intent and chance discovery and, although the uncertain number of lost implements cannot be taken into account, over 2400 complete and fragmentary axe blades have been recorded (Table II). In addition to this total are the battle axes, axe hammers, adzes, and mace heads, all shafthole implements, that are not included in this study.

In the examination of this very large number of flint and stone axes it becomes obvious that a broad typological classification based on technique and shape, as well as raw material, is possible for some 75% of the assemblage (Table I, which excludes reworked axes). At one extreme are flint nodules converted to axes by a minimum of flaking and grinding, and pebbles which have been utilized by the grinding on of a cutting edge. At the other extreme are axes that have undergone such extensive reworking that their original shape has been completely lost. With any typological scheme for artefacts of a functional character like axe blades it must be clearly recognized that shape and proportions undergo modification by breakage, reflaking, and regrinding. However, there are also certain less common forms, like Duggleby adzes, that have a combination of features distinguishing them as highly specialized products with a limited chronological life.

Typology of flint and stone axes

The study of axes in Yorkshire enables a threefold classification to be proposed; (i) material, ie flint or stone; (ii) production technique; (iii) intended shape.

Flint and fine-grained rock were worked by striking off flakes until the required shape was attained, followed by complete or partial grinding of the blade. Coarse-grained rocks were worked by pecking, a technique that would not allow the same range of shape to be attained as in tine-grained rock, although grinding was applied to finish the artefact.

Classification by technique:

A Flaking. Flaked rough-out (flint and fine-grained rock).
B Complete grinding, although with deeper flake scars remaining (flint and fine-grained rock).
C Pecking and grinding (coarse-grained rock).
D Flaking with grinding confined to the cutting edge (flint and fine-grained rock).
E Reworking by coarse flaking (flint and fine-grained rock).

Classification by shape (Figs 1,2,3):

1 Pebbles and nodules with a cutting edge produced by flaking or grinding.
2 Broad-butted axes, thin profile: a Faceted sides (Figs 2, 1; 3, 4); b Oval, rounded sides (Figs 2, 2; 3, 3); c Elliptical (Fig 3,2); d Rectangular.
3 Narrow-butted axes, thin profile: a Faceted sides (Fig 1,4); b Oval, rounded sides; c Elliptical (Fig
4 Rounded thick-butted axes: a Oval (Fig 1,8); b Round; c Rectangular.
5 Thick tapering butted axes: a Oval (Fig 1,7); b Round.
6 Pointed butted axes, elliptical section (Fig 1,5).
7 Adzes, blades of asymmetrical section: a Triangular; b D-shaped; c Elliptical, curved profile (Fig 1,6).

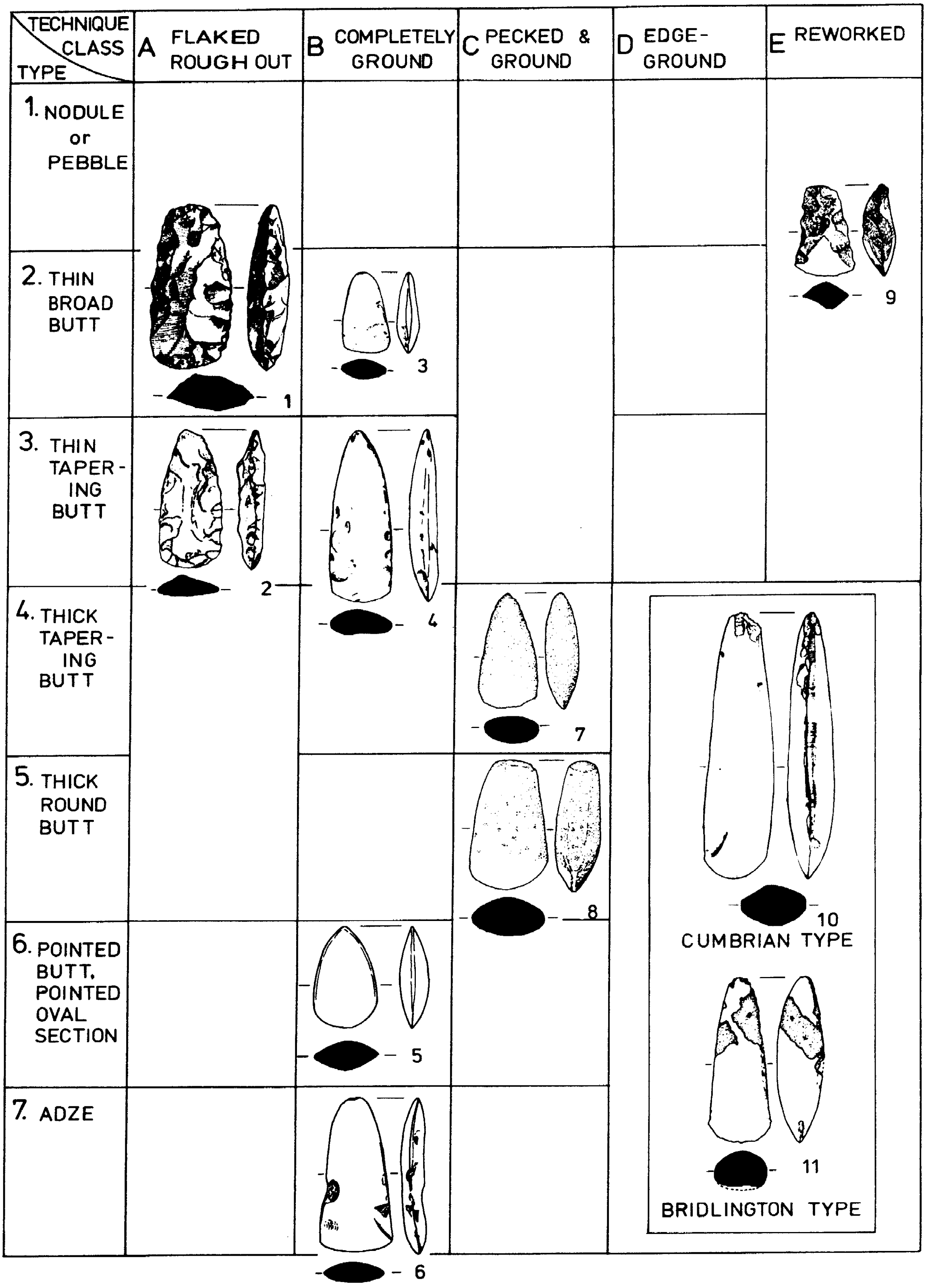
Within the above classes some characteristic types are distinguishable.

Cumbrian type axes (Fig 1, 10)

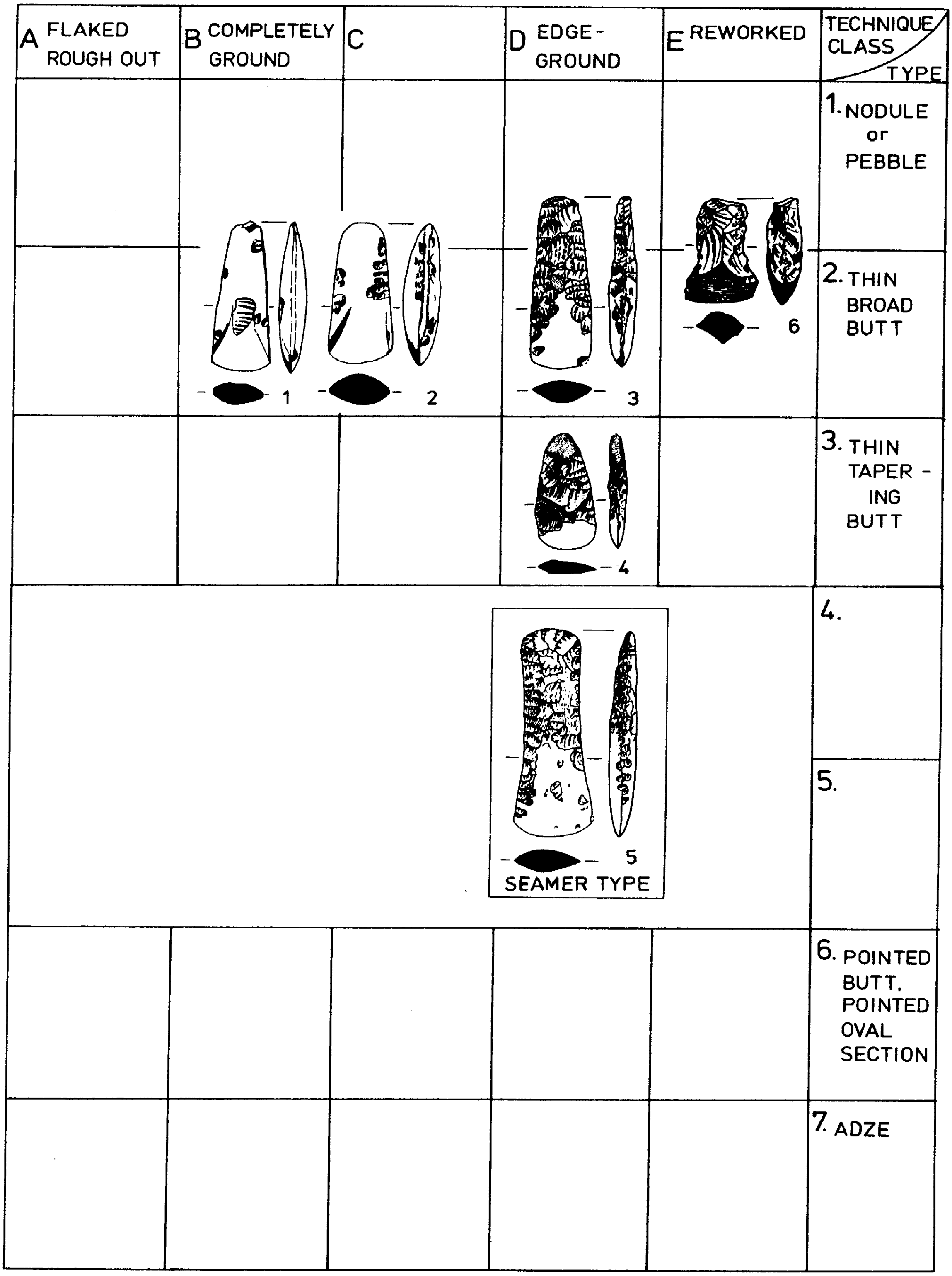
These very large broad-butted axes represent a standard finished product of the Great Langdale-Scafell group of axe factories (Fell 1964). The majority are of Class 2a, although there are numbers of Class 2b (Variant A) and Class 2c (Variant B) as well as a small number of Class 3 forms (Manby 1965, 8–9). These implements are 150–380mm in length and their petrology is always Group VI or similar tuffs likely to have originated in the Lake District. Axes less than 150mm long with the same shape and petrology are also common. It is advisable to confine the term Cumbrian to the large axes as they are unlikely to have been produced by the reworking of broken axe material outside the Lake District. The same cannot be said with certainty of the smaller ones.

Butt-faceted axes

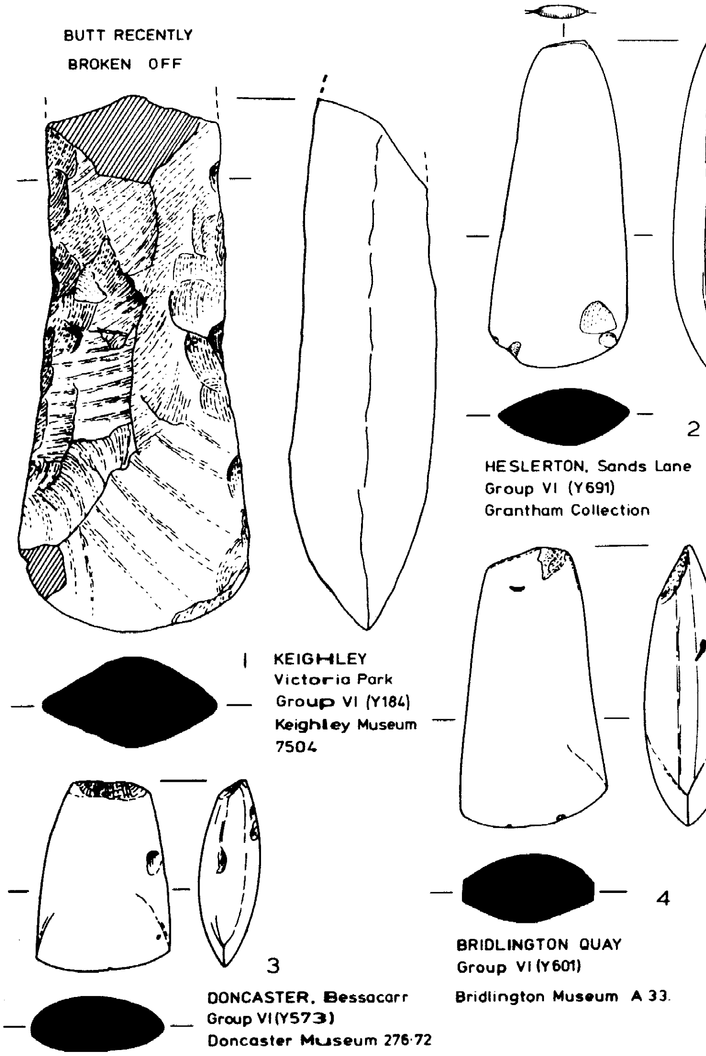
There is a significant number of blades of Class 2c that display a broad, ground facet across the butt (Fig 3,2). These also belong to Group VI or ungrouped tuffs. A fragment of an axe of this variety was found at the North Carnaby Temple Grooved Ware site (Manby 1974, 62, Fig 26,2), and another accompanied a cremation burial at Seamer Moor (Appendix B).



1 Typology of stone axes: 1 Stockbridge, WR (Group VII), Sheffield Museum, 2 Scarborough, NR, Yorkshire Museum, 413.1948, 3 Ribston Lodge. WR (Group VI, Y165). Yorkshire Museum. 325.1948, 4 Ulrome, ER. Yorkshire Museum, 162.1948. 5 Norwood. WR (fossiliferours limestone, Y160), Harrogate Museum, K74, 6 York Hoard, Yorkshire Museum, 417.1948, 7 Bempton. ER, Roman Malton Museum, 101.8, 8 Flixton Carr, ER (Group XVIII, Y193), Bridlington Museum, 9 Willerby Wold. ER, Yorkshire Museum. 1960. 1948. 10 Giggleswick, WR, T Lord Collection, Settle, 11 Grindale, ER, Bridlington Museum, A77.



2 Typology of flint axes: 1 Burshill, ER, Yorkshire Museum, 470.1948, 2 Whitby, NR, Yorkshire Museum, 434.1948, 3–5 York Hoard, Yorkshire Museum, 446.1948. 100.17, 100.16, 6 Rudston East Reservoir, Site 8, Grantham Collection, Driffield



3 Stone axes, Group VI: 1 Rough-out, 2 Class B2c butt-faceted, 3 Class B2b, 4 Class B2a. Scale 1:3

Bridlington type axes (Fig 1, 11)

This name was given to a type of axe commonly found in the Bridlington district during the 19th century. It has been described as 'broadly oval or almost circular in section and gradually tapering from an almost rounded cutting edge to a pointed butt' (Sheppard 1920, 50, Fig 8). Well-preserved axes have a splayed cutting edge, but many have a rough, weathered appearance due to the dissolution of feldspars. It was formerly believed that these Bridlington type axes were manufactured from boulders collected from local beaches (Elgee & Elgee 1933, 49–50). However, all examples petrologically examined indicate a Cornish origin; the grouped examples belong to Group I, with a single one of Group III (Keen & Radley 1971, 19). These axes belong to Class 5. The splayed cutting edge is not a universal feature of the Bridlington type in Yorkshire and it does occur amongst the forms of Group I axes in south-western England (Stone & Wallis 1951, 103, Fig 6).

Edge-ground axes

These implements, after flaking to shape, have had grinding applied to the cutting edge only. It is necessary to distinguish them from reworked blades, where an existing ground cutting edge had a butt flaked on it. The grinding of the cutting edge extends up to a third of the length of the blade in most cases, but a small group has only a very narrow zone of grinding following the curve of the cutting edge (Fig 4,4). In the instance of an axe from Ampleforth the grinding is confined to such a narrow zone that it requires very close inspection to see it (Elgee 1930, Pl V, Fig 2). These can appropriately be called marginally ground axes. The majority of edge-ground axes taper to a narrow butt (Fig 4,3), and there are comparable rough-out axes without grinding (Fig 4,2). Broad butted axes with edge grinding are less common (Fig 2,3) but we can distinguish amongst them a small number of larger and heavier blades with a ground edge; produced from rough-outs (Fig 4,1) similar to those

Table I Totals of classifiable axes, adzes, and chisels

	A Flaked rough-out	B Complete grinding	C Pecked & Ground	D Edge-ground
1 Pebbles & nodule	F3			F2 S11
2 Broad-butted axes				
a		F66 S258		
b		F6 S125		
c	F4 S7	F20 S190		F25
d		F5 S8		
3 Narrow-butted axes				
a		F2 S17		
b		F1 S10		
c	F34 S1	F4 F4		F159
4 Rounded thick-butted axes			S169	
5 Thick tapering butted axes			S240	
6 Pointed butted		F3 S5		
7 Adzes				
a	F5	S27		F5
b	F4			F5
c		F1 S12		
Chisels	F20	F6 S10	S2	F27 S9

(F) = flint, (S) = stone

required for the completely ground type of axe. Edge-ground axes are almost exclusively of flint, and may be a response to the difficulty of grinding this material (Coope, this volume).

Duggleby adzes and Seamer axes

Less numerous are blades distinguished by a well-rounded cutting edge, slightly concave sides, and a broad butt. These are both axes and adze forms. The axes have elliptical sections, and from their occurrence in the Seamer Moor hoard or grave group (Smith 1921, 121, Fig 4,3) can conveniently be called the Seamer type (Fig 2,5). The adze form also occurs in the Seamer Moor deposit but, to avoid confusion in nomenclature, these can be called the Duggleby type, after the large and splendid blade that accompanied Burial G at Duggleby Howe (Mortimer 1905, 28, Fig 56). The Duggleby adzes have the additional refinement of a slightly curved profile (Fig 5,5). The Seamer and Duggleby types are further characterized by the quality of their grinding which, in many cases, is a true polishing of high gloss. Colourful raw materials are a feature of these blades. The majority were produced in fine-quality coloured flints – in red, yellow, orange, and mottled varieties. The stone used for such blades appears from macroscopic examination to be the fine greenish tuff of Group VI. These stone versions are all completely ground, like the adze (Fig 5,6) from Willerby Wold Barrow 32 (Greenwell 1877, 181, Fig 11); the sole exception is the broken axe blade from Ebberston (Elgee 1930, Pl V, Fig 4).

The quality of the Seamer and Duggleby blades, coupled with their associations in a number of burials, serves to indicate the very specialized nature of these implements. It has been suggested that they were the products of an individual craftsman or workshop (Manby 1974, 98). Their distribution is not confined to Yorkshire, nor to northern England, and a wider study will be required to confirm any standardization, or the range of local or regional variation, in the Seamer and Duggleby blades.

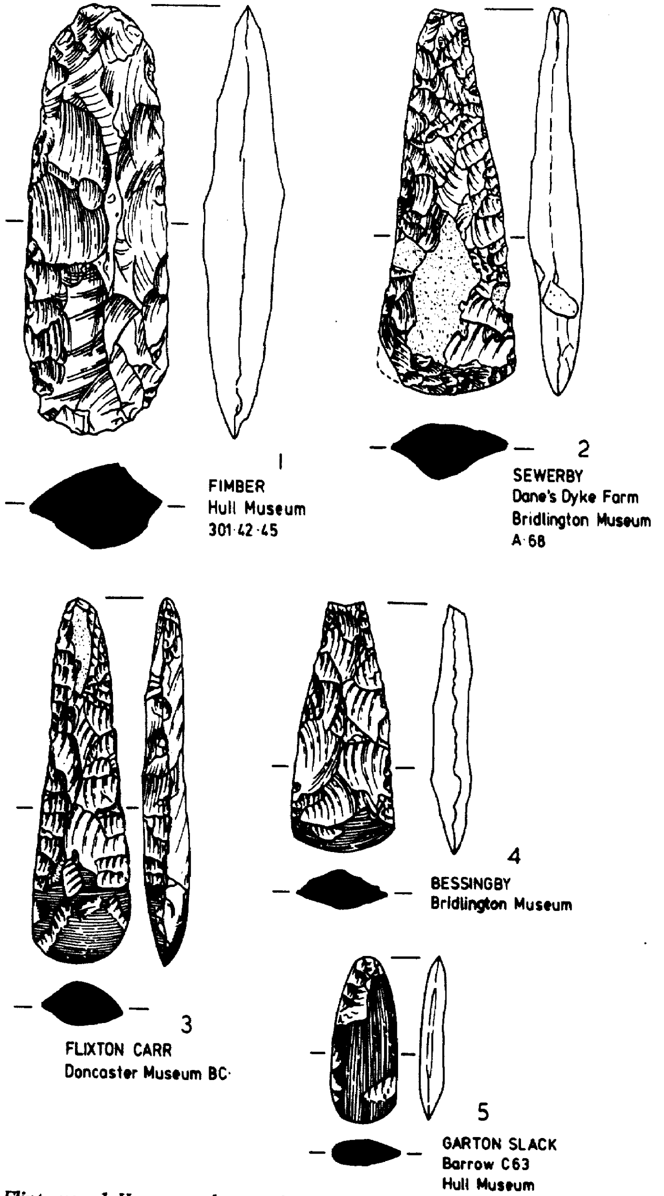
The working life of axe and adze blades, which require reflaking and regrinding, must result in a reduction in size and a change in proportions that makes metrical analysis of doubtful value amongst utilized blades. Although the majority of blades are longer than 75mm, smaller examples do occur, such as the ground flint axe that accompanied a Beaker burial at Garton Slack Barrow C63 (Mortimer 1905, 215, Fig 541).

Chisels

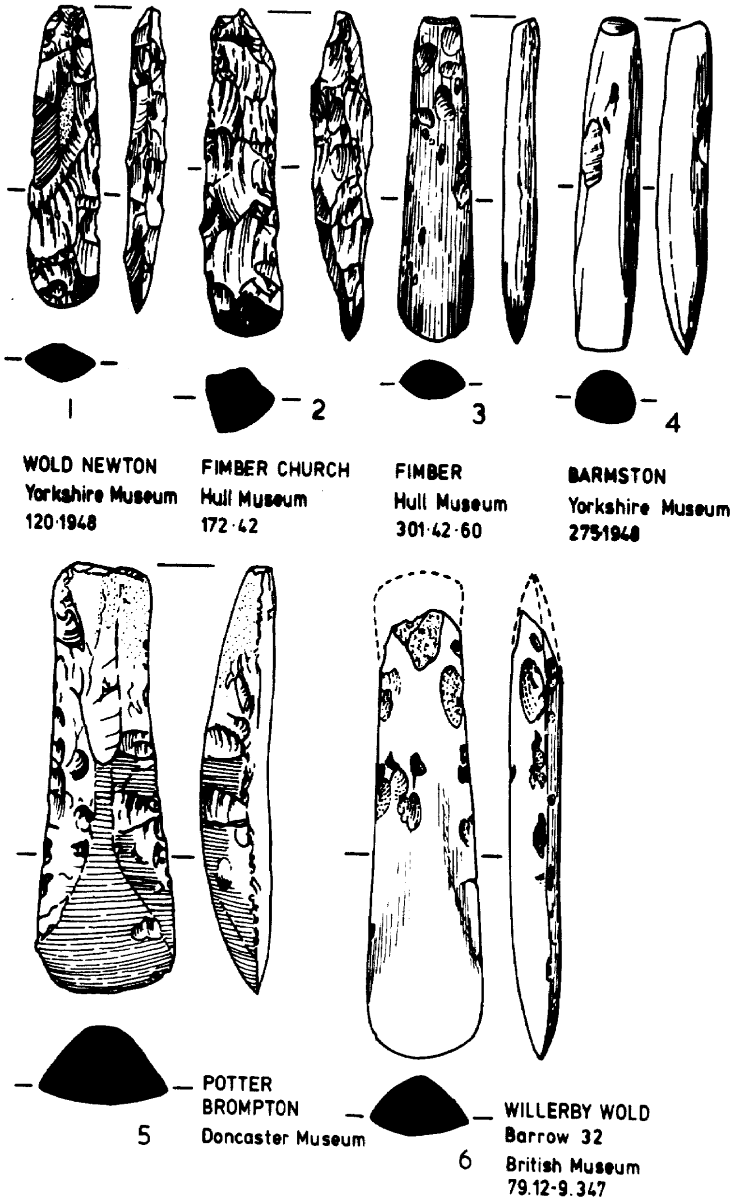
A series of narrow blades, clearly allied to axes in technique and raw material, are classed as chisels; they are bars of flint or stone, 75–125mm long and not more than 25mm in width (Manby 1974, 90). These are distinct from the very long, tapering, implements represented in the Bexley Heath hoard that have also been called chisels (Smith 1921, 117–18, Pl V, 3–4). In Yorkshire the chisels have good associations with Grooved Ware at Fimber and Flamborough (Manby 1974, 11, 74). The majority of these blades are flint, with flaked (Fig 5,1) and edge-ground forms predominating; regular shapes, wider at the cutting edge, prevail, although a crudely flaked blade with only marginal grinding came from the Grooved Ware pit at Fimber (Fig 5,2). Completely ground flint blades are not numerous (Fig 5,3), but stone chisels are always completely ground (Fig 5,4), except where they have been produced by reworking an older axe blade (Manby 1974, 117–19).

Raw materials

The pioneer study of the sources of materials employed for axe blades in Yorkshire was published by Sheppard in 1920. Sheppard, Curator of Hull Museum, had a wide knowledge of both artefacts and geology, and based his observations on macroscopic examination (1920). Apart from Yorkshire axes in distant museums, the petrological identification of stone axes did not get under way until the mid-1960s and the first report, published in 1971, contained 350 identifications of axes and perforated tools (Keen & Badley 1971). The total of petrological identifications now available for Yorkshire has risen to 800 and a second report is in preparation by A P Phillips and W A Cummins. Over 1900 stone axes are known and recorded from Yorkshire sites; to these can be added flint axes, making a total of 2409 implements (Table II). The 20% of axes in flint have only been identified by macroscopic methods and imported flint blades cannot be distinguished at present. All the flint axes could have been produced from local sources and the total in this material assumes some importance in relation to those of imported stone.



4 Flint axes: 1 Heavy rough-out, Class A2, 2 Light rough-out, Class A3, 3 Edge-ground, Class D3c, 4 Marginal edge-ground, Class D3c, 5 Partially ground, Class 6. Scale 1 : 3



5 Chisels: 1 –3 Flint, 4 Stone. Duggleby adzes: 5 Flint, 6 Stone. Scale 1 : 3

Table II Flint and stone axes from Yorkshire

	Flint axes	Stone axes	Ratio flint/ stone	Total axes	%	Area (sq miles)	Average axes per sq mile
Wolds	240	1220	1/5	1460	60	337	4.3
Holderness	49	115	1/2.3	164	7	256	0.6
Vale of Pickering	37	56	1/1.5	93	4	152	0.6
North York Moors	44	197	1/4.5	241	10	632	0.3
Howardian Hills	2	44	1/22	46	2	90	0.5
Vale of York	51	140	1/2.7	191	8	1512	0.1
Pennines	44	170	1/3.8	214	9	3087	0.06
Total	467	1942		2409		6066	

Flint

The indigenous rocks of Yorkshire are essentially sedimentary, consisting of limestones, sandstones, shales, and chalk of Carboniferous, Triassic, Jurassic, and Cretaceous age. Chert occurs in beds in the Carboniferous limestone formations of the Pennines and outcrops in Upper Ribblesdale, Wharfedale, Nidderdale, and Swaledale. The material is dense and occurs in various colours – light and dark greys, black, brown, pale green, and banded in various shades; flaking qualities vary from bed to bed. Although chert was extensively utilized at Pennine Mesolithic sites, it was little used in the Neolithic period and no definite chert blades are known. It may have been very difficult to find large enough pieces, owing to the natural fracturing of this material.

Flint occurs naturally in the Lower Chalk of the Yorkshire Wolds in solid beds and as layers of nodules. This is a dense flint, light grey to white in colour, with a yellowish-brown nodular skin. The bedded flint occurs in layers up to 1ft (30cm) thick but it tends to be brittle and fractures too easily for implement manufacture. The nodular flint has better flaking qualities, but close to the surface both bedded and nodular flint has been fractured by frost action under the periglacial conditions prevailing in eastern Yorkshire during the last glaciation. The digging of pits into the very hard Yorkshire chalk would be arduous below the level of the loose frost-fractured rock. The diggers of the southern ditch of the Willerby Wold long barrow had cut through several thin layers of flint but had left a massive boss of flint projecting out of the western wall (Manby 1963, 186, Pl XXII, d). The hardness of the chalk, and the poor quality of the flint, makes it unlikely that mining methods would have been employed to exploit this source on the Yorkshire Wolds. Axe blades of white and grey flint, like the Wold material, form only 5% of the flint axes available for study in Yorkshire, the majority of these being completely ground axes.

The remaining 95% of Yorkshire flint axes were made of coloured flint, derived, as recognized by Sheppard (1920, 36), from the boulder clays of the Yorkshire coast. Flint blocks and nodules can be picked out of the Drab and Purple boulder clays or tills attributed to the Late Devensian Glaciation. The boulder clay forms a strip down the Yorkshire coast from the mouth of the River Tees to Flamborough Head; south of this headland the clays form most of the low-lying area of Holderness and extend inland to the foot of the Wolds. This erratic flint is most readily available on the coastal beaches, liberated by erosion from the boulder clay cliffs. Today large flint blocks can be found on the beaches of Filey and Bridlington Bays; they are in fresh condition and can be up to 2ft (60cm) in length. The remains of chalk cortex and lack of rolling would indicate they had been torn from the Cretaceous outcrop by the passage of the glacier; the chalk extends eastwards from Flamborough Head under the North Sea to Germany. The larger blocks are of translucent brown and mottled varieties of flint, the smaller ones of pink and chestnut colours. This fresh material can be picked out of the boulder clay along with smaller rolled and battered flint pebbles that must have been derived from earlier beach or boulder beds. South of Bridlington Bay the size of flint boulders decreases, though the material is still plentiful as far south as Easington. North of Filey Bay flint is available on most beaches but pieces larger than 1lb (0.5kg) are rare. Apart from the colours mentioned above there are less common varieties of light brown, amber-brown speckled, honey-coloured, yellow, and dense red; the yellow and red are only found as very small pebbles and their flaking qualities are very poor.

The exploitation of the flint source provided by the coastal beaches is demonstrated by vast quantities of flint working debris on Flamborough Head and around Filey Bay, at cliff top localities overlooking gulleys that provide easy access to the beach (Moore 1964, 192–4; Sheppard 1910). Massive primary flakes amongst the debris indicate that blocks and pebbles were brought up from the beach and trimmed to workable shape. Large cores, including tortoise cores, large scrapers, and fragments of flaked-out axes show that implement production was carried out. Two small areas at Beacon Hill, Flamborough, have been excavated, part of the great spread of flint debris on the cliff top west of South Landing. At the first site two broken flint axes came from the Beaker Floor' (Moore 1964, 194, Fig 3, Nos 295, 305) and half an axe blade came from Beacon Hill East site (Manby 1975, 47, Figs 17, 19). The area of flint debris spread on the western side of Hartendale Gutter, Flamborough, has been destroyed by gravel extraction, and large quantities of flint work have been recovered from pits accompanied by Grooved Ware (Manby 1974, 70–6).

South of Flamborough Head the Neolithic coastline has been destroyed by erosion, along with any flint-working sites. North of Filey Bay flint debris sites on the cliff top are unknown, and likely areas are covered by modern settlement.

Flint pebbles occur amongst the inland boulder clays and gravels of the Vale of York and in the Pennine Dales. These include white Wold flint and brown and other

Table III Totals of petrologically grouped axes from Yorkshire to 1977

	I	III	VI	VII	VIII	IX	XV	XVI	XVIII	XX	XXIII
Wolds	25	1	153	20	1	3		1	44	1	2
Holderness	2		24	7				1	6		
Vale of Pickering	6		18	2					6	1	
North York Moors	8		26	2		1			1		
Howardian Hills	1		4	1							
Vale of York			22	2							
Pennines	1		40	10		6	2		6	2	
Total	43	1	287	44	1	10	2	2	63	3	2
% of total* *(700* axes examined)	6	< 1	41	6	< 1	< 1	< 1	< 1	9	< 1	< 1

* 35% ungrouped

coloured flints, as well as Pennine cherts. These are all small and hard to find, in comparison with those so readily available on the coastal beaches.

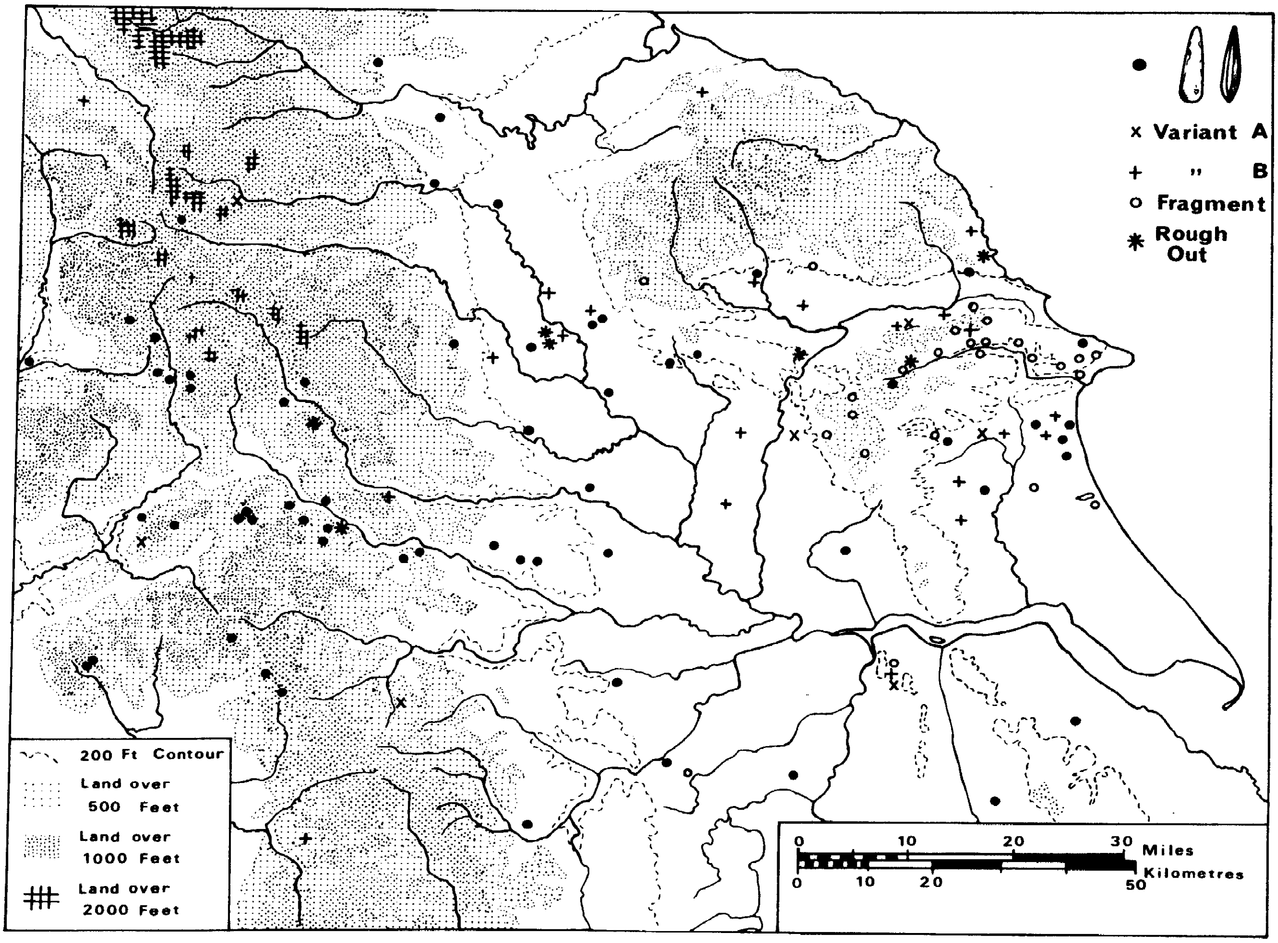
Stone

The petrological identification of stone implements from Yorkshire has reached a total of 800 implements and if the 100 shafthole tools are omitted we can say that nearly 40% of available axes have been examined. Of these 700 axes, some 65% have been assigned to petrological groups (Table III). The sample that is now available for study is sufficiently large for some definite conclusions to be drawn regarding the sources of stone axe material used. It is unlikely that any other major group will be recognized, as macroscopic examination of unsliced axes suggest that Lake District tuffs will still predominate.

In 1920 Sheppard expressed the view that over 50% of stone axes found in East Yorkshire were of 'Borrowdale ash' (Sheppard 1920, 45). He also pointed out that the smallness and scarcity of Borrowdale erratics in the local glacial drift made it unlikely that the axe material was glacially transported and that there must have been a direct importation of axes from the Lake District. The Yorkshire Boulder Committee of the Yorkshire Geological Society undertook a very extensive survey of erratics during the period 1886 to 1906 with the assistance of a distinguished band of geologists and petrologists. The Committee's report still forms the widest study of erratic boulders available for the Yorkshire Region (Howarth 1908). Rocks derived from a western Lake District source, like those of Borrowdale Ash, were identified in the central Pennines and southern Vale of York. The largest boulders identified as Borrowdale ash were 1½ft (450mm) long (Howarth 1908, 219). Sheppard's Borrowdale ash was the tuff of Group VI, although he may have included Welsh axes of Group VII in this class as his identifications were macroscopic.

Of petrologically determined axes, Group VI forms 41% (Table III) and a proportion of ungrouped axes classified as tuff must also be added to the total of axes of Lake District origin. This high percentage of Lake District stone is also indicated by the recent macroscopic examination of axes still to be sliced. The Lake District appears to have provided some 45% of the total axe material in Yorkshire, and was clearly the dominant source of supply. Lake District axes are twice as numerous as flint axes, and almost as common as all other stone and flint axes together. It is obvious that a large portion of the production of the Lake District axe factories was absorbed by Neolithic communities in Yorkshire. The economics of this trade have still to be fully determined but direct participation in the working of the factory sites by communities from the Yorkshire region may have to be recognized. Certainly some rough-outs of axe-factory quality reached our region (Manby 1965, 26). Two have been identified as Group VI; one is from Keighley (Fig 3,l) (Keen & Radley 1971, 19, 27, Fig 20), and the second is one of two rough-outs in the Wakeman's House, Ripon, without data but likely to be local finds. Undetermined rough-outs also come from Scarborough (Fig 1,2) and West Luttons (both in Yorkshire Museum, 413. 1948; 1516. 1948), and a partially ground axe comes from Malton (Manby 1965, Fig 2,3).

The large finished form of Group VI axe, the Cumbrian type, has been found in Yorkshire in some numbers. The grinding of these axes was undertaken on the Cumberland coast and in Furness (Manby 1965, 3–8). Further grinding areas around the fringe of the Lake District mountains are likely, wherever suitable sandstones could be found. The scatter of Cumbrian axes from the Pennines and Vale of Yorkshire consists of blades in mint condition that could represent losses in transit. In contrast, Cumbrian axes from the Wolds, the major area of axe concentration (Fig 6), consist of blades that have obviously had their cutting edges reground or broken, and fragmentary blades. Evidence of axe-grinding activities in Yorkshire are few, although the rough-outs are an indication that some finishing did take place, Flakes of Group VI have been found on occupation sites in East Yorkshire (Appendix A) but, in most cases, have grinding on one face, demonstrating that they were struck off during the reworking of damaged axe blades. The association of Group VI axes (Appendix A) with pottery of the Peterborough, Grooved Ware, and Beaker styles indicates the wide range of cultural communities utilizing the products of the Lake District axe factories. Regrettably, Yorkshire sites provide little evidence for the



6 Distribution of Cumbrian-type axes and rough-outs

full chronology of exploitation of this source of material, as the cultural associations are all with the Later Neolithic period.

Finished forms of Group VI axes are predominately of Class B2a, with smaller numbers of B2b and B2c. Less frequent are those of Class B3 with the same variety of sections; there are also small numbers of adzes and chisels. The working properties of Group VI permitted the reworking of axes, by flaking, down to very small proportions, and blades 60–75mm in length occur.

The contrast in numbers between Group VI and other petrologically grouped axes in Yorkshire is outstanding (Table III); the next group in order of abundance is XVIII, forming only 9% of determined axes. Group I from Cornwall and Group VII from Graig Llwyd are equal, with 6% each of the total of determined stone axes. The number of axes from Cornish sources is increased slightly by the inclusion of Groups III and XVI and some of the ungrouped rocks identified as epidiorite. Group IX axes are few and Groups VIII, XV, XX, and XXIII are very scarce.

Axes of Group XVIII, a quartz dolerite originating in the Whin Sill of northern England, are of some special interest. Apart from the axe blades considered here, the same rock was utilized for battle axes, axe hammers, and mace heads in Yorkshire. It has been suggested that the source of axe material was the Whin Sill outcrop of Upper Teesdale in the extreme north-west of Yorkshire (Evens *et al* 1962, 224). Search in Teesdale, amongst the Whin Sill screes around High Force, failed to locate any factory sites although pieces of scree appropriate in size for axe production were readily available (Keen & Radley 1971, 26). The physical nature of the rock would require working by pecking and the dust produced would not lead to the recognition of a factory site.

Attention has been drawn to the widespread occurrence of Whin Sill boulders in the glacial deposits of the Yorkshire coast and the possibility of at least some of the Group XVIII material coming from this source (Keen & Radley 1971, 26–7). The Whin Sill boulders in the drift along the coast are likely to have been transported by ice from the outcrops on the Northumbrian coast. Whin Sill boulders also have been noted in the Vale of York (Howarth 1908, 221) and, like other rocks derived from sources in the eastern Lake District, may have their origin in the Whin Sill outcrop of the Eden Valley. The use of erratics as a source of some of the Group XVIII axes finds support in two axes that appear to be pebbles with cutting edges worked onto them. Both come from East Yorkshire localities: Wold Newton (Hull Museum, 300.42.245) and Wilsthorpe (Bridlington Museum, A31).

Whin Sill boulders, of various sizes, are readily available on the coastal beaches. In many instances the surface of the boulders is patinated and they resist breaking up by hammering. The utilization of large boulders for axe material would require a method of splitting to obtain fresh flakes; fire setting is an obvious possibility that would leave burnt primary flakes as a by-product. Group XVIII axes were prepared by pecking and grinding and, in shape, the majority belong to Classes 3 and 4 (Table I). The question of the sources of Group XVIII rock, whether from erratics or outcrops, cannot be resolved until petrological identifications are available for axes in the areas around the Whin Sill outcrops in the Eden Valley and Northumberland.

About one-third of petrologically identified Yorkshire axes do not belong to any of the recognized groups. The Lake District origin of many of the tuffs, and the probably Cornish source of many epidiorites, has already been mentioned. Other rocks are greywacke, several varieties of dolerite, basalts, slates, and quartzites. Quartzite is readily available in the local glacial drift, and other varieties of igneous and metamorphic rock can be recognized in the boulder clays. The sources of these hard rocks were very wide as several Pleistocene icesheets invaded Yorkshire bringing rock material from the Lake District, southern Scotland and Norway (Howarth 1908, 219–24; Harker 1901). The utilization of these erratics for axe material was postulated by Sheppard (1920, 36) and this is a likely source for the wide range of sandstone, quartzite, dolerite, and jasper pebbles, utilized as hammerstones, rubbing stones, and pot-boilers at local Neolithic sites (Manby 1974; 1975). However no petrological comparisons have yet been undertaken between the ungrouped axe materials and the locally available erratics. A reference collection of Yorkshire erratics, for petrological comparison with Yorkshire stone axes and other utilized stones from Neolithic and Bronze Age sites, is being built up.

Not all Yorkshire axes were produced from hard rocks; there is a small number of axes made of sedimentary rock. Sandstones and siltstones occur, and the most unlikely material is represented by limestones (Keen & Radley 1971, 24). The axe from Norwood (Fig 1,5) is a black fossiliferous limestone that takes a high polish; similar Carboniferous limestones were employed in the Middle Ages as a ‘marble’ to enrich churches and tombs.

Distribution of flint and stone axes

Axes are the most significant indicators of Neolithic settlement in Yorkshire; the size and colours of these implements attract recovery by the casual observer where smaller flint implements and sherds are only obvious to the more purposeful collector. In areas of old established and intensive cultivation field monuments rarely survive but ploughed fields provide good collecting conditions. The lowest chances of discovery are in areas of permanent pasture and stable moorland. These factors are all reflected in the distribution of flint and stone axes from the various natural areas of Yorkshire (Table II). The total distribution of flint and stone axes (Fig 7) demonstrates the predominance of finds from eastern Yorkshire, especially the Wolds. Most of the axes preserved in museum collections were found during the 19th century and although their provenance is usually only to a parish or township, a large number do have an additional attribution to a wold, carr, or moor. Parishes around the edge of the Wolds extend out into the lowlands of the Vales of York and Pickering and in such instances it is wrong to assume that locations such as Willerby or Ganton mean they were found on Willerby or Ganton Wolds. More recent and better documented finds demonstrate that axes can be recovered from the lowland areas like Willerby Carr.

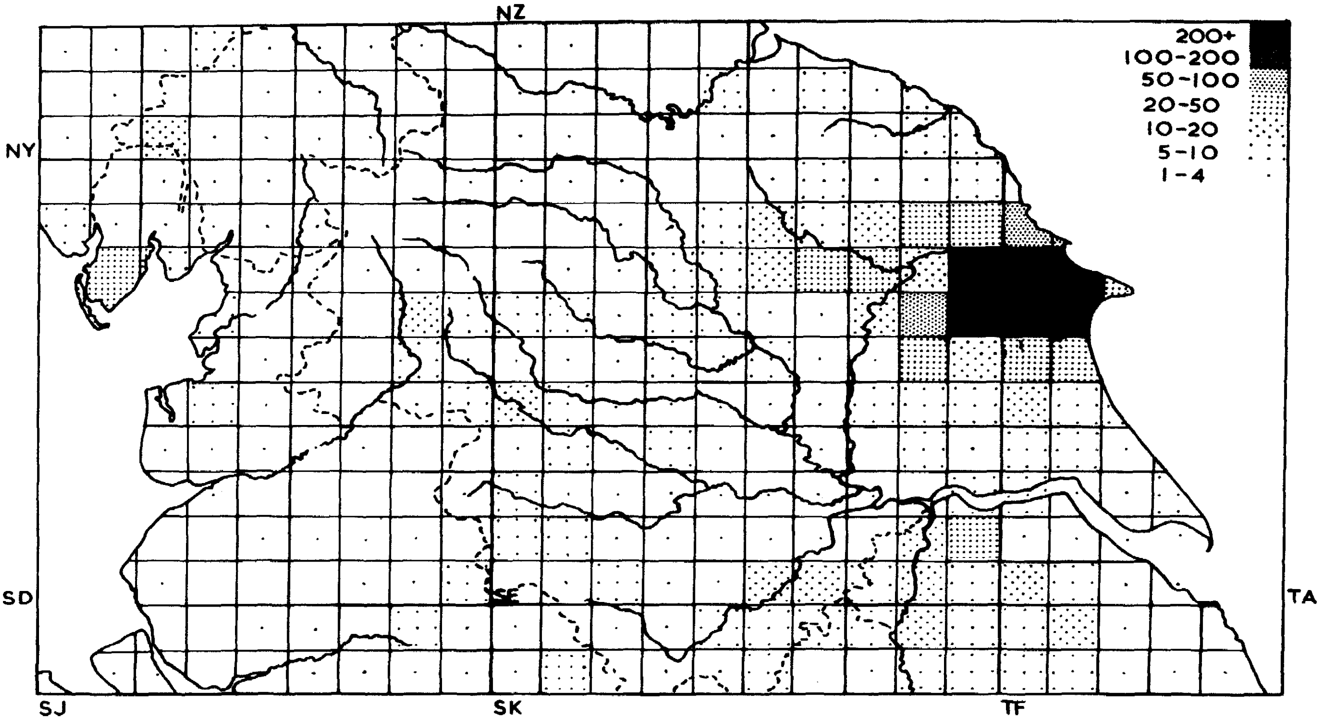
The final agricultural enclosures of the early 19th century brought an extension of arable farming to the Yorkshire Wolds and the limestone hills that form the southern slope of the North York Moors, giving rise to ideal collecting conditions in these areas. Farm workers collected axes and other implements, providing a field-collecting activity of unrivalled intensity. The 19th-century collecting centres of Bridlington, Scarborough, Malton, and Whitby are likely to have axes attributed to them that were actually found in neighbouring parishes. This is certainly the case for some of the vast numbers attributed to Bridlington and to Whitby.

The numbers of axes from eastern Yorkshire are so great that it is impossible to plot their individual distribution on any small-scale map. The overall frequency distribution is represented by recording the number of axes known from each 10km square of the National Grid. The map (Fig 7) shows most dramatically the great number of finds from the northern and central Wolds. The map does not take into account a further 32 flint axes and 143 stone axes localized only to the Wolds; these would increase the density on the Wolds west of Driffield. These are all axes in the Mortimer Collection, now housed in Hull Museum, that were found by local farm labourers collecting for John and Robert Mortimer of Fimber. The very great concentration of axe finds from the eastern end of the Wolds come from those parishes along the coast that are mantled by boulder clay or include within them the floor of the Great Wold Valley: in fact the best agricultural land.

Axe finds are not numerous on the western Wolds and scarce from the southern Wolds, even though these areas have been searched by modem field workers. Recent field walking over the Wolds between Bridlington and Driffield has produced large numbers of broken axes and flakes. Complete blades are now scarce in localities where the thin soil has been ploughed continuously for the past century and a half.

The lowlands around the Wolds have produced scattered finds of axes, especially the northern half of Holderness and the Vale of Pickering. The lowland distribution in the Vale of Pickering was noticed by Elgee (1930, 38); the Vale is floored by various drift and alluvial deposits overlying Kimmeridge Clay. During the Middle Ages and down to modem times this former glacial lake bed has suffered from flooding caused by the rapid inflow of water from the surrounding Wolds, North York Moors, and Howardian Hills. Drier conditions are indicated during the Neolithic, caused by the prevailing forest environment controlling the run-off of surface water from the hills, and axes are recovered during drainage works beneath waterlaid clays as well as from islands and the sandy fringes of the surrounding hills.

The extensive area of limestone and sandstone hills forming the North York Moors has provided 10% of the axe finds, but their distribution is limited to the impure limestone hills along the northern side of the Vale of Pickering and along the coast (Elgee 1930, 38–40). These are areas of modem arable cultivation, and the extension of cultivation onto the Hambleton Hills in recent decades has extended their distribution. The sandstone watershed area of Blackmore has few axe finds and these are confined to moor-edge locations, although soil and peat erosion with large areas of forestry ploughing have provided good collecting conditions for Mesolithic flints



7 Distribution of flint and stone axes; density of axes plotted for the 10km squares of the National Grid

and later arrowheads and other tools. The local concentration of axe finds from Whitby reflects the role of this town as a marketing centre for antiquities and many Whitby axes must have been picked up from arable land along the coast.

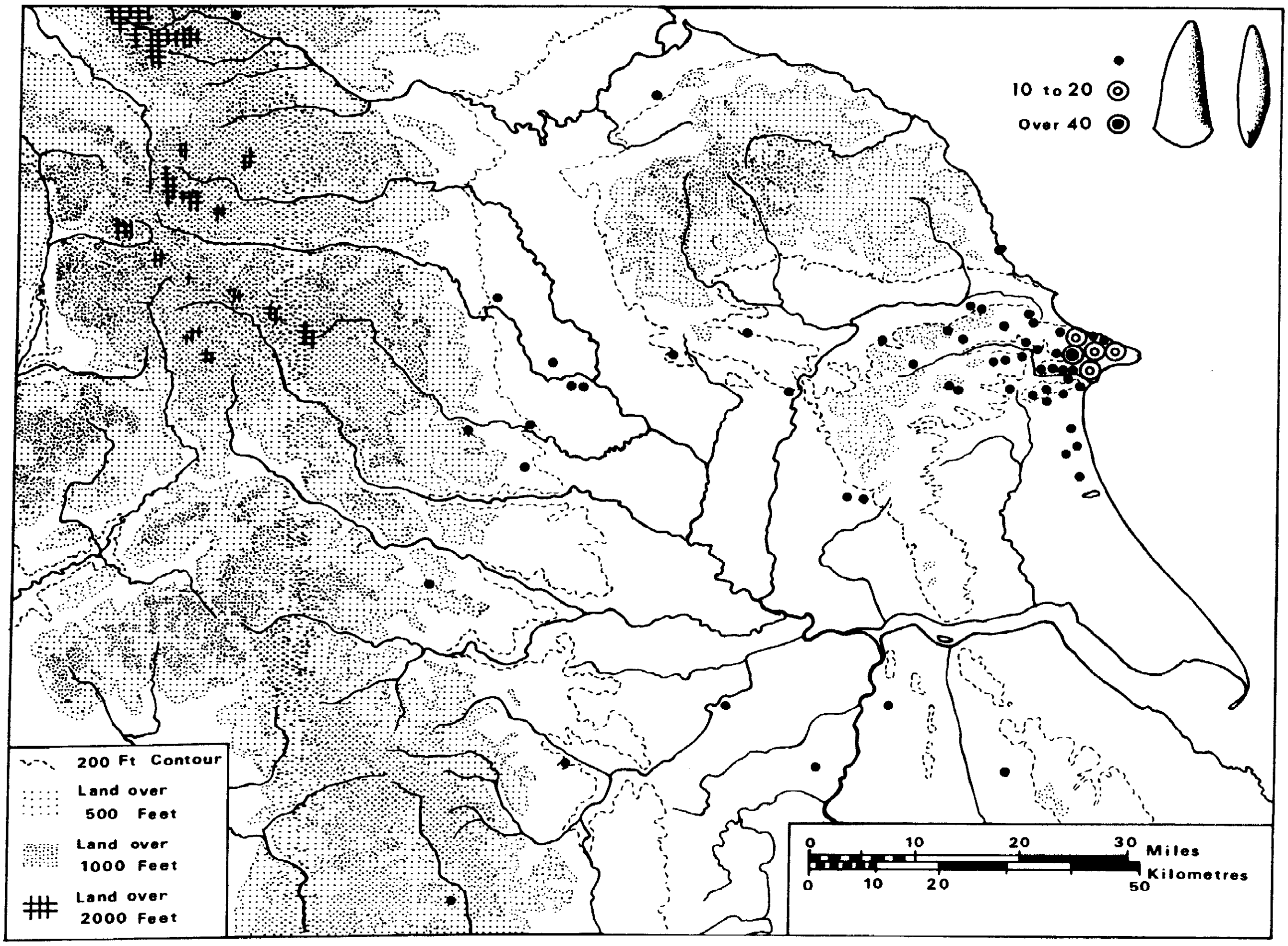
The extensive lowland area of the Vale of York extends north to south across Yorkshire, separating the Wolds and Moors from the Pennines. The Vale is floored by a complicated series of glacial and more recent deposits, including peat, alluvium, and windblown sand, that in extensive areas of the central and southern portion of the Vale actually blanket the Neolithic landscape. Minor concentrations of axes occur around Ripon and Doncaster, reflecting the attraction of established collectors and museums, but this great area of 1512 square miles (3914km^2), or about a quarter of the land area of Yorkshire has only 8% of the total axe finds.

The Pennines are a complex area of Carboniferous gritstones, sandstones, shale, and limestone hills divided by great dales; although they can be divided into six natural areas, they are treated as a unit for present purposes. The Pennines represent about half the total area of Yorkshire, some 3087 square miles (7991km^2), but only 9% of axe finds have come from this vast area. Axes are scarce in many areas; the high peat-covered gritstone moors of the southern and central Pennines have few axes, although the eroding peat provides ideal collecting conditions. Minor concentrations of finds have developed in modem times with the expansion of towns like Bradford, Keighley, and Huddersfield. The conversion of former pastureland to suburban gardens has been responsible for these finds.

The extension of arable cultivation to former pastoral areas of the Coalfield in the southern Pennines, around Barnsley and Wakefield, has produced some axe finds, but large areas have been destroyed by opencast mining, making this one of the poorest find areas. Find prospects are also limited in the pastoral area of Craven with its limestone hills in the central Pennines, but none the less a significant number of the large Cumbrian axes have been found here (Fig 6). Also, determined field-workers have recovered flakes of ground flint and stone axes from such limited exposures as molehills.

The northern Pennines, dissected by Wensleydale, Swaledale, and Teesdale, have relatively few axe finds but circumstances are extremely unfavourable for the casual discovery of archaeological material. The dales are almost entirely pasture, over a rocky soil that discourages cultivation, and the hills are pasture or heather moor, where game preserving or army training prohibits access and search. This is a critical area for understanding the stone axe trade, as within it are both the Teesdale Whin Sill outcrop, a possible source of Group XVIII rock, and the Stainmore Pass.

The Pennines must not be regarded only as a transit zone between axe-producing localities, in the Lake District and North Wales, and the major marketing area in eastern Yorkshire. Flint axes in the Pennines, and axes of imported rock like Groups I and XX, and probably Group XVIII, were clearly attracted to be used locally. However the vast numbers of Group VI axes found in eastern Yorkshire could only have arrived by way of the traditional Pennine routes over the Stainmore Pass or through Craven (Manby 1965, 11–15). The



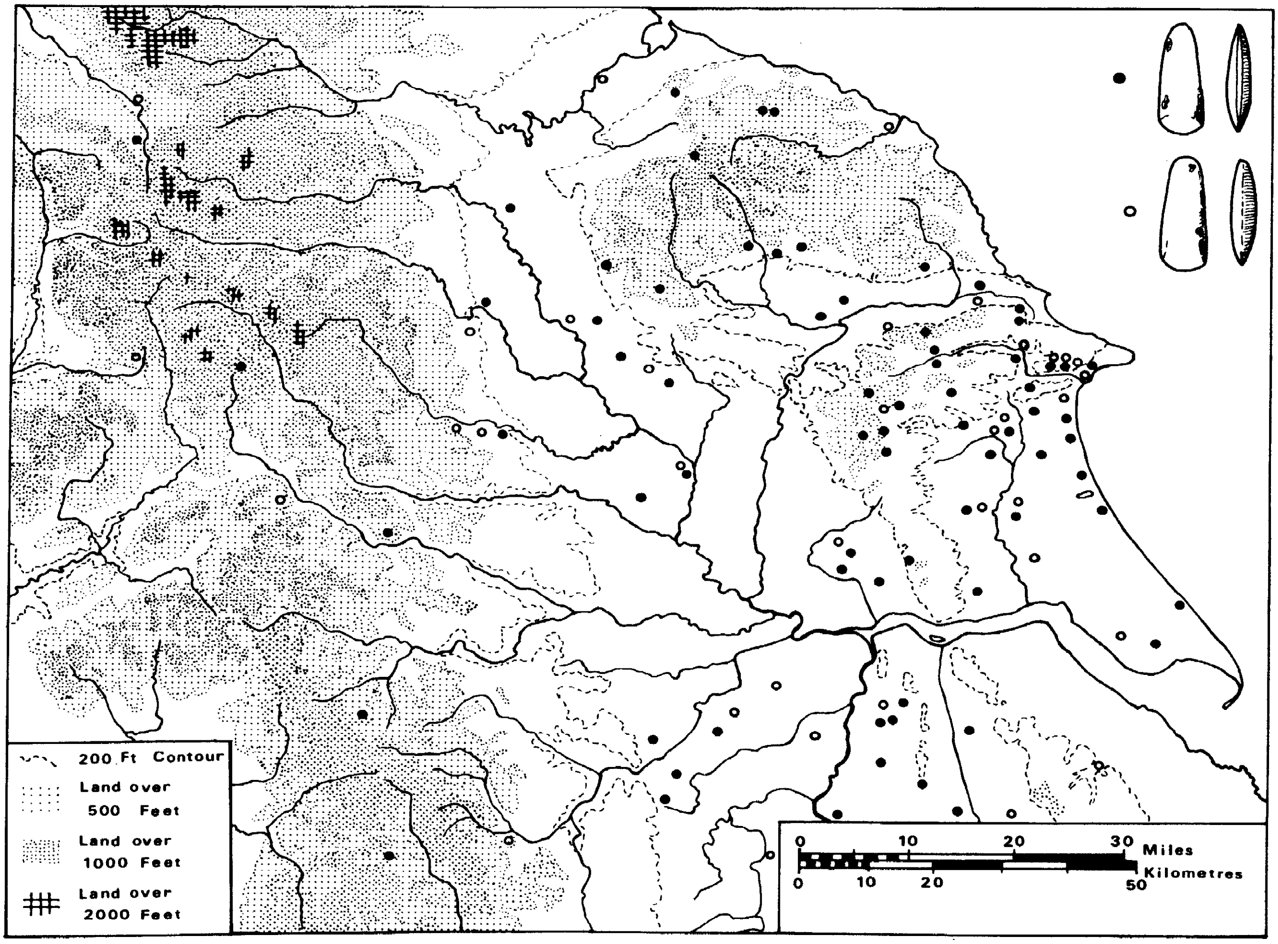
8 Distribution of Bridlington-type and Group I axes

economics of the stone axe trade between eastern Yorkshire and Lake District axe factories are difficult to understand but clearly a large portion of the Lake District axe production was attracted to eastern Yorkshire. The movement of bulky foodstuffs such as grain in return for stone axes would be difficult over great distances and rough country. However, rather than long distance trade in consumer products we might consider a local movement of people, with cattle herds, to the Lake District mountains as part of a migratory cycle. This would require a seasonal movement into the Lake District where mountain grazing of herds could have been undertaken in the late spring at the same time as the roughing-out of axes. A move would then be required to the sandstone margins of the Lake District, where the grinding of rough-outs was undertaken. An autumn return over the Pennines would follow, using some of the migrating cattle as pack animals; this would enable a far greater number, and weight, of axes to be carried than would be possible by human porterage.

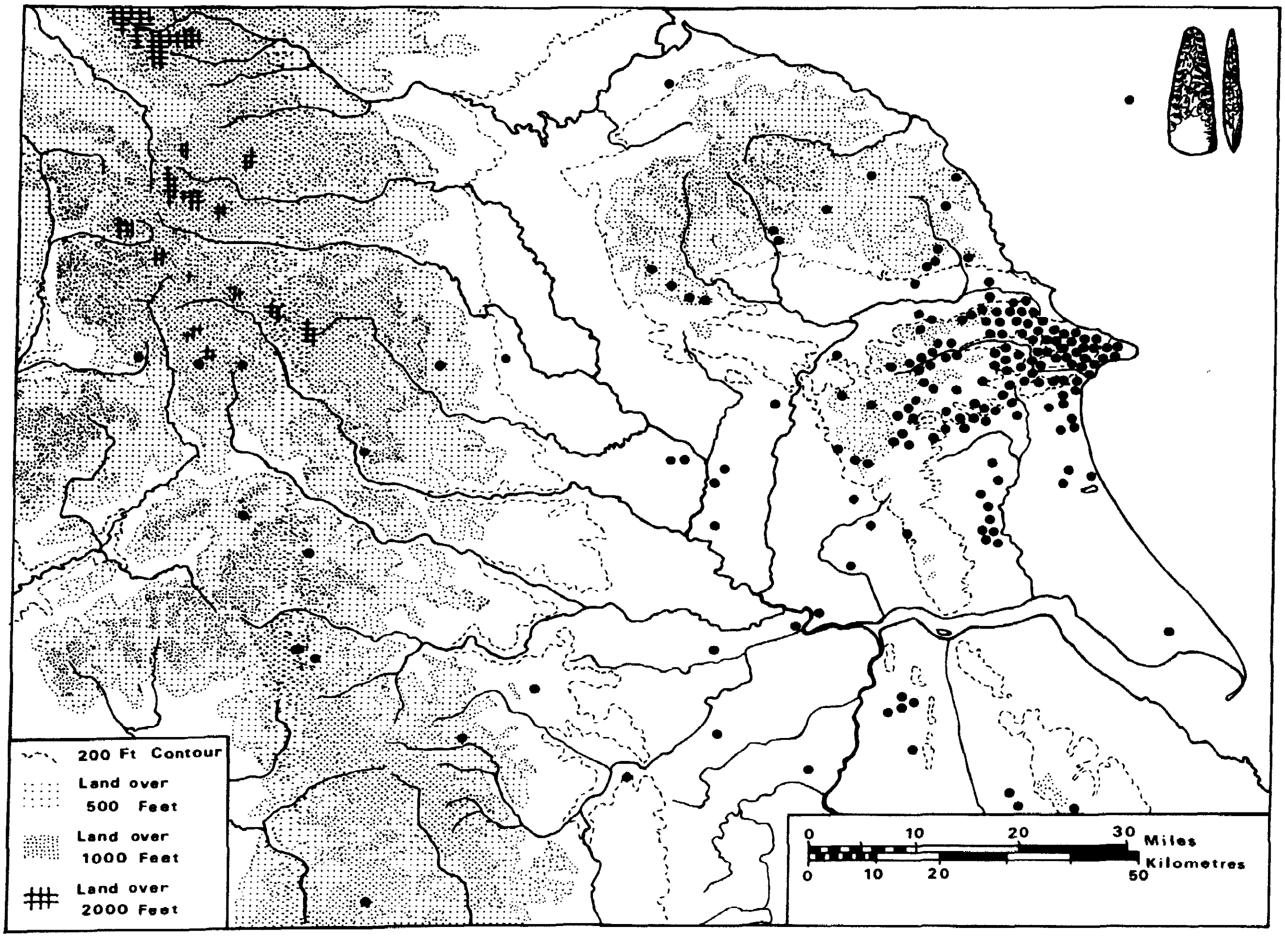
Such a cycle of activity would leave little permanent archaeological evidence, except for the axes themselves. But it is a system that could have been operated by communities based in the eastern Pennines or the Vale of York. In this way the intensively settled area of eastern Yorkshire could be provided with axe blades for forest clearance and the creation of timber structures. This area of permanent agricultural settlement could have provided a surplus of grain for trade as well as a desirable raw material, flint, to exchange for Lake District axe blades, without any trade exchange in consumer products actually taking place between the two regions. It is tempting to consider that such community trading activities might have focal points in the region equivalent to the causewayed enclosures of southern England, that have been interpreted as centres of communal, economic, and cult activities (I F Smith 1971). It is at once obvious that the great concentration of henge monuments in the northern portion of the Vale of York, between the Rivers Ure and Swale (Wainwright 1969, 128) could have served this purpose in connection with the axe trade. The six henges of this locality, Thornborough, Hutton Moor, and Nunwick, are situated in sandy country that is not a rich soil for agriculture. But the locality is also strategically placed for access both to the Pennine crossings, via Craven and the Stainmore Pass to the west, and over the Vale of York to the Wolds, North York Moors, and Howardian Hills to the east. The dating and cultural evidence for these henges is scanty and only limited excavation has been undertaken at two of the Thornborough and the Nunwick henges. However, the monumental scale of all six sites indicates intensive activity in an area that otherwise lacks evidence of dense Neolithic settlement. The very absence of cultural material from the henges could be evidence for their use as a focus for a seasonal activity such as trading.

The distribution of individual axe types in the Yorkshire region continues to repeat the concentration pattern of total axe finds in most instances. This is readily seen in the spread of Bridlington axes (Fig 8) where the concentration is in the coastal parishes of the Wolds but spreads out into the Vale of York and the Pennines. This same pattern is repeated in the highly specialized blade forms of Duggleby adzes, Seamer axes (Manby 1974, Fig 40), and chisels (Manby 1974, Fig 38). However, there is a significant contrast in the distribution pattern of completely ground flint axes, Classes B2 and B3, which are widespread in the region (Fig 9). Over half the finds come from lowland areas like Holderness, the Vale of York, and Vale of Pickering. They are also responsible for the high ratio of flint to stone axes in these particular areas (Table II). This pattern can be contrasted with the distribution of edge-ground flint axes, Classes D2, D3, and D7, which show a concentration on the Wolds and other calcareous uplands (Fig 10). The associations of edge-ground axes are with the Later Neolithic and, in these two contrasting distributions, we may have evidence for a shift in settlement patterns from the widespread utilization of many soil types including lowland areas in the Earlier Neolithic to a concentration on upland calcareous soils. The pattern of ground flint-axe distribution is repeated in such flint types as single-piece sickle blades, but it cannot yet be clearly demonstrated for other axe types or petrological groups.

The overwhelming number of stone and flint axes from Yorkshire are surface finds and without cultural associations. While a small number of axes have been found in the material of barrow mounds, most of these were probably accidental inclusions, the content of the soil. Axes from occupation assemblages from excavated sites, or occupation debris in barrows, are fragmentary and are typologically difficult to determine (Appendix A). A small series of burials with axes is available (Appendix B), as well as a smaller number of ‘hoard’ finds (Appendix C) to provide cultural and typological links.



9 Distribution of ground flint axes, classes B2 & 3



10 Distribution of edge-ground flint axes, Classes C2, 3, 6

The modern trade in axes

The final agricultural enclosures of the early 19th century were followed by a vast increase in arable farming, with old pasture and moorland brought into cultivation for the first time. This extension of ploughing yielded a harvest of flint, stone, and bronze implements; and, coupled with an interest in antiquities by the leisured and rising middle classes, a trade in archaeological material grew up in eastern and central Yorkshire.

Throughout the next hundred years there was an economic incentive for farm labourers and shepherds to recover artefacts for sale to dealers and collectors, in the market towns of Bridlington, Malton, Pickering, and York. Implements were recovered from the surface of cultivated fields, during stone-picking and during drainage work, and their sale was a useful supplement to the small fixed agricultural wages. The ready market for antiquities caused Edward Simpson of Whitby to abandon field collection for direct production. In his home town, Simpson was known as 'Bones', but in the East Riding he was 'Flint Jack'. Although their crudity and unorthodox shapes are obvious today, the products of 'Flint Jack' were to cause much concern to the local dealers and collectors in the 1850s. James Ruddock of Pickering, and later Whitby, principally known as a purveyor to Thomas Bateman of Lomberdale Hall, was especially concerned to expose fake implements. Ruddock combined with Edward Tindall and George Pycroft, of Malton, in an exhibition held in the Hospitium of the Museum Gardens, York on 5 and 6 August 1857. According to the report sent to The *Gentleman's Magazine* 'By a Correspondent of the Malton Messenger' (Charles Monkman) the exhibition compared the genuine with fake artefacts. There was a 'large blue celt . . . made for 2s 6d, beautiful hammers for 5s each and some arrows and spears, whose history and place of manufacture are well known, have been sold for 1s each.' These activities were to stimulate a greater awareness of typology and a caution in establishing the provenance of implements.

The centre of the trade in prehistoric artefacts was Bridlington where Ruddock's contemporary Edward Tindall was the most important dealer. 'The Anthropological and Ethnological Museum at 5 High Street is the property of Mr Edward Tindall, who freely opens it to the public. It contains many objects of interest and some fine specimens of flint implements' (White 1867, 305).

We are also informed that Edward Tindall was a tobacco pipe manufacturer and land agent; also at 5 High Street was George Tindall, pianoforte dealer (White 1867,307). The creation of Scarborough Road at the beginning of the present century resulted in the destruction of no 5, and other buildings, at the eastern end of the High Street of Bridlington Old Town. However the premises must have been very small with a shop frontage of about 15ft. Tindall supplied flint and stone implements to large and small collectors in different parts of Britain, including John Evans of Nash Mills. Another famous customer was the Rev William Greenwell of Durham; Tindall also assisted Greenwell in his barrow-digging operations on the Yorkshire Welds west of Bridlington. Greenwell acquired a vast number of flint and stone axes and other implements from eastern Yorkshire and had agents and collectors, often village parsons, working on his behalf.

The competition for newly recovered artefacts during the second half of the 19th century in the East Riding was intense, with resident collectors in Bridlington, Pickering, Malton, Scarborough, and Whitby, as well as the distant collectors like Evans, Greenwell, and Blackmore of Salisbury. There were also the local Philosophical Society Museums in Hull, Leeds, Scarborough, Whitby, and York. A useful account of the collectors and dealers of this period was left by John Mortimer (Sheppard 1900, 9–16). John and Robert Mortimer, corn merchants of Fimber, near Driffield, trained farm servants and labourers to recognize implements. In the face of keen competition from rival collectors the Mortimers were once forced to issue handbills, offering monetary rewards and a free pass to the Leeds Exhibition of 1860, to those who would supply the greatest number of articles. John Mortimer was able to buy out a number of the minor collectors and their material was merged with the great Mortimer Collection. The fate of this and other large collections like Greenwell’s, Evans’, Boynton’s, and Kendall’s, and others that passed into the hands of public museums is known. But much material was sold in small lots to minor and undistinguished collectors in Yorkshire and distant parts of the country. The trade continued down to the time of the World War I and then died out. Itinerant dealers were still active in the Driffield-Bridlington area within living memory. Charles Grantham of Driffield recalls a ‘Watch Jack’ who travelled round the Wold farms selling watches and jewellery and buying flint and stone implements. This man came from Hull and his real name is unknown. There was also a dealer called Marshall who threw away fragmentary implements at the farm gate after purchase from farmers and labourers. The last dealer in Bridlington High Street was a chemist who kept a stock of black shag to exchange for axes and other implements. On his death a stock of stone and bronze items remained and these have recently been given to Bridlington’s Sewerby Hall Museum; they were unlabelled and would doubtless have been intended for sale as coming from ‘Bridlington’.

Information on the whereabouts of Yorkshire flint and stone tools, in public and private collections in other parts of the British Isles would be greatly appreciated by the writer.

Appendix A

Yorkshire flint and stone axes from an occupation context

ER = East Riding
NR = North Riding
WR = West Riding

1	Boynton, ER, Carnaby Top Site 1, TA 123 666	Ebbsfleet style pottery; a flake of a Group VI axe (Manby 1975, 40, Fig 8,12), Grantham Collection, Driffeld
2	Boynton, ER, Carnaby Top Site 2, TA 123 666	Peterborough Ware; three flakes of Group VI stone (Manby 1975, 41), Grantham Collection, Driffield
3	Boynton, ER, Carnaby Top Site 18, TA 121 666	Grooved Ware; flake of axe, possibly Group’ VI, macroscopic (Manby 1974, 33), Grantham Collection, Driffield
4	Boynton, ER, Carnaby Top Site 22, TA 122 667	Nine pits with Bell Beaker sherds, fragments of four axes: edge-ground flint; coarse lithic sandstone, Class 5c; Group VII, Class 2a; Group VII; Grantham Collection, Driffield
5	Boynton, ER, North Carnaby Temple, TA 135 670	Durrington Walls style Grooved Ware; flakes and butt fragment, Group VI, Class 2c, butt-faceted (Manby 1974, 62, Fig 26,2), Grantham Collection, Driffield
6	Flamborough, ER, Beacon Hill, TA 224 693	Lower occupation layer with Towthorpe style and Ebbsfleet style pottery; fragment of a Group VI axe. Upper occupation level with Bell and AOC Beakers; two fragments of Group VI axes (Y123 124), two fragments of siltstone axes (Y337 341) and pieces of five flaked flint axes (Moore 1964, 196, 202), Scarborough Museum
7	Flamborough, ER, Beacon Hill East, TA 226 693	Flaking site with Towthorpe and Ebbsfleet style pottery; a broken flaked flint axe (Manby 1975, 47, Fig 17, 19), Grantham Collection, Driffield
8	Millington, ER, Ousethorpe, SE 813 512	Plain Neolithic pottery; fragment of a Group VII axe (Y342). Unpublished excavation by J W Varley. Hull Museum
9	North Deighton, WR, Green Howe, SE 388 512	Occupation debris, incorporated in an Early Bronze Age barrow, including pottery in Peterborough Ware, Grooved Ware, and Beaker styles; fragments of axes of Group VI (Y4,5), Group VII (Y6) and hornblende granophyre (Y3) (Wood 1971, 13–16. Fig 9, 1–5), Harrogate Museum

10	Rudston, ER, Barrow 62, TA 098 658	Occupation debris incorporated in the mound of a round barrow; fragment of an edge ground flint axe with Towthorpe style pottery (Pacitto 1972, 15, Fig 8, 19), Grantham Collection, Driffield
11	Rudston, ER, Corner Field, TA 098 658	Rudston style Peterborough Ware; three fragments of Group VI (Manby 1975, 34) Grantham Collection, Driffield
12	Rudston, ER, West Reservoir Field, TA 108 662	Rudston style Peterborough Ware; four flakes of Group VI and a butt of an edge ground axe or chisel of Group VI (Manby 1975, 37, Fig 10, 11–12), Grantham Collection, Driffield
13	Rudston, ER, 2nd Field West Reservoir, TA 104 662	Pottery of Peterborough Ware, Grooved Ware, and Beaker type; flake of a Group VI axe (Manby 1975, 39), Grantham Collection, Driffield
14	Rudston, ER, East Reservoir Site 2, TA 111 663	AOC and Bell Beaker; two fragments of Group VI axes and a butt fragment of spotted slate utilized as a hammerstone, Grantham Collection, Driffield
15	Rudston, ER, East Reservoir Site 5, TA 111 662	Woodlands style Grooved Ware; six flakes of Group VI (Manby 1974, 22), Grantham Collection, Driffield
16	Rudston, ER, East Reservoir Site 8, TA 112 664	Rudston style Peterborough Ware; reflaked flint axe retaining older ground cutting edge (Fig 2,6) (Manby 1975, 39–40, Fig. 12,4), Grantham Collection, Driffeld
17	Seamer Moor, NR, East Ayton parish, TA 000 864	Hollow adjoining a Neolithic round barrow; occupation debris with Grooved Ware, stone axe fragment (*Archaeol Newsletter,* 7, 1963, 213–4), Leicester University Dept of Archaeology
18	Willerby, ER, Binnington Barrow 31, TA 00 76 area	Occupation debris on the old surface beneath a round barrow, Grimston style pottery; broken axe, Class 2a, Group VI-macroscopic (Greenwell, 1877, 179) British Museum

Appendix B
Flint and stone axes accompanying burials in Yorkshire

1	Brandesburton, ER, Brandesburton Barff	Stone axe of Class B2c, according to attached label 'Found with an interment . . . 1894', Sewerby Hall Museum, Bridlington
2	Bridlington, ER, Bessingby, TA 166 676	Marginally ground flint axe, Class D3c, with a skull burial in a stone lined pit (Earnshaw 1973, 22–24, 38, Fig 12, No 63), Sewerby Hall Museum, Bridlington
3	Burythorpe, ER, Whitegrounds, SE 782 682	Round barrow; crouched inhumation in a central intrusive grave accompanied by a Seamer-type flint axe and a jet slider (*Archaeol Excav,* 1968 [HMSO 1969], 14), in possession of the excavator T C M Brewster
4	Duggleby, ER, (Kirby Grindalythe) Duggleby Howe. SE 880 669	Round barrow; Burial G, a crouched inhumation with a Duggleby-type flint adze, antler mace head and a lozenge-shaped flint arrowhead (Mortimer 1905, 28, Fig 56), Hull Museum
5	Garton, ER, Carton Slack Barrow C63, SE 958 588	Round barrow; crouched inhumation with small flint axe of Class B3 (Fig 4, 5) N3(L) Beaker, flint knife and flakes, bone pin (Mortimer 1905, 214–5, Fig 541), Hull Museum
6	Ingleborough, WR. (Horton in Ribblesdale), SD 785 740	Crouched inhumation in a grike (fissure) with a Cumbrian-type axe, T Lord Collection, Settle
7	Pickering, NR, '7 miles east of' SE 88 84 area?	Round barrow; inhumation beneath a large stone accompanied by an axe of Class C4a, epidiorite (Y291), and a flint knife (Bateman 1861, 221–222), Sheffield City Museum
8	Seamer Moor, NR, (East Ayton parish) TA 000 864	Long barrow; intrusive deposit beneath a flat stone, human and animal bones, an assemblage of flint tools including edge-ground flint axes and adze of Seamer and Duggleby type and a chisel (Smith 1921, 121–2, Fig 4), British Museum
9	Seamer Moor, NR, TA 00 86 area	Barrow; a cremation accompanied by a stone axe of Class B2b, butt faceted (Evans 1897, 96), British Museum, Sturge Collection
10	Seamer Moor, NR, TA 00 86 area	Barrow; a cremation accompanied by a reworked stone axe (Evans 1897, 96), British Museum, Sturge Collection

Appendix C
Hoards of flint and stone axes from Yorkshire

1	Beverley, ER, 'Near'	Three axes found together (no further details); reworked flint with ground edges (Sheppard 1930), Hull Museum

2	Cottingham, ER, Cottingham Common, TA 05 34	Three axes found together in a gravel pit; one Class B3c and two Class B2a, Group VI (Y 141, Y253) (Sheppard 1926), Hull Museum
3	Long Preston, WR, Bookilber, SD 85 59	A hoard of six axes exposed by stream erosion, one large Class B2b axe of greenish rock and one Class C4a, also four Class B3b axes, probably Group IX-macroscopic, T Lord Collection, Settle
4	Seamer Moor, NR, (East Ayton parish) TA 000 864	(See Appendix B, no 9) Hoard of flint axes, adze, and chisel, intrusive burial or votive deposit in a long barrow (Smith 1921, 121–2), British Museum
5	York, Holgate, SE 583 514	A hoard of flint implements discovered in 1868; one stone adze Class B7c and edge ground flint axes of Classes D2c, D2c and Seamer type (Fig 1,6; 2, 3–5). (Monkman 1870; Radley 1968), Yorkshire Museum, York (and lost)
6	Wakefield, WR, Stanley SE 34 22	Two flint axes and a dagger of Scandinavian-North German type in a 19th-century collection are very doubtful as a local find (Smith 1932), Wakefield City Museum

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Stone axes from the East Midlands

C N Moore

Abstract

The distribution and typology of stone axes in the East Midlands are considered. In particular, attention is paid to the way collections have been built up and the ways in which distribution patterns may be affected by local circumstances. Our knowledge of axe distribution in relation to settlement sites is discussed, and the correlation of the distribution of axes with recognized geographical regions. The typological similarities between certain flint and stone axes are noted, and an attempt is made to classify the main types of flint axes which occur in the East Midlands.

In two previous papers the writer and Cummins have surveyed the implement petrology of the East Midlands (Cummins & Moore 1973; Moore & Cummins 1974). These covered the old (pre-local government reform) counties of Lincolnshire, Nottinghamshire, Rutland, Leicestershire, and Derbyshire. At the time the writers concentrated mainly on the petrological identification of implements from the area. Here it is proposed to discuss in greater detail the distribution and density of finds of axes, their typology, and, more particularly, the relationship of stone axes to flint axes.

Tables I and II give some idea of the frequency with which stone and flint axes are found, the proportion of stone axes which have been sectioned, and the relative importance of the various petrological groups. Almost two-thirds of the known stone axes have now been sectioned and a high proportion of these have been grouped. The high density of axes in Derbyshire should be noticed; most of these are concentrated in the Peak District. In contrast, flint axes are rare in Derbyshire, whereas slightly more than a quarter of the Lincolnshire axe finds are of flint. For the East Midlands overall, Group VI (Great Langdale) axes are by far the most common grouped axes, followed a long way behind by Group VII (Graig Lwyd), Group I (Cornwall), and Group XX (Charnwood Forest).

Before discussing the archaeological implications of the distribution of axes, it seems worth isolating those factors which may distort distribution maps. Foremost amongst these are the existence of collectors and the position of active museums. The most outstanding of all East Midland collectors was Thomas Bateman, whose collection of some 60 axes and many other important finds from the Peak District is now in Sheffield Museum (Howarth 1899, 12–25). Bateman was collecting mainly between 1830 and 1860, a time when much of the pastureland in the Peak District was being improved, stones were being removed, and it was being ploughed and reseeded. This afforded Bateman an excellent opportunity for collecting archaeological material, but it may have tended to give the Peak District undue prominence. However, there is little doubt that axes are prolific in this area. In the case of museums, finds made in the immediate vicinity are more likely to be reported than those from further away. In Lincolnshire, Scunthorpe Museum (Dudley 1949) and the City and County Museum, Lincoln, have a long history of active collecting, but they have mainly covered central and northern Lincolnshire, and there is a strong suspicion that areas such as the Lincolnshire Wolds and the uplands of South Kesteven are under-represented. This is certainly true for northern Nottinghamshire, which lacks any old-established museum. Distortion caused by field walking should also be taken into account. In Lincolnshire, field walking by amateur archaeologists at Newton-on-Trent (B Minnett, personal communication), Barrowby, near Grantham (Grantham Museum), and Thoresway in the Wolds (D Everatt, axes now with H Mossop) have produced many additional stone axes and axe fragments, while in Derbyshire the Heathcotes of Birchover and others in the Elton (Radley & Cooper 1968) and Taddington (Radley & Plant 1967) areas have recovered similar concentrations. This does tend to create a false impression when shown on a distribution map of finds without any immediate explanation.

Human activity must also greatly affect the chance of discovery. In Leicestershire and Rutland the fact that a fair proportion of the land is still under pasture seems to have greatly restricted the number of finds, but in the vicinity of Leicester and Loughborough rather more finds have been made as a result of building activity. A similar concentration in the Scunthorpe area must be partly explained by increased activity mainly connected with ironstone mining. In most of Lincolnshire there has been a rapid increase in intensive arable agriculture since World War II, and this is likely to account for the great increase in the finds of axes that have been made in recent years. Again, quarrying in the vicinity of Buxton has produced a disproportionate number of axes from that area (Imperial Chemical Industries collection in Buxton Museum).

Turning to the evidence of axes for indicating Neolithic activity and settlement patterns, it does appear that there are certain genuine lacunae in the distribution of axes which can be equated with recognized geological and geographical areas. First, the marshland zone running along the eastern coast of Lincolnshire has not produced any axes, tending to confirm that this has been formed since prehistoric times. Likewise, apart from a number of axes found on slightly higher land just to the north of Boston and at Crowland, there are no axe finds from the Fens. It seems likely that the Fens were inundated by

Table I Relative numbers of stone and flint axes and shafthole implements

	Number of stone axes	Flint axes	% flint axes of total number	Number of shaft hole implements	Sectioned implements
Lincolnshire	396	138	25.84	129	343
Leicestershire (including Rutland)	80	13	13.98	29	50
Nottinghamshire	96	29	23.2	32	75
Derbyshire	*c* 295	17	5.45	86	206

Table II Density of axes by county

	Area of county in sq miles	Total number of stone and flint axes	Number of axes per sq mile
Lincolnshire	2665	534	0.20
Leicestershire (including Rutland)	984	93	0.09
Nottinghamshire	844	125	0.15
Derbyshire	1041	312	0.30

the sea during the middle Neolithic period, and this would explain the lack of axes. Those finds that have been made suggest that there was a number of inhabited islands. Again, the belt of Bunter sandstone, which runs to the west of the River Trent in Nottinghamshire, is singularly lacking in axes. There are few springs in this area and so it would have been very unattractive in the Neolithic period; until fairly recently much of it was covered by Sherwood Forest, and presumably it would have been heavily forested in Neolithic times. A further area which seems to have been unattractive, if stone axes are taken as an indication of early settlement, is that of the Coal Measures around Chesterfield in Derbyshire.

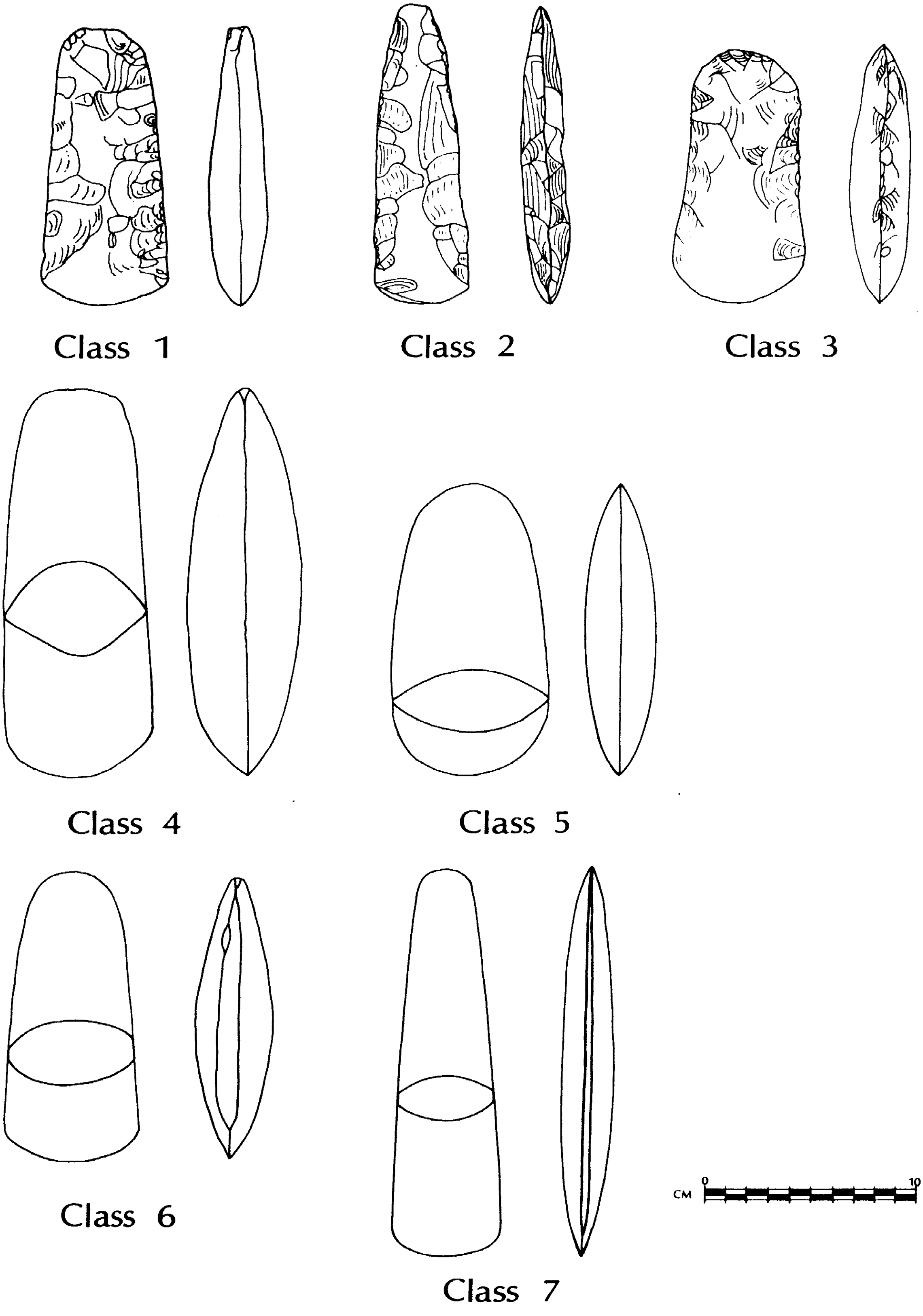
In some instances the distribution patterns of grouped axes may give some insight into their chronology. In Lincolnshire it has been noted that, even though their distribution is similar elsewhere in the county, Group VII axes are not found in the Wolds, whereas Group VI axes are. Presumably these two axe groups were not completely contemporary in their use, and it may be that the Lincolnshire Wolds were opened up later in the Neolithic period, when Group VI products were predominant.

A noticeable feature of axe distribution in Lincolnshire is the clustering of axes and perforated implements along the edge of the Fens, especially along the line of the Roman Car Dyke and at the southern end of the Wolds. It will need much further research to explain this feature, but it may be that it is connected with settlement sites around the edge of the flooded Fens. A parallel may be drawn with a similar phenomenon along the eastern edge of the Fens of Norfolk and Cambridgeshire (Clough & Green 1972). Also great concentrations of axes, as well as many other prehistoric finds, have turned up in the area of Tattershall Bridge, a historic fording site. Other fording sites may be indicated by small concentrations of axes at Heighington and Fiskerton at the east end of the gap cut through the ridge by the River Witham at Lincoln, and above and below Nottingham on the River Trent.

The lack of settlement sites is still a tantalizing feature of the Neolithic in the East Midlands. Further study of the coincidence of the distribution of stone axes with that of flintwork and possibly pottery could lead to important discoveries. A number of stone axes have been found at Mister-ton Carr in north Nottinghamshire, but unfortunately a trial excavation (Buckland & Dolby 1973), though producing a Neolithic flint industry, did not reveal the settlement which is likely to be in the vicinity. Newton-on-Trent, where numerous axe flakes have turned up on a number of sites, in association with a Neolithic flint industry and some pottery (not seen by the writer), also seems a most promising site.

It is difficult to assess trade patterns in Neolithic axes, and many earlier discussions appear to be little more than speculation. One useful indicator of trade is the presence or absence of rough-outs. Manby (1965) has demonstrated that Group VI rough-outs travelled as far as the Vale of York. The fact that Langdale products show considerable standardization seems to indicate that these axes were normally traded in a finished state. One Group VII rough-out is known in the East Midlands, from Holme Pierrepont, near Nottingham. Very often Group VII axes are very much less finished in appearance, suggesting that they were being transported to the East Midlands in a rough-out state and being finished locally.

while it is dangerous to generalize about the typological relationships between axes with specific petrological groupings, it is becoming increasingly easy to relate particular shapes or features to a particular group. The standardization of Group VI (Great Langdale) axes has been remarked on and Manby (1965; this volume) has distinguished a main type with faceted edges and two variant types, which are either rounded or come to a point at the edge. It is curious that finds of Group VI axes in Lincolnshire almost exclusively have faceted edges, while in Derbyshire the variant types are much more common. The so-called ‘Cumbrian’



1 Main types of blade polished and all-over-polished flint axes from the East Midlands axes with faceted sides are well represented in the East Midlands, for example by those from Netherfield (Nottinghamshire) and Woodhall Spa (Lincolnshire). It should not be overlooked that a proportion of Group VI axes started as large 'Cumbrian' axes but have been either broken and re-fashioned or gradually ground down into smaller axes. The Group VI axe from Kirton Lindsey, Lincolnshire, which has a flattened profile and a pointed butt, imitating a jade axe, is an interesting deviant and apparently unique (Cummins & Moore 1973, Fig 5, No 25).

The lack of good specimens of axes from well-dated archaeological contexts in the East Midlands, or for that matter elsewhere, does not help with typological dating of axes. One feature that does appear to be fairly late in the Neolithic is the pointed butt. This occurs particularly on axes coming from the south-west and Pembrokeshire. Of most interest in the East Midlands is the occurrence of a number of axes of 'Bridlington' type (Manby, this volume). These are small with an oval cross-section. Five examples come from Lincolnshire and two from Derbyshire. All are of Group I origin, except for one from North Kelsey which is similar to Group XVIII (Whin Sill).

Axes of Group XX (Charnwood Forest), the only ones produced within the area of this study, call for special comment. Group XX axes vary from those that are well finished and polished to those which are rather crude. They have often been finished by a pecking process, and in one case (Holton-le-Moor, Lincolnshire) the whole of the upper part has been pecked after polishing, possibly to give greater stability to the hafting. Two distinctive shapes call for comment. First, a Group XX adze with a rectangular cross-section from Horncastle, Lincolnshire, must surely have parallels in the late Neolithic in north-west Europe (Cummins & Moore 1973, 238, Fig 12). A similar Group XX adze comes from Caister-by-Yarmouth (Clough & Green 1972, Fig 12). Secondly, there is a rather bulbous form of axe with an elliptical cross-section, which can be paralleled by flint axes of Class 6 mentioned below.

Turning now to flint axes, the East Midlands is of interest because it must have been an area where flint and stone axes were in competition, and the surviving axes would suggest that stone axes were more favoured.

Flint axes appear to have been either imported from East Anglia or produced from local glacial deposits. Axes manufactured from the latter source have a typical reddish-brown iron staining and are in the majority. There is no evidence that flint from the Lincolnshire source was ever mined for axe production, and it has been suggested that the natural Lincolnshire flint is too brittle for this purpose. There are various rough-outs for flint axes from Lincolnshire, and these often seem to be mistaken for Mesolithic tranchet axes. A mined flint rough-out from Edenham in South Lincolnshire (Lincoln Museum) is similar to some of those from Grimes Graves, Norfolk, while a block rough-out from Tetford (Lincoln Museum) bears considerable resemblance to a Grand Pressigny core. A map showing the distribution of finished flint axes in Lincolnshire has recently been published by May (1976).

There has been little attempt in the past to classify flint axes, probably because the vast numbers surviving in Wessex and East Anglia give the impression that there are numerous variant forms. However, when considering flint axes from the East Midlands, it soon became apparent that when rough-outs and re-fashioned tools are excluded, the flint axes from the area can be divided into seven main classes (Fig 1). This classification is purely regional and does not readily apply, for example, to East Anglia, showing that there must be quite distinct local styles of flint axe in other areas. The basis of the classification is the separation of those axes which are flaked all over and blade-polished from those which have been polished or partly polished over the whole of the surface of the axe.

2 Flint axe of class 7 from Helpringham, Lincolnshire

Blade-polished axes

class 1 Small well-flaked axes, trapezoid in shape, normally made from brownish glacial flint. This type often appears in the low-lying river valleys of central Lincolnshire and is often found in peaty deposits. Lincolnshire examples come from Tattershall Thorpe

(Tattershall Castle Museum), and Goltho (private possession); one of the axes from Liff's Low, Derbyshire (Sheffield Museum) is also of this type.

Class 2 Basically the same as Class 1, but with thin pointed butt and long slender form, often quite elegant. The only Lincolnshire example is from Fenton (Lincoln Museum); there is a good example from Middleton Boulevard, Nottingham (Nottingham University Museum), and the type specimen *par excellence* is from Liff's Low, Derbyshire (Sheffield Museum).

Class 3 Axes with expanding blades, This so-called 'Seamer' type has been described by Manby (1974, 95, Fig 40 and Appendix 8; this volume). Two varieties may possibly be distinguished — those which have a rounded crescentic blade (true 'Seamer') and those which have a curved blade meeting the body at an angle. There are three of the latter from Lincolnshire and four from Leicestershire. Nationally, axes with expanding blades have a widespread distribution, occurring in Wessex (Burchard 1973) and East Anglia; though the true 'Seamer' type appears to he restricted to Yorkshire and Lincolnshire.

Axes polished all over

Class 4 Axes with crescentic blade and fat elliptical shape. These tend to occur in large and small sizes, and are normally made of glacial flint. They are also known in Norfolk, eg an axe from Feltwell (Clarke 1960, 52, Fig 11), which is very similar to some of the Group XX stone axes, such as one from West Rasen, Lincolnshire (Cummins & Moore, 1973, Li 101).

Class 5 Very thin, broad axes with crescentic blades, normally of glacial flint and coming mainly from the Trent Valley. Examples come from Barlings (private possession and Barkston (Grantham Museum) in Lincolnshire, and Harby, Nottinghamshire (British Museum).

Class 6 Axes with faceted sides. These show a considerable range of variation and are by far the most common form of flint axe in the East Midlands. They are virtually identical in type to Group VI axes with faceted sides. It is possible that stone axes were imitating the flint axes which are sharper. This type of axe is normally made from mined flint, and some of the Lincolnshire examples may be East Anglian in origin.

Class 7 These are exceptional axes and may be ceremonial rather than functional Basically they have the same form as the Class 6 axes, but are very finely finished and are more than 230mm in length. They are made from a curiously mottled fossiliferous flint (or possibly chert); a very fine axe from Helpringham Fen, Lincolnshire, has been shaped so that a fossil belemnite shows on both faces of the axe (Moore 1972, 6). Otherwise these, while rare, are scattered over much of England and Scotland. Examples come from East Rudham, Norfolk (Norwich Castle Museum); Crudwell, Wiltshire (Annable & Simpson 1964, No 15); Gilmerton, East Lothian, and Kirkauchline, Wigtonshire (National Museum of Antiquities, Edinburgh). There must be more examples, and they warrant a special study.

This survey has briefly covered the great wealth of finds of stone and flint axes in the East Midlands. While considerable strides have been made in the past few years to identify the rock sources of the axes, there is still much further work to be undertaken on distribution and typology. Likewise the results of petrological studies can only now begin to he fitted into the overall patterns which are beginning to emerge from the whole of the United Kingdom.

Acknowledgements

I must thank Mrs F E S Roe for kindly allowing me to use her totals of perforated implements for the East Midlands, and Mr T G Manby for assistance with comparative material. I have been helped in many respects by Dr W A Cummins and Mr T H McK Clough. Mr P Alebon of the Grosvenor Museum, Chester, kindly drew the diagram to show flint axe types.

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The Langdale and Scafell Pike axe factory sites: a field survey

C H Houlder

Abstract

A long history of discovery of axe flaking sites on Scafell Pike led to field survey in 1961, followed by comparison of thin-sections and published geological mapping. It is shown that petrological Group VI and its variants were being exploited at many points around the outcrop of a syncline extending from Scafell Pike at least as far as Great Langdale to the east. An incongruity in the geological mapping is finally combined with archaeological evidence from behind the Langdale Pikes to argue that Group VI sources are to be found at widely separated depositional levels in the Borrowdale Volcanic Series.

One of the commendable aspects of stone implement petrology is the clinical objectivity that is applied to the main task of defining petrological groups. Yet it is a welcome feature of this symposium that there is an opportunity to indulge in the construction of a broader, humanistic picture by the pursuit of various other lines of study. Some of these are purely archaeological, and follow directly from the petrological results. Others involve ethnographic comparison, in the technical aspects of tool typology and in the sociological and economic aspects of trade and tool usage. This paper differs from other contributions in that it goes no further than to place on record an observational study of the sources of one rock type already defined by petrologists. For archaeology this involved the identification and accurate mapping of flaking sites; for geologists and petrologists it poses more problems than it helps to solve, through an attempt to reconcile the mapping of two field geologists.

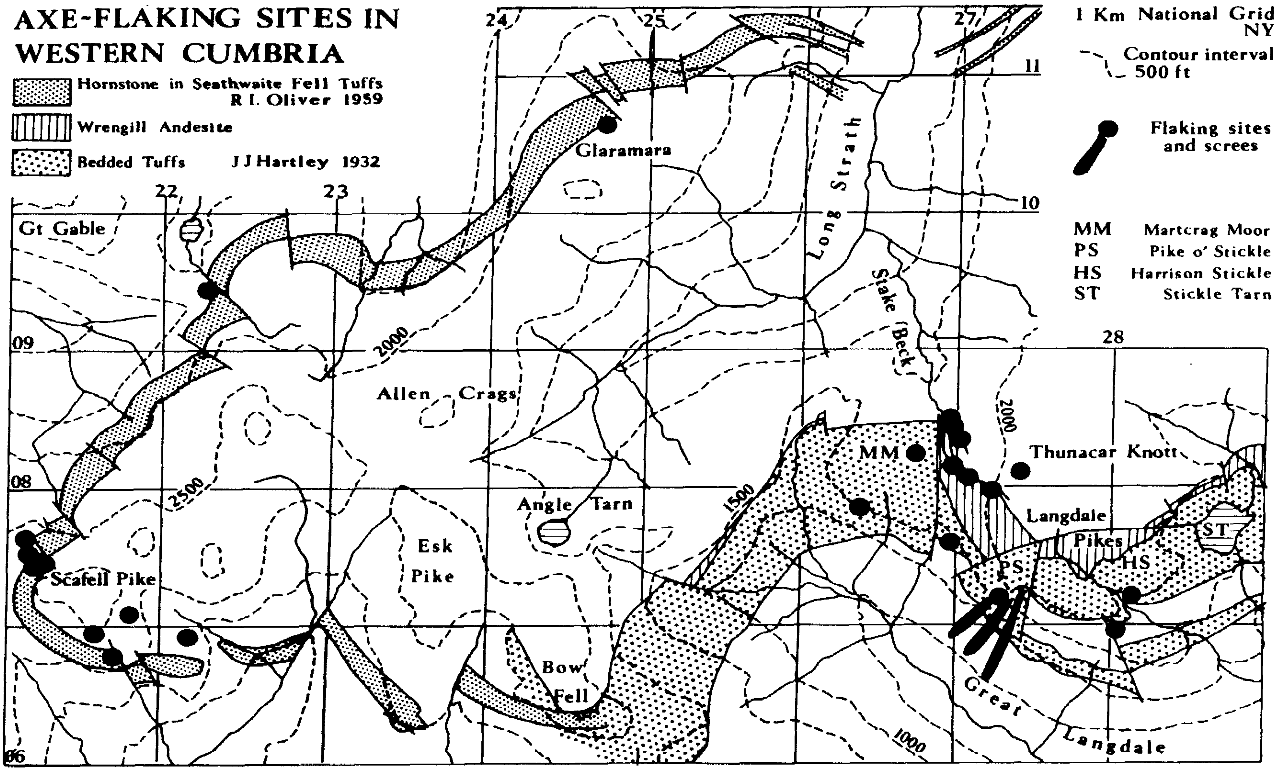
Group VI as a stone implement rock type was originally defined by Wallis (Keiller *et al* 1941, 58–60) as ‘an epidotised tuff of intermediate or basic composition’, supposedly originating from a factory site at Stake Pass that had been found by Watson. The original site has never been located precisely, but this ceased to matter when the greater extent of axe making activity in the area was recognized and published by Bunch and Fell (1949), and the name of Great Langdale was adopted for Group VI. A further change of name could perhaps now be justified, since discoveries around Scafell Pike, 6km west of the Langdale Pikes, show that rock of the same petrological type was being exploited there, derived from geological formations of the same series.

The arousal of interest in Scafell Pike as a focus of axe manufacture is mainly due to Plint. His account of early discoveries (1962) need not be repeated, though a specimen in Keswick Museum dated 1874 may be added as the first discovery. Of several flakes submitted to Dr Wallis, two from this mountain were described as ‘practically indistinguishable from Group VI’ (Evens *et al* 1962, Nos 907, 908). Others only qualified as ‘tuff, near Group VI’ (eg Nos 1112–14), while some were not acceptable even in those terms. The situation deserved investigation in the field, and the writer was invited by Miss Clare Fell, on behalf of the Cumberland and Westmorland Antiquarian and Archaeological Society, and with the sanction of the National Trust, to map accurately all known flaking sites in relation to the geological formations, taking in the wider area that includes the Great Langdale outcrop of Group VI. The essential geological mapping had been recently done by Oliver (1961, published at 4in to the mile) for an area representing the northern and part of the southern limb of the syncline that has Scafell Pike at its western angle. For the remainder of the southern limb between Bow Fell and Harrison Stickle the work of Hartley (1932) was the only readily available study, couched in broad terms and published at an inconveniently small scale.

Shortly before the main survey Season of July 1961 Mr W Fletcher of Seascale, with a party of boys from Pelham House School, had revealed an extensive spread of axe-making waste at about 3000 ft on the western side of Scafell Pike. The boulder scree on the easy slope of the summit is fairly static, and this flaking debris apparently lay where it had fallen between the stones in prehistoric times. By contrast with the continuously moving screes of the Langdale Pikes, most of the flaking sites in this area were comparatively undisturbed. One site on a rock shelf was overlain by blanket peat, and in another place a rough-out was found on an almost inaccessible ledge, covered with inches of moss, where it may well have been placed by human hand in antiquity. The position of the archaeological material in relation to rock sources was thus likely to be fairly close.

The survey methods employed were the best possible without having to resort to traverses over long distances. Precisely identifiable points are rare on Ordnance Survey maps in high mountain areas, however accurate the survey. When visibility permitted, sights had to be taken on distant triangulation pillars, with steep-angle checks on such features as wall junctions in the surrounding valleys. A lightweight theodolite ensured reasonable accuracy for the setting up of sighting marks around the cap of the Pike, from which site details could be taken by magnetic compass bearings and direct measurement. Results were plotted at 1:2500 for the Pike itself, but directly onto the 6in map elsewhere.

Specimens were collected at all identified flaking sites, as well as from the rock formations of Oliver’s



2 *Axe flaking sites in the Langdale and Scafell Pike area of western Cumbria*

mapping. Useful advice was given on site by Mr J Konig, and particularly by Dr W J Phillips, who also confirmed the occurrence of flaked material indistinguishable from Group VI. The latter came from locations on or below the band of hornstone which Oliver had distinguished as a component of his Seathwaite Fell Tuffs (see map), and which equates in thin section with Group VI. The coarser parts of these tuffs contain finer-grained bands suitable for flaking, but none of the specimens from above the hornstone is close enough petrographically to merit inclusion in Group VI.

The course of the hornstone along the northern limb of the syncline has been searched thoroughly, both during the 1961 season and subsequently by mountain walkers furnished with the geological map, but sites there have proved to be rare. Though fine enough in grain and having a suitable conchoidal fracture, the hornstone is extensively fissured into too small a basic unit for axe making. The southern limb of the syncline has not been so well searched, and may yet yield more sites, which would be of greatest significance in the Bow Fell area, as will be seen.

Turning to the Great Langdale area, the known sites have been plotted in the same way, with particular attention paid to the course of the axe rock round the head of the valley to the west of the Pikes. Exposures of the rock are infrequent on these gentler and soil covered slopes, so that it cannot be followed with certainty towards Bow Fell. It is clear from Hartley's mapping that the main screes and the central buttress of Pike of Stickle, the most productive source of Group VI axes, lie well within the strata to which he referred when his opinion was sought by Wallis in the first definition of the material (Keiller *et al* 1941, 58). He suggested 'that the rock is identical with the epidotised tuffs which occur as a band about 800 feet thick extending from just south of the summit of Bow Fell to the eastern end of the Langdale Pikes. These tuffs belong to the upper portion of the Bedded Tuff division of the Borrowdale volcanic series. It is only however near the rhyolite that they exhibit as much epidotization as shown in the axes.' Hartley also suggested Bow Fell as a likely source of Group Vi, and there is some initial satisfaction in noting a coincidence there with Oliver's hornstone, in spite of variance in the orientation of the mapped margins of the formations. There is, however, an outstanding complication to the overall picture.

Overlying his bedded tuffs Hartley identified intermittent occurrences of Wrengill Andesite, which in turn are overlain by 'felsitic and basic tuffs'. Oliver recognized Wrengill Andesite at the extreme north east of his mapping (about 2km beyond the limit of the map reproduced here), but it is *inferior* to the Seathwaite Fell tuffs which contain the hornstone of Scafell Pike. Various possibilities suggest themselves in explanation of this incongruity. Dismissing the idea of gross mapping errors, it may be that there is room for disagreement on the identification of Wrengill Andesite, but closer consideration of the locations of flaking sites behind the Langdale Pikes suggests a happier conclusion, though it is one requiring confirmation by geological field work beyond the scope of the present writer.

When publishing the definitive description of the Langdale axe factories Bunch and Fell (1949, 3) referred to additional flaking sites which came to light near the source of Stake Beck in the course of searching for the Stake Pass site of Watson. It should be noted that Bunch and Fell's map wrongly applies the name Stake Beck to what is named Stake Gill on the OS map. Stake Beck has its source at approx NY 273 079, and it is to the several sites along this stream and in the vicinity that attention has recently been drawn in the publication of an excavation by Clough (1973). Important dating and botanical evidence was obtained at the site examined (Clough's Site 5, otherwise referred to as Thunacar Knott), but it is the position of the whole group of sites that provides at least an opening for a solution to the problem posed above.

Eight flaking sites shown on the map are on or near Stake Beck, which here follows the lower margin of Hartley's Felsitic and Basic Tuffs. Other sites and individual finds could be added in this region, which presents an irregular surface of glacial outwash formations and peat-filled hollows, dominated from the east by the steep slope of Thunacar Knott. Clough notes the absence of immediately visible outcropping rock in the vicinity, but dismisses the idea that blocks of raw material might have been brought from sources on the Langdale Pikes. If, as seems possible, the raw material was derived, perhaps as glacial detritus, from some formation above these sites, then it would follow that Group VI rock should be identifiable, perhaps only as narrow bands, in the series of tuffs that overlies the Wrengill Andesite as well as in the inferior position that it occupies on the Pikes in the bedded tuffs.

It would remain then to reconcile Hartley's and Oliver's mapping at the Bow Fell overlap, and finally to seek acceptance of the fact that petrographically similar axe material is available in this volcanic series both from above and below the Wrengill Andesite. Archaeologically speaking, the map remains open to additions of further flaking sites, and further excavations may be worth considering in suitable situations.

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European Neolithic jade implements: a preliminary mineralogical and typological study

AR Woolley, A C Bishop, R J Harrison, & I A Kinnes

Abstract

The types, distribution, and cultural contexts of jade implements in Europe are briefly discussed. It is shown that axes can be grouped typologically in terms of their length, width, and thickness, and this is demonstrated graphically. The chemical composition of the constituent pyroxenes of fourteen implements, representing the principal typological groups, has been determined and is illustrated graphically. A wide range of compositions is found, and a good correlation exists between pyroxene type and axe typology.

Jade implements are of considerable significance, for although they are relatively rare among the many Neolithic stone tools found in Britain they are undoubtedly imports from continental Europe. Among the first to recognize their potential importance were Piggott and Powell (195 1) who, following their work on the Cairnholy tomb in Kirkcudbrightshire, listed the jade axes then known from British sites. They also persuaded Dr W Campbell Smith to examine not only their own recent find at Cairnholy but other British jade implements as well. The results of these studies are given in three papers by Campbell Smith (1963, 1965, 1972), in which he presented a typology and gave petrographic descriptions of the constituent material based on examination with the polarizing microscope.

Archaeological implications of jade use

Jade implements are found throughout Europe and comprise axes, adzes, and gouges, with a smaller number of rings and pendants. Many of the larger axes are so thin and highly polished that they can be considered as no more utilitarian than the large rings known from northern Italy and Brittany. It is clear that the use of jade frequently transcended simple economic or technological needs.

There is a continuing tendency to link jade axes to Beaker and Early Bronze Age cultures, as an appropriate context for the wide dispersal of rare or prized raw materials. However, chronological evidence is slight; most finds are undatable, and none is of unequivocal Beaker date. On the evidence of association, the earliest jade is linked to the Fiorano or Square-Mouthed Pottery culture of northern Italy, with radiocarbon dates centring on 3500 bc. Both functional and so-called ceremonial forms are known, along with large flat rings. Documented working floors in the Piedmont and Liguria might be associated with this phase. The latest context is exemplified by a Rhone culture grave of the early second millennium bc at Fontaine-les-Puits, Savoy. Within this bracket other examples may be singled out. Large axes and rings occur in several Breton chambered tombs, but none has a stratigraphic context. Functional axes, frequently mounted in antler sleeves, are familiar components of the Alpine lake settlements of Cortaillod, Chassey, Michelsberg, and Lagozza affiliations of the later fourth and third millennia bc. The one secure, datable context for a ceremonial form is that for the axe sealed by the Sweet track in the Somerset Levels, with radiocarbon dates of around 3200 bc (Coles *et al* 1974).

To summarize, therefore, it is possible to document the widespread use of jade for both functional and ceremonial purposes from at least 3500 bc in northern Italy and the Alpine zone. A scatter of functional axes or specialized tools, with some ceremonial forms, occurs throughout central and western Europe and, from the evidence of the Sweet track, this distribution begins in the fourth millennium. The evidence of geology and known factory sites indicates that Alpine and Piedmont sources supplied extensive and long-lived exchange networks. There are major problems; not least being that of reconciling jade axe distribution with known intra-cultural contacts. Equally one might point to the curious fact that jade objects other than tools are known only in the source areas and in Brittany. The Breton rings were therefore either manufactured locally from sizable imported blanks or were acquired as finished objects. In the absence of waste material in Brittany and the lack of rings to document any routes across the intervening area from the Alps, neither argument seems plausible. Nevertheless, at present there is no real alternative.

Campbell Smith showed that most of the British implements are made of a sodic pyroxene, jadeite, and that those fashioned from nephrite (an amphibole in the tremolite-actinolite series) are rather rare. Further, it was clear from the variation found in the refractive index and the specific gravity of the ‘jadeite’* of the various axes that a range in composition was to be expected, such as Foshag (1957) had found for Guatemalan jade.

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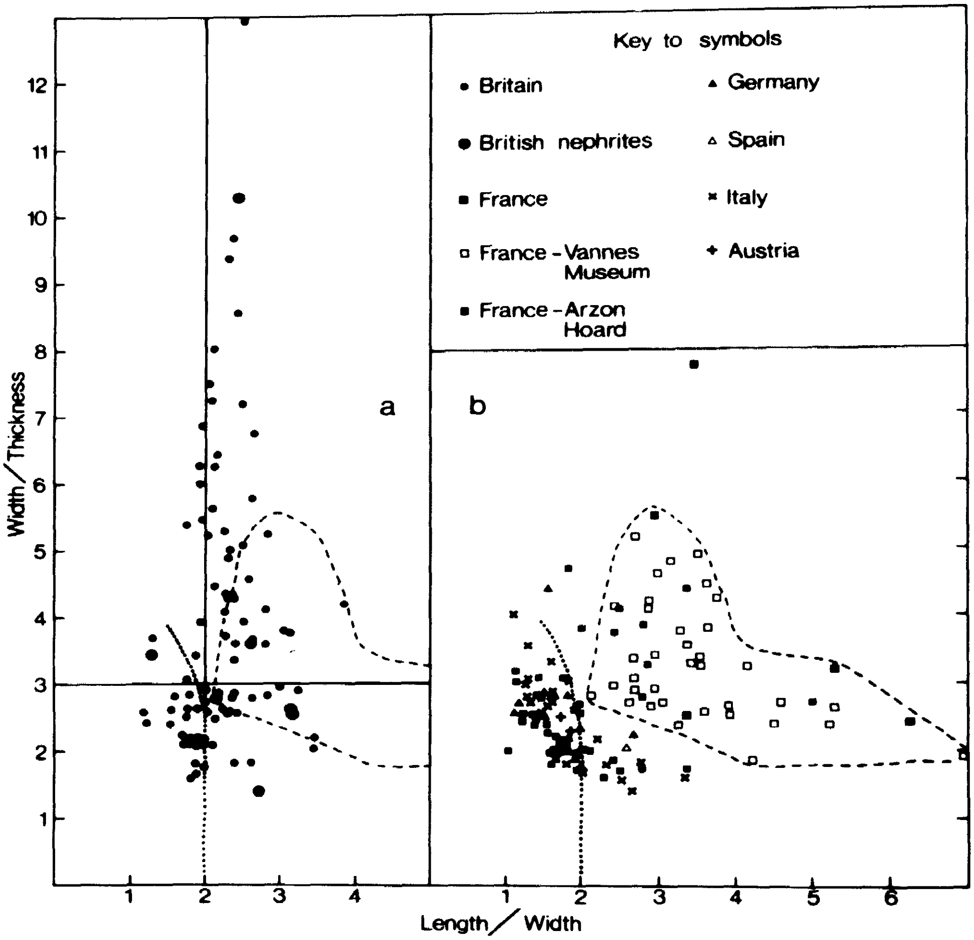
*The findings reported here, that the pyroxenes of some of the implements hitherto called jadeite are in fact chloromelanite, omphacite, and aegirine-jadeite, pose a problem of nomenclature. Such implements are not composed of jadeite in the strict mineralogical sense (although they usually contain 50% or more of the jadeite molecule), and so the correct portmanteau term for them would be sodic pyroxene. However, this term is too broad as there are a number of sodic pyroxenes not represented amongst the artefacts. A further, and we feel important, consideration, is the widespread use of the term jadeite in the archaeological literature. Our preference is, therefore, to use the term ‘jadeite’ in quotes as a useful synonym for pyroxene jade, and to use jadeite without quotes for the mineral in its strict mineralogical sense. The term jade, which has no scientific status, can still be used for all the greenish-coloured axes whether composed of pyroxene or amphibole (nephrite).



1 Plot of width over thickness (W/T) against length over width (L/W). a All British 'jadeite' and nephrite implements; the solid lines at L/W=2 and W/T=3 are the limits used by Campbell Smith in defining groups of implements; hachettes occupy the field to the left of the dotted line; the dashed line is that shown on b. b All European 'jadeite' implements in the British Musem and Ashmolean Museum Collections; hachettes occupy the field to the left of the dotted line; open squares – implements in the Vannes Museum (Marsille 1921; Jauneau 1974); the dashed line encloses the Vannes Museum implements; note that these implements extend to high L/W ratios, in contrast to those from Britain (we are grateful to the editor of Archaeol Atlantica for permission to reproduce this figure)

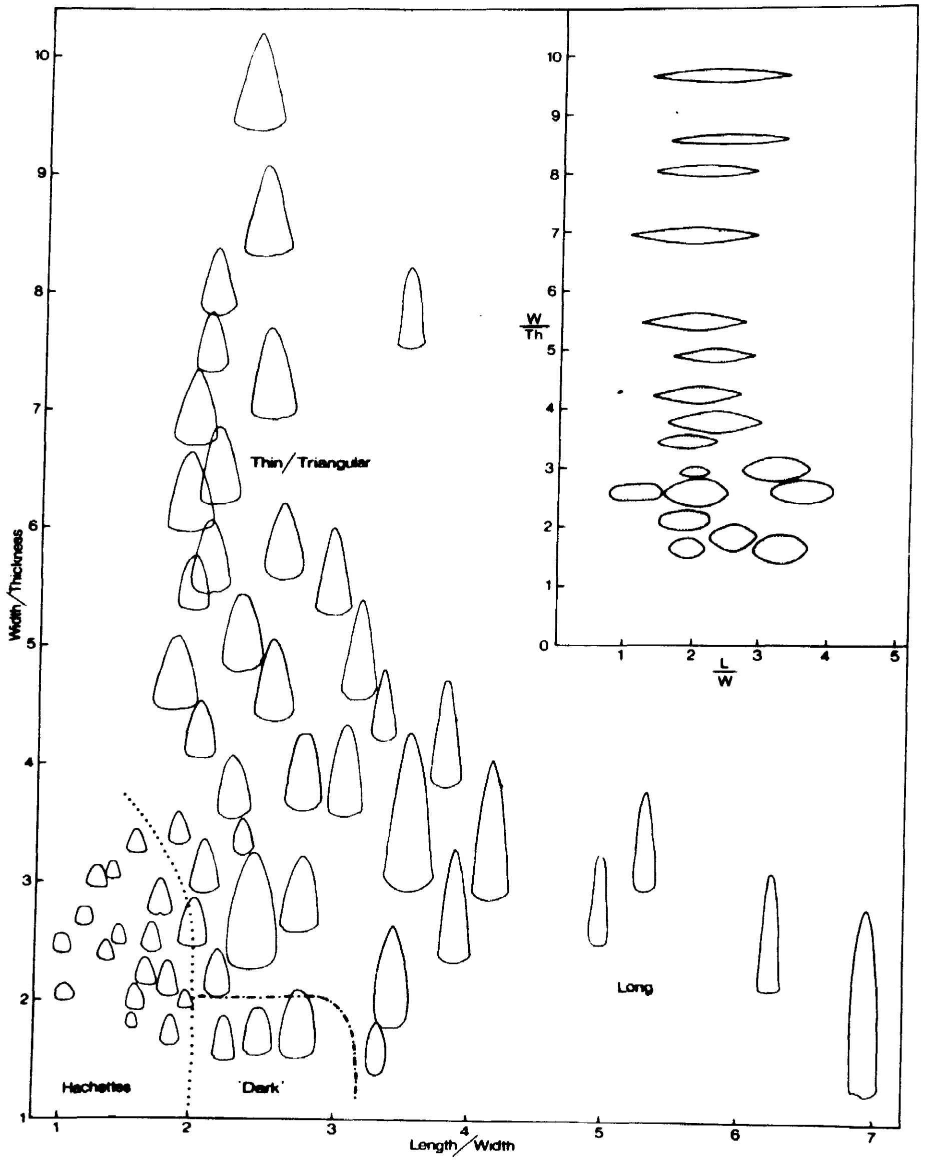
There is a wide colour range within the 'jadeite' implements which is further suggestive of compositional variation; a range from pale green, through shades of darker green, to black. It therefore seemed appropriate to reexamine British and such European axes as are available in British collections, and we are grateful to the many museum authorities and curators who have made their material available to us.

A further spur to this re-examination was the fact that within the last fifteen years two techniques have been developed which were not available at the time Campbell Smith made his reports. One is the development of the thin-wire saw which enables implements to be sampled for petrographic and analytical purposes in such a way as to minimize damage (Bishop & Woolley 1973). The other is the development of the electron probe microanalyzer, which permits chemical analyses to be obtained from minerals in thin sections made for petrographic examination.

We were fortunate in being able to reexamine and, in some instances to sample for the first time, 'jadeite' implements from Britain and Europe and the preliminary results of these investigations are presented here.

Typology

We have discussed the typology of jade axes in detail elsewhere (Bishop *et al* 1977) but an outline of this is given here, in order that the mineralogical work shall be in context. Campbell Smith (1963) grouped 'jadeite' axes, according to the ratios of width to thickness and length to width, into thin, squat, and plump types, which were further subdivided on the basis of other features of their shape. We found that, by using a graphical plot of width/thickness (W/T) against length/width (L/W), it was possible to represent the variation within the axe population (Fig 1, a), and the lines drawn at W/T=3 and L/W=2 on this plot are those chosen by Campbell Smith to define his types. Although these lines define four areas, Campbell Smith grouped together as his thin axes all those with W/T > 3. These divisions were well chosen: W/T=3 divides the implements into two distinct groups and, although the line L/W=2 passes through a cluster of points, it does effectively divide the squat from the plump axes and, moreover, it makes a distinction between the two in terms of size. To the left of L/W=2 all the axes are small.



2 Visual presentation of the outline of implements on the W/T vs L/W plot. Inset: cross-section of implements (half scale of main diagram) to show the variation in the W/T parameter (we are grateful to the editor of Archaeol Atlantica for permission to reproduce this figure)

These are the *'hachettes'* of the French literature.

Fig 1, b shows the distribution in terms of the W/T against L/W plot for the continental European axes available in Britain-mainly in the Ashmolean and British Museums. These are predominantly hachettes, with fewer plump axes. There is a noteworthy absence of thin axes. The boot-shaped area on the diagram outlines a population of axes from Brittany in the Vannes Museum. These axes are torpedo-shaped and the longer types are not represented in Britain.

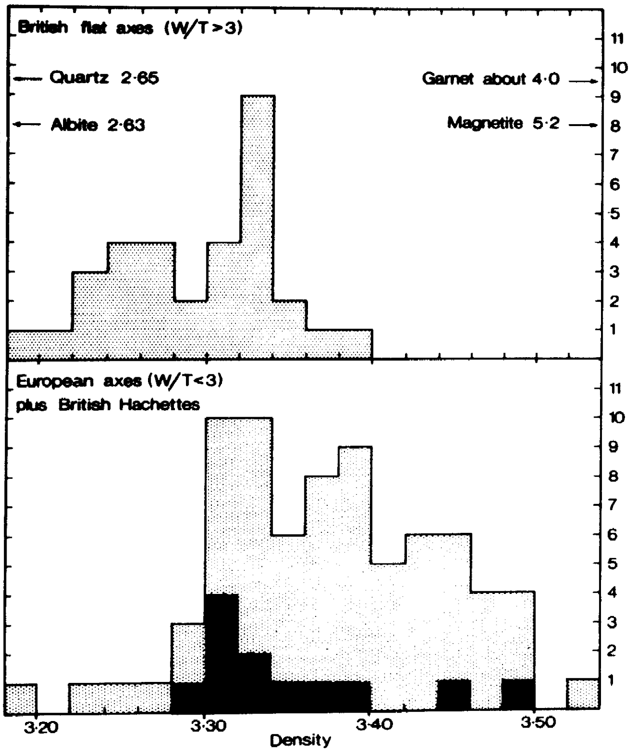
Two points are worthy of further mention. Although the W/T ratio of the thin axes varies considerably, giving a spread parallel to the W/T axis, the L/W ratio varies hardly at all, because the implements all have a similar profile. By contrast the hachettes and plump axes show a slight spread parallel to the L/W axis.

Five types of jade implement can be distinguished and are summarized in Fig 2: (i) thin axes with a triangular outline, characteristically found in Britain; (ii) hachettes; (iii) the distinctive population of torpedo-shaped axes (within the boot-shaped area of Fig 1, b) from Brittany; (iv) a broad range of plump axes within which there is probably an overlapping of populations; and (v) a group of dark axes distinguished mainly by their colour. These groups are not randomly distributed in Britain. Thin axes predominate in the north, hachettes and plump axes in the south. In East Anglia there is a mixed population of jade implements (Bishop *et al* 1977).

The typological work is of value in that it suggests an approach to the problem of the mineral chemistry of the 'jadeite'. The aim has been to sample the various groups in an attempt to determine whether meaningful chemical differences exist between them and, if so, to search for European sources of 'jadeite' in the hope of finding possible matches.

Specific gravity

Campbell Smith (1963) has described the application of specific gravity as a rapid and convenient method of distinguishing not only between nephrite and 'jadeite' but also between varieties of 'jadeite', in particular between iron-poor types and the iron-rich chloromelanites. It is a simple matter to determine the specific gravity of an implement but it must be appreciated that this is the specific gravity of the rock as a whole and is likely to depart from that of the dominant mineral if other minerals are present. Fig 3 depicts the specific gravities of (a) British thin axes, with W/T > 3 and (b) European axes with W/T < 3. British hachettes are separately shown within the latter group. It is evident that although there is a considerable spread of data and the two groups overlap, the medians of each population are distinct, showing that the thin axes, as a group, have lower specific gravities than the plump and squat implements. This suggests, if the effects of other minerals are ignored, that the specific gravity of the constituent pyroxene is different in the two groups.



3 Specific gravities of 'jadeite' implements. The upper part of the diagram is for British 'thin 'axes (W/T>3), and the lower for European axes with W/T<3 together with British 'hachettes', which are distinguished by the darker shading. It is apparent that the thin axes have a lower median specific gravity than the others

Mineralogy

Chemical analyses of the pyroxenes of fourteen implements have so far been made, using the electron microprobe, and some of these are presented in Table 1. Between three and eight analyses were obtained for each implement, and averages of these results are given in the Table. However, all the individual analyses are plotted on Fig 4. The pyroxenes, like most silicate minerals, do not have unique chemical compositions, but have a widely varying chemistry. The sodic pyroxenes, which include jadeite, can be considered conveniently in terms of three end members, and individual pyroxenes corresponding to all possible combinations of these. The three end members and their chemical compositions are jadeite ($NaAlSi_2O_6$), acmite ($NaFe^{3+}Si_2O_6$), and augite ($(Mg,Fe^{2+},Al)_2(Si,Al)_2O_6$).

It is convenient to plot the three end members as the apices of a triangle, which is then subdivided into seven pyroxene fields (Fig 4). The points in this figure represent all the analyses obtained so far, and it can be seen that analyses conforming to the compositional ranges of jadeite, chloromelanite, omphacite, and aegirine-jadeite have been obtained. Points enclosed by dotted lines are all from single implements and indicate the variation that sometimes occurs within a specimen. This variation is sometimes between the rims and cores of individual crystals, and sometimes between grains. The plots extending across the diagram from the aegirine-jadeite to the omphacite field are for the black axe from Feltwell Fen, and it is noteworthy that the greatest variation for individual axes occurs between the concentrations in the jadeite and omphacite fields. We should add at once that the preponderance of analyses within the jadeite field (Fig 4) does not in any way reflect the

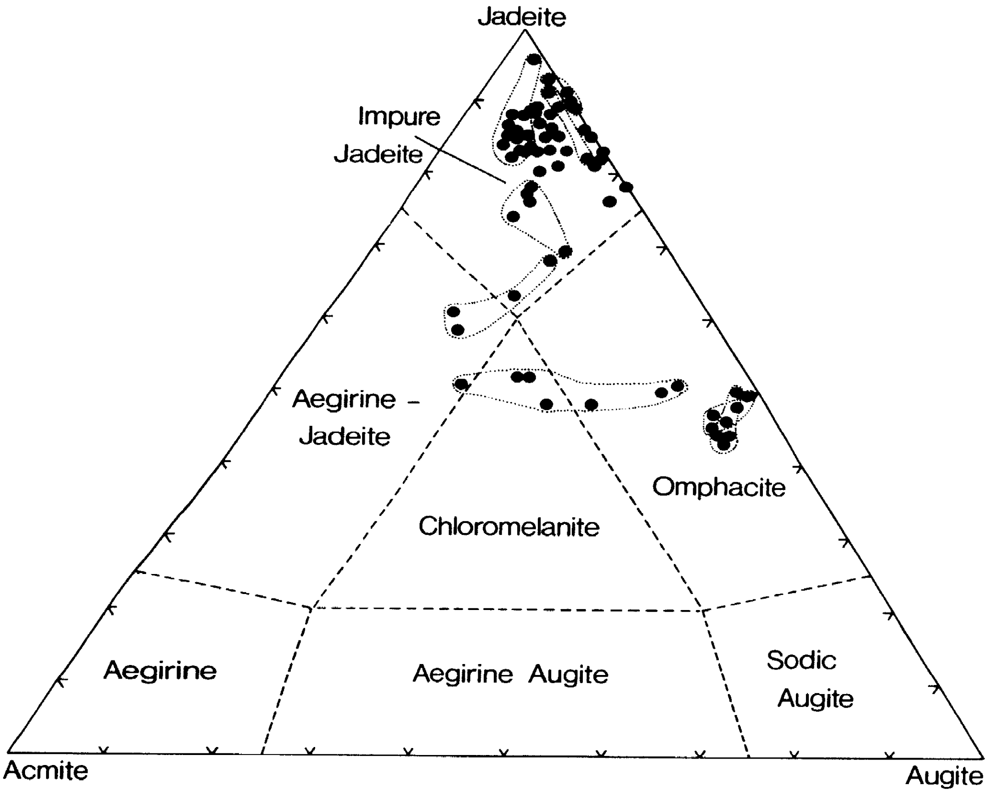
Table I A selection of electron microprobe analyses of implement pyroxenes

	1	2	3	4	5	6
SiO_2	59.16	58.77	58.63	56.63	56.23	54.72
TiO_2	0.31	0.02	0.17	0.09	0.42	0.28
Al_2O_3	23.66	20.98	18.29	14.79	12.37	11.05
FeO*	1.19	2.18	3.41	9.11	11.29	5.76
MnO	0.05	0.02	0.08	0.03	0.14	0.17
MgO	0.23	1.81	2.62	2.16	3.75	6.60
CaO	0.81	3.02	3.94	3.59	5.44	13.16
Na_2O	14.68	13.60	13.76	13.21	11.13	7.32
K_2O	nd	0.01	nd	0.0	nd	nd
Total	100.09	100.41	100.90	99.61	100.77	99.06
% Jadeite	96	85	72	61	52	46
%Acmite	1	5	14	26	24	5
%Augite	3	10	14	13	24	50

* Iron determined as ferrous iron

1 Jadeite (Dunfermline axe; WCS 48); 2 Jadeite (Sidmouth axe; WCS 12); 3 Jadeite (Fort William axe; WCS 50); 4 Jadeite (Knebworth axe; WCS 26); 5 Chloromelanite: other analyses from the same axe are omphacite (Feltwell Fen - a new find, for details see Jones *et al,* 1977, Axe 102); 6 Omphacite (Site unknown; WCS 47)

Analyst V Jones



4 Plot of 'jadeite' compositions from fourteen axes, obtained by electron microprobe, plotted in terms of jadeite ($NaAlSi_2O_6$), acmite ($NaFe^{3+}Si_2O_6$) and augite ($(Mg,Fe^{2+},Al)(Si,Al)_2O_6$). Dotted lines enclose data obtained from single implements; the fields of the various types of sodic pyroxene are indicated

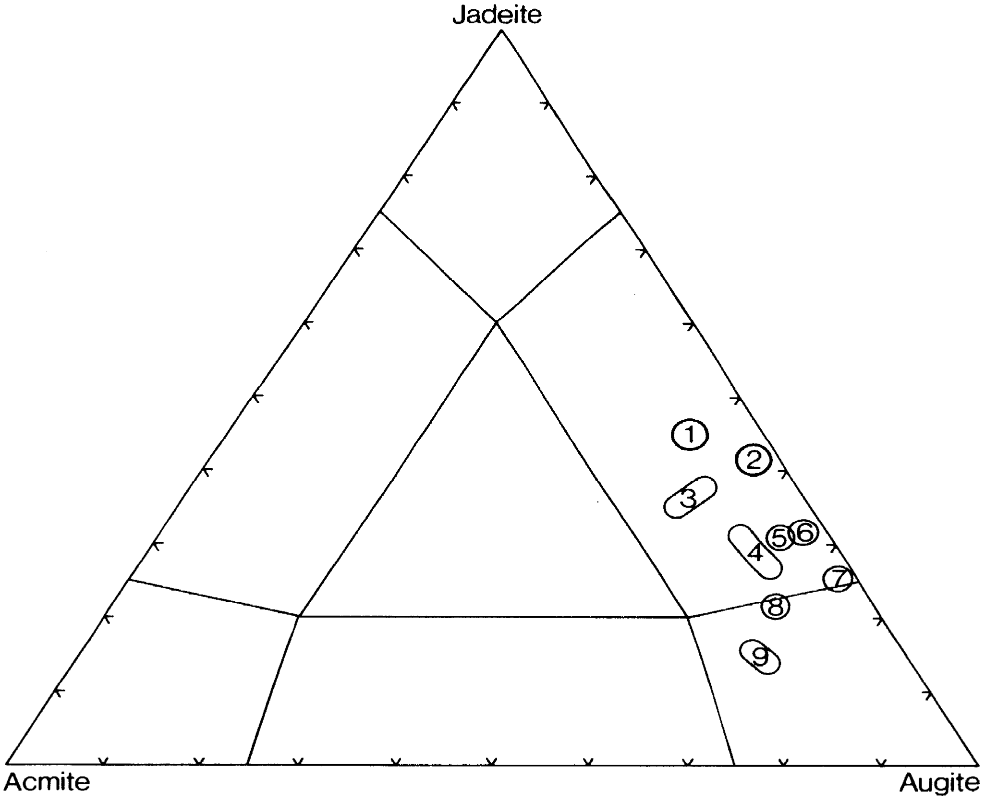
relative abundance of implements of this composition. The initial sample we have analyzed is not statistically representative of the frequency of occurrence of 'jadeite' implement types; in fact it is biased towards the granular axes because, being coarse grained, they are the best for analytical work. We expect that as the work continues the concentration in the central parts of the omphacite field will be considerably increased, thus giving the distribution a strong bimodality, probably with lesser concentrations between the two.

Essene and Fyfe (1967) have investigated the chemistry of sodic pyroxenes from a large number of localities and some of their European results are presented in Fig 5. It is noteworthy that (a) they found no jadeite from European sources; (b) they found omphacitic pyroxenes from localities in the Swiss, Italian, and Austrian Alps and from the Fichtelgebirge in Bavaria, which are comparable with some of the implement pyroxene compositions given in Fig 4, and (c) the pyroxenes of the only possible British source, Glenelg in Scotland, have a composition on the border of the omphacite and sodic augite fields, and would seem to be excluded on compositional grounds. We must emphasize that a thorough search has not yet been made and that we present here only preliminary results, but it is clear that the Alpine Belt and Fichtelgebirge are probable sources and, of course, implement working sites have been reported from the Swiss and Italian Alps.

There is a good correlation between implement composition and typology, and this is illustrated by Fig 6. The tie lines link the positions of implements on the W/T against L/W plot to their average pyroxene compositions on the jadeite-acmite-augite diagram. The diagram indicates (a) that all the thin axes are composed of jadeite (the one exception is a rather small axe, which is of omphacite); (b) all hachettes are of omphacite or a pyroxene of intermediate composition; and (c) one plump axe is composed of jadeite, but this axe plots only just below the W/T = 3 line separating plump from thin axes. In summary the thin axes are jadeite and the hachettes omphacite. There is not yet enough information to categorize the plump axes or the Breton axes of torpedo shape.

It is interesting to note that the implements of jadeite correspond to the group with the lower specific gravities in Figure 3.

Thus, although the data are limited, they do show a broad range of composition within what are generally termed 'jadeite' axes. It may be that some refinement in terminology may become necessary in the future. More importantly, the results suggest that it is most unlikely that the material of the implements came from a single



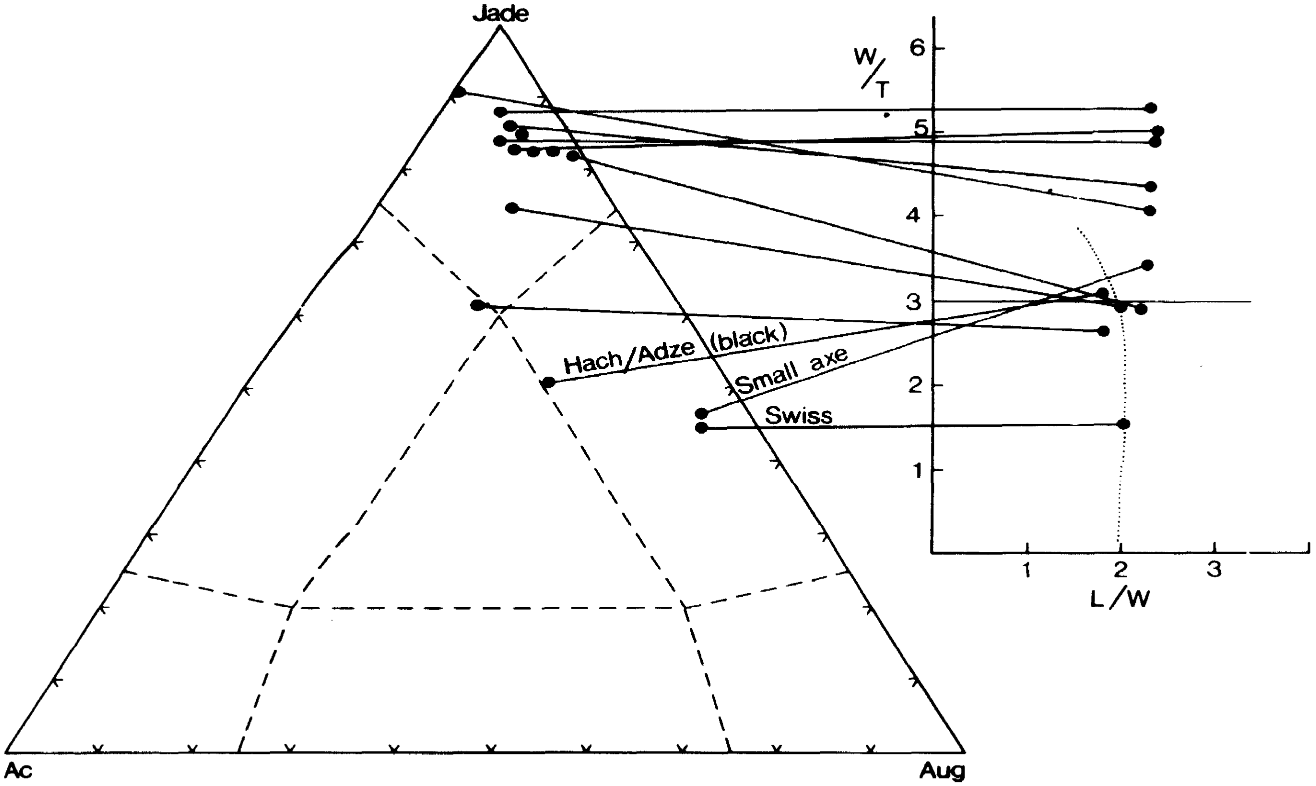
5 Pyroxene composition fields from various European localities obtained by Essene & Fyfe (196 7). It is apparent that implements made of omphacite (Fig 4) can be matched from continental European localities, but that in situ material comparable with that of the jadeite implements has not yet been described. The localities are as follows: 1 Lac du Minerone, Oropa, Italy; 2 Val Arrami, Gorduna, Switzerland; 3 Fattigau, Fichtelgebirge, Germany; 4 Getrusk, Sau Alpe, Austria; 5 Glenelg, Scotland; 6 Kupler Brunn, Sau Alpe, Austria; 7 Sauviat, France; 8 Glenelg, Scotland; 9 Langenfeld, Otzdahal, Austria

source. The differences between the pure jadeites on the one hand and the omphacite/chloromelanite implements on the other, especially when taken together with the typological correlation, are strongly suggestive of different origins.

The present investigation will be continued until the number of analyses can be considered representative of the various implement types. It is obviously undesirable to slice some of the finest 'jadeite' implements, no matter how pressing may be the scientific need. However, it is possible to apply two further techniques in this investigation. First, it is possible to analyze small samples for trace elements using the neutron activation method. What is here sought is not so much the absolute concentration of minor elements but, in particular, the ratios of the rare earth elements which could prove to be diagnostic. This should help both to confirm and refine the present chemical grouping of the pyroxenes based on major element concentrations and possibly to act as a means of comparison with pyroxenes from possible source areas. The other technique is to attempt to obtain, by the K/Ar and Ar/Ar methods, the date of formation of the sodic pyroxene itself. A meaningful geological date for the formation of 'jadeite' may point directly to the orogenic belt from which it was obtained and so exclude other areas as possible sources. This technique is particularly promising because 'jadeite' usually forms as a result of high-pressure metamorphism. Such high pressure conditions have obtained only locally within the several temporally distinct orogenic belts of Europe and so it is possible that some positive indication of source may be given. Although preliminary work is in hand using both these techniques, results are still awaited.

In conclusion, the chemical work reported here shows definite correlation with implement type, hence with implement distribution (Bishop *et al* 1977) and, we think, with implement function. Further, there are pointers which tend to confirm the view that the dark green pyroxene, so characteristic of many working implements, may well come from a European, Alpine source. On the other hand, we fear that the source of the light green pure jadeite from which many British large, thin axes are fashioned is likely to prove very elusive.

A full catalogue of jade implements with descriptions of those which have been brought to our notice since the publication of Campbell Smith's 'Second supplement' (1972) has been compiled (Jones *et al* 1977).



6 Diagram correlating mineralogy with typology of 'jadeite' implements. The tie lines link average pyroxene compositions, in terms of jadeite, acmite, and augite. with implement typology as expressed in a W/T against L/W plot. That 'thin' axes are principally composed of jadeite is apparent, while hachettes are dominantly omphacite (for full discussion see text)

Acknowledgements

We have been able to undertake this work only through the help of curators in many British and Irish museums. Without exception we have been loaned those jade implements for which we have asked, and for this we are most grateful. In particular we thank Dr J Close-Brooks of the National Museum of Antiquities of Scotland, Mr H J Case and Mr Andrew Sherratt of the Ashmolean Museum, Oxford, and Miss M D Cra'ster of the University Museum of Archaeology and Ethnology, Cambridge, for putting their extensive collections at our disposal. The following have most generously provided us with other implements: F K Annable, Miss S Archibald, Miss P M Butler, G Butler, D T-D Clarke, Dr J Coles, H Douch, G Drew, A R Edwardson, Miss L S Garrod, Miss R A Gilmore, Miss E B Green, A K Gregory, N Harris, Miss J Macdonald, R Milne, Miss S M Pearce, R N R Peers, D F Petch, M V Radcliffe, Dr J Raftery, A B Rance, J Scott, H Short, Dr J J Taylor, and D B Taylor. The diagrams were drawn, the electron microprobe analyses made, and much other help afforded by Miss V Jones; this valuable assistance is very much appreciated.

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Geochemistry and the provenance of flint axes (synopsis)

P R Bush & G de G Sieveking

Editors' note: A revised version of the paper given by Dr Bush and Mr Sieveking will be appearing in a forthcoming volume of the *Journal of Archaeological Science* but we could not let the conference proceedings appear without reference to their contribution. The authors have accordingly supplied this synopsis.

The prehistoric flint mines of the Chalk country of lowland England appear to be larger in scale than the highland axe factories and many more of the polished axes found in museum collections are made from flint than are made from any other rock type.

The techniques developed during 30 years' successful research on the distribution of stone axes, based on the comparative petrographic study of the rock types used, cannot be applied directly to the petrographically homogeneous material used in the production of axes from the flint mines. However, these studies did point the way to the use of chemical data to characterize flint petrologically, which has enabled us to define the distribution of flint axes from a restricted number of known axe factories.

Initially twenty samples were taken from material collected from each of seven major Chalk flint axe factories, five in southern Britain and two in north-west continental Europe. These samples were analyzed using optical spectrography and atomic absorption spectroscopy, and the results were studied first graphically and then statistically using a computer.

After encouraging results were obtained from the initial work the number of mines studied was increased to eleven; however, in two cases adjacent mine sites were paired; this gave nine mine areas. To improve analytical accuracy and precision all the samples were analyzed for aluminium, iron, magnesium, calcium, sodium, potassium, lithium, and phosphorus, using atomic absorption spectroscopy. With the exception of calcium these trace elements were present in the range 1 to 2,000ppm and were normally distributed.

Analyses of flint using neutron activation analysis were carried out by de Bruin and his co-workers in Delft and Aspinall at Bradford. This technique gave data on many more elements, some of them at the trace element level. Data for some of the elements proved very valuable, and for others, less so.

For a geochemical classification of the products of flint mines to be viable the following criteria have to be satisfied. The flint must be shown to be a piecemeal replacement of the carbonate host rock retaining the non-carbonate material within the flint. The sediment being replaced must be homogeneous laterally and contain a uniform distribution of non-carbonate material. There must be a vertical or regional variation in non-carbonate content to give variations in trace element chemistry from one mine site to another.

The Chalk and its flints satisfy all these criteria over most of its outcrop. Chalk flints are demonstrably replacement products, and the fine carbonate sediment contains very low concentrations of finely divided non-carbonate material which is uniformally distributed laterally but variable vertically.

Archaeological support for the working of the technique is given by the fact that chemically analyzed flint axes from provenances close to Grimes Graves classify with the flint mines. Also, axes with archaeological provenances in sites dated between 3000 and 2700 BC classify with the South Downs and similar mines which are also radiocarbon dated to the same period, and do not classify with Grimes Graves which is radiocarbon dated between 2500 and 1500 BC.

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The influence of geology on the manafacture of Neolithic and Bronze Age stone implements in the British Isles

G R Coope

Abstract

It is suggested in this paper that there were two distinct traditions in the manufacture of Neolithic and Bronze Age stone implements. One was essentially a flint technology that involved the selection of rocks with similar physical properties to flint. This technique resulted in prodigious quantities of waste material in the form of flakes and discarded rough-outs. The second technique was largely based on pecking and involved the selection of quite different rocks — most usually moderately coarse basic igneous rocks that did not flake when struck with a hammer. The by-products of this technique were largely dust and rock flour. It is interesting that, in spite of the abundance of products of this second technique, no factories have been discovered in the British Isles that involved pecking in the shaping of stone implements. We should not expect to find at such sites the characteristic waste products that betray the existence of the well known factories that employed flaking in the initial stages of production of stone tools.

This essay is essentially an accumulation of ponderings; the result of over twenty years of sporadic investigations into the petrology and manufacture of Neolithic and Bronze Age stone implements. My views are unavoidably the views of a geologist and, though not presuming to scientific objectivity, they may point the direction of new avenues of enquiry or possibly block off others that seem likely to be unprofitable.

In common with so many fields of scientific endeavour that seem to pose more questions than offer solutions, the petrological investigation of stone implements is generating new problems at a very encouraging rate — the hallmark of a successful scientific enterprise. I am going to concentrate here on three of these questions that have not received much attention in this symposium. First, why was Neolithic and Bronze Age man so selective in his choice of raw materials for stone implement manufacture? Second, why did certain centres of manufacture concentrate on a limited range of products? Third, why have no factory sites yet been located that produced shafthole implements in spite of the accumulated knowledge of the precise whereabouts of suitable rock types and the abundance of their dispersed products? These three questions cannot be dealt with independently since they are interrelated. The Ariadne's thread that meanders through the following discussion tying these points together is that petrology dictates what can and what cannot be done in the manufacture of implements from stone.

It was, I believe, Heath Robinson who said that one can do anything with string except push with it. Stone is not quite so versatile but given the right rock type and suitable techniques one can do almost anything with stone except forge it. Clearly to ancient man the choice of raw material depended upon three related factors: the available technology, the end product desired, and the rocks at their disposal.

The earliest means of modifying the shapes of rock for human purposes was almost certainly a flaking technique, later developed to near perfection in the flint technology of the Upper Palaeolithic. The methods involved are so well known, and modem exponents so expert, that it would be an impertinence for me to elaborate them here. From our point of view it seems plain that the roughing out of Neolithic axes was but a slight modification of the old technology. Certainly flint rough-outs, when compared with others made from stone at the well known factory sites in the west of the British Isles, are identical in flaking style. It seems inescapable that men conversant with flint technology searched for analogous rock types as colonization pushed north and west out of the areas where flint occurred naturally. They were looking for a rock that had the same tendency to take a conchoidal fracture when struck with a hammer (the first geological hammer) with the same uniformity as their familiar flint. This rock had to be fine grained, homogeneous, and compact. They found suitable rocks of diverse origins; igneous rocks at Graig Lwyd (Warren 1919), metamorphic rocks at Tievebulliagh (Jope 1953) and at Mynydd Rhiw (Houlder 1961), and volcanic ash at Langdale (Bunch & Fell 1949). The results of their labours can be seen to this day in the prodigious heaps of waste flakes and discarded rough-outs that litter the working sites and betray their existence to the archaeologist.

It is strange that no site has yet been discovered as the direct result of the petrological investigation of thousands of Neolithic axes, many of which must have been produced by this technique with the consequent accumulation of characteristic waste products. May I recommend a diligent search for the sites of Group VIII in south-west Wales, and Group XX in the ancient rocks of Charnwood Forest which must surely be recognizable by accumulations of struck flakes?

Before leaving these stone axe factory sites using flint technology, mention should be made of the curious transverse fracture so commonly seen among the discarded rough-outs. These broken axes, with their ripple fractures at right angles to the long axis of the implement, do not seem to have been broken by an accidentally misplaced blow during flaking (there are many such *accidentally* ruined products on most factory sites) and the implements are usually in a fairly complete stage of shaping. The breakage seems deliberate and due to a sharp blow on the flat side of the axe about midway along its length. But why they should do such a thing must be a matter of speculation. My personal prejudice favours some Neolithic equivalent of quality control though a less materialistic explanation may appeal to some.

To return to the factors limiting the choice of rock type for implement manufacture we must consider the next stage in the process, namely, the grinding of the surface to produce the desired shape and sharp edge. The constraint here was essentially the relative hardness of the available abrasive compared with the utilized rock. The only widespread grinding medium that was hard enough to cut most of the rock-forming minerals was quartz sand or sandstone. It is true that garnet sands occasionally occur as beach deposits, and natural emery occurs on the Mediterranean islands Naxos and Samos, but these harder abrasives can certainly be disregarded in the normal grinding procedures of British axes. The ubiquitous use of quartz sand as an abrasive explains why flint implements are so hard to grind since flint is a form of microcrystalline quartz and is thus only marginally softer than the abrasive. Now quartz itself is a very common constituent of rocks and if quartz-rich rocks were selected for implement manufacture, grinding difficulties would arise. Fine-grained rocks would just be difficult to work, but coarser-grained rocks would become etched by grinding as the softer minerals like feldspar, augite, and hornblende were cut away leaving the quartz standing proud of the surface. I have no doubt that Neolithic man was well aware of the limitations of his grinding techniques and chose his rocks accordingly.

This technical combination of initial flaking followed by surface grinding, imposing as it did a strict limit on the choice of rock type that could be used, also imposed a restriction on the range of products that could be produced. It was naturally the technology *par excellence* for the manufacture of flint axes and also the production of the long thin-butted axes that are so characteristic of the great factory sites centred on Langdale (Group VI), Graig Lwyd (Group VII), and Tievebulliagh (Group IX). Both rock type and technology are admirably suited to the production of axes that could be hafted by means of a perforated shaft. But the rock that flakes well and is hard and flinty does not lend itself to drilling techniques. Odd perforated mace heads of Group VI and VII are known to be sure but they are very rare indeed. For the manufacture of shafthole implements, be they axes or hammers, a different technology was required involving a different type of rock.

A brief survey of the petrological groupings assigned to Neolithic and Bronze Age implements shows that a large proportion are made of medium-grained basic igneous rocks, that is, they contain little or no quartz. These rocks are usually described as uralitized gabbros, epidiorites, picrites, or greenstones. Apart from the minor details that enable the rocks to be allocated to their respective groups, the bulk of their component minerals are really very similar. The feldspar is usually some form of plagioclase almost always riddled with sericite, an alteration product somewhat akin to mica. The most common dark minerals are augite, hornblende, and, in the picrites, olivine. The augite is often altered to rather fibrous amphibole, the hornblende to chlorite and epidote, and the olivine to serpentine.

I am well aware that these generalizations will seem too sweeping to my geological colleagues but, from the point of view of Neolithic and Bronze Age man's choice of raw materials, it is the physical properties of these minerals that determined the utility of the rock rather than the intricacies of their petrography.

A few minutes' practical experiment with these rocks will soon convince the most hardened sceptic that they cannot be worked by any modification of flint technology. They simply will not take a conchoidal fracture. It is certainly possible to strike pieces off the rock to accomplish some very preliminary shaping, but if these bits were left at the factory site they would, after four or five thousand years, be difficult to recognize as the products of human activity. To make matters worse, these basic igneous rocks weather very readily, as the surface of so many of the implements testifies. Any diagnostic details once possessed by such waste products would thus be doubly difficult to recognize in contrast to the by-products of factories using flint or flint analogues as their raw material.

In summary I believe that we shall be disappointed if we expect to find factory sites using basic igneous rocks marked by spoil heaps of waste flakes.

The technology appropriate for the shaping of these basic igneous rocks is one of surface pecking; that is, sharp blows are delivered to the rock, hard enough to produce small hollows on its surface. It is the accumulation of such dimples that gradually eats away at the surface permitting the rock to be fashioned into almost any shape required. The reason why these rocks are so easily pecked is because the chief minerals of which they are composed are all readily crushed (as opposed to quartz which is not) and this is particularly so if these minerals have been to some extent altered, as is the case with so many of the rock types chosen. Furthermore, the igneous texture, with all the mineral grains interlocking, plus the fibrous and platey nature of many of the individual minerals, confers upon these rocks a toughness and resilience that enables them to take numerous hard blows without splintering. The minerals themselves are fairly hard but all are just a little softer than quartz, the abrasive used to smooth the implement surface and to sharpen the cutting edges. The fact that these rocks also lack any preferred orientation of their constituent minerals (in contrast to many sedimentary and regionally metamorphosed rocks) means that they can be worked with equal ease in any direction; they are 'freestones' in quarrymen's terminology.

This pecking technique is, however, very time consuming. Apart from some rudimentary preparation it is unlikely therefore that much of the shaping was actually carried out at the site of the outcrop. Pecking is not so risky as flaking, where so much depended on the run of the conchoidal fracture and an ill-judged blow might so easily result in having to start again from scratch. With pecking, the blows were not hard enough actually to fracture the rock, and the problems that beset the flint worker, such as excessive thickness of the axe that would not reduce by flaking, were easily resolved by the pecking technologist. It is for these reasons that I do not expect the outcrops of these source rocks to be littered with discarded rough-outs either. I envisage much of the implement shaping taking place nearer home as a Neolithic or Bronze Age equivalent of a cottage industry. Perhaps we can imagine the activity as a productive pastime during the evenings, rather like the role that knitting played before the intrusion of television into the family circle. The by-products of this activity would be very small rock fragments and dust that would be almost impossible to recognize in an archaeological context.

The versatility of this technique meant that the typology of its products could be much more complex than that generated by the flaking technology. By pecking it is possible to produce almost any shape one wishes so that in many ways it is similar to sculpture. Many of these shapes are difficult to produce by flaking. Thus we find basic igneous rocks being used to produce round- or oval-butted axes with occasionally expanded cutting edges as in the 'Bridlington' axes. Above all, however, these medium-grained igneous rocks could be readily drilled either by pecking two hollows in opposing sides of the implement until they met forming an hour-glass shaped hole, or alternatively they could be drilled by a rotating bit or tube forming a shafthole that was much more parallel sided. Complex axe hammers and battle axes were carved from stone in this manner for both ceremonial as well as practical purposes. From the appearance of many of the more elaborate products, they may well have had metal prototypes. This is particularly so of some of the smaller products of the Group XII factory (Shotton *et al* 1951) though other implements from the same material seem to be little more than perforated lumps of rock. It is interesting to note that axe hammers were most frequently made of basic igneous rock with the noteworthy exception of the hard siltstone of Group XV (Shotton 1959), which will be discussed below.

Little need be added here about the grinding of these implements except that both grinding and pecking procedures seem to have been intimately related; sometimes pecking can be seen to be followed by grinding and then more pecking after that. Seemingly the two jobs were being done at the same place; further evidence that much of the shaping was done away from the outcrop of the source rock. The avoidance of quartz-rich rocks, though these greatly outnumber the more basic rocks in natural occurrence, is also probably due to the difficulties of grinding the surface successfully. But this cannot be the only reason. Granites, by far the most abundant of medium- to coarse-grained igneous rocks, are doubly difficult to work because the large crystals of quartz are hard and resilient and can be crushed or dislodged only with great difficulty without the aid of a modern masons' steel chisel. It is small wonder that only thirteen implements of granite are recorded from the south-west of England out of a total of 1200 examined and of these granite implements a high proportion seem to have been abandoned in despair by their makers (Evens *et al* 1962). I have dwelt on this problem of granite at some length because it seems to me to be important to ask why some common raw materials were *not* exploited, if we are to understand why much rarer rocks were diligently sought out and utilized.

There is, however, one quartz-rich rock that was extensively used in the production of axe-hammers and also, to a lesser extent, round-butted axes. These products seem to have been strictly utilitarian as they have few refinements of structure and all are of a sensible functional size. The raw material (Group XV) was a fine siltstone made largely of quartz, feldspar, and some mica and probably originated in the southern part of the Lake District in the 'Coniston Grits' (Shotton 1959). Since the rock is a hardened sediment, the quartz granules are not so interlocked into the structure of the rock as they are in igneous rocks, and they can be dislodged by pecking and grinding. The planes of original sedimentation can sometimes be recognized in the axe hammers at right angles to the cutting edge and the perforation. In this particular case the yet unrecognized factory site may well be characterized by slab-like sedimentary units of about 8 cm thickness with shale partings. The quarrying technique was probably the simple prizing free of these slabs along the shaly horizons, after which they were broken into more or less triangular slices. After a small amount of pecking and grinding, the axe hammers were ready to have their shaftholes drilled. Here again, apart from some very preliminary shaping by chipping, most of the work would probably have taken place away from the quarry.

If we are to find the actual quarry sites that provided the source rock for those groups for which a pecking technique was appropriate, I believe that we should revise our search image. Maybe the term 'factory site' conjures up a misleading impression. We are looking not so much for a working place, but rather for a locality that was visited infrequently and only then probably for brief spells when the need arose to replenish the stocks of raw material. The finding of such localities must be by close cooperation between the geologist and the archaeologist; the former to pinpoint with maximum accuracy the localities of the source rocks and the latter to investigate these sites for hints of human quarrying activity that may be much more subtle than at any of the self-advertising sites so far discovered.

My thesis, then, is that there would seem to have been two traditions of manufacture of stone implements during the Neolithic and Early Bronze Age in Britain (see Table I). Each had its own preferred choice of rock, its own technology, and characteristic products. It is difficult to determine to what extent these traditions were born of necessity, dictated in the last resort by the availability of suitable rocks, but it is tempting to see in them two routes of ingress of the Neolithic culture into the British Isles. First we have the early Neolithic settlers in south-east England moving over from France and Belgium and bringing their flint technology with them. Their spreading north and westward took them out of the areas of chalk outcrops and thus further and further from the source of flint. Their search for flint substitutes led to exploitation of all manner of rocks with similar physical properties, from areas as far apart as south-west Wales to northern Ireland and the Shetland Islands. Some of these products, for instance the Group VI axes from Cumbria, competed successfully with flint,

Table I Petrological groups of Neolithic and Bronze Age implements arranged according to their techniques of manufacture

	Flaking		*Pecking*
VI	Langdale*	I	Cornwall
VII	Graig Lwyd*	II	Cornwall
VIII	S W Wales	III	Cornwall
IX	Tievebulliagh & Rathlin*	IV	Cornwall
XX	Charnwood Forest†	XII	Cwm Mawr (Hyssington)
XXI	Mynydd Rhiw*	XIII	Preselau Hills
XXII	Shetland*	XIV	Nuneaton
XXIV	Killin*	XV	S Lake District
		XVI	Cornwall
		XVII	Cornwall
		XVIII	Whin Sill
		XXIII	S W Wales

*Factory sites known from the presence of flakes and rough outs

†Implements sometimes show signs of pecking as well as flaking, though the latter technique was undoubtedly the most important in the initial stages of manufacture.

possibly because of their ease of sharpening, though their handsome appearance may well have contributed to their success. The second tradition owes nothing to flint. It was carried on by men who laboriously pecked greenstone axes from the tough basic rocks of the south-west peninsula. It seems on geological and typological grounds that this tradition probably came to England from Brittany. The popularity of these products is well illustrated by the widespread trade in Cornish implements into northern England (Cummins 1974) and even the establishment of factories producing almost identical axes from the dolerites of the great Whin Sill.

In the end it was the technology dominated by pecking that won the day. Although it started by producing simple axes with rather pointed butts of rounded cross-section, the technique eventually proved so versatile that, at its acme, it was possible to carve out of tough rock the magnificent double-bladed ceremonial battle axes of the Early Bronze Age. On the other hand the flint technologist of the Neolithic was far more limited in what he could produce and the flaking-grinding process led to the manufacture of rather stereotyped thin-butted axes only. Since flint (or any of its analogues) does not lend itself to the production of serviceable hafted hammers, the old technology was eventually superseded in the manufacture of large implements and only survived, in reduced circumstances, in the production of projectile points and barbs. Here then is a picture of cultural evolution in which the survival or extinction of technologies was dictated by their inherent potentialities and limitations in a changing environment, where the selective forces at work were the ever-expanding demands of human ingenuity, and the eventual inability of the range of rock types to fulfil these demands.

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Reconstruction of the hafting methods and function of stone implements

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Abstract

The work described stems from a continuing teaching project run by the Department of Archaeology, University of Durham, in which a small area of woodland (initially 400m^2) is being felled with stone axes, after detailed study of soils, vegetation, pollen rain, etc. The intention is that cereal crops (principally emmer) should be sown and harvested, and the environmental effects studied.

An experiment involving the felling of three trees with different types of axe is described. Also discussed are the practical problems of sharpening the axes; of obtaining suitable wood for the hafts; of obtaining and working antler; of fashioning the hafts; and of preventing the haft head from breaking.

Various methods of hafting stone axes have long been known, and experiments are continuing with some of these. The question of function is more difficult: it seems likely that stone axes were used both as axes and as adzes; it is less likely that they were also used as hoes, although such implements are not, apparently, otherwise represented. Finally, the question of the purpose of the stone axe trade and in particular the relative merits of stone versus flint is a matter on which experimental work can help to shed light.

Study of the hafting methods and study of the function of stone implements are two closely related activities. It is not until we know how tools were wielded that we can say for what purpose they were wielded, Even then the available sources of evidence leave us an uncomfortably large range of choices, and a measure of subjective judgement, supported if possible by experimentation, is bound to enter the discussion. Yet these two complementary studies are basic to our understanding of stone age technology and, hence, economic activity, so that we feel little apology is needed for the continuance of work along lines already followed.

The reconstruction of hafting methods, and thereby function, of stone implements (for our present purposes, Neolithic ground implements, mainly axes) depends on three main sources: (i) archaeological finds of preserved hafts, (ii) modern ethnographic parallels, and (iii) empirical deduction, which may be based on study of the tools themselves or on their experimental hafting. Dr Phillips discusses elsewhere (this volume) the uses of axes in ethnographic situations; we will review briefly the archaeological sources and past experimental work, and then pass to some mention of our own experiments.

The richest source of hafted stone implements in archaeological contexts is the lake sites of Switzerland. Most of the finds are conveniently assembled and studied by Müller-Beck (1965). At Seeberg, fourteen whole or fragmentary hafts were found, of which two had stone axes still in position. The wood used was, with only one exception, ash. The hafts were from substantial trees cut at the bottom so that the top of the root projected back above the axe slot in a gradual curve. The slot is rather roughly fashioned but usually fits round the axe tightly. In addition to the genuine axes, numerous other handles, some with stone and antler tools in position, were recovered at Seeberg, so that an overall picture of relative tool functions may be obtained. Other hafts, some with the axe in position, come from Egolzwil, Vinelz, Lüscherz, and various other sites: many of these have antler sleeves. A vast amount of unrecorded material has also been found on various sites and dispersed through public and private collections of the world (there is, for example, an antler sleeve in Durham, which has no museum, and a small axe in a sleeve, as well as much other material, in Sunderland Museum).

Other hafted axes have been found in Denmark and Germany (Becker 1945), and the odd piece has turned up in Britain (Evans 1897, 119, 151—2). The haft from Solway Moss illustrated by Evans does not greatly help one's efforts at reconstruction, for the wood seems to have shrunk considerably through desiccation. The Danish axes are of interest in that, in all four studied by Becker, the axe was set in the ash haft at an angle of about 80°. At least one of these pieces Becker considers to have had a non-practical purpose.

Experimental hafting of axes and tree-felling has taken place on a number of occasions (Table I). The most famous attempt is that of Iversen, Troels-Smith, and Jørgensen in the Draved forest in Jutland (Jørgensen 1953; Iversen 1956), using flint axes, and cutting down trees less than 35cm in diameter: larger trees were ringed and left to die. Even more remarkable, though less sustained, results were achieved in Russian and Czech experiments, using stone axes mostly on softwood trees. In the Czech experiments 100 trees of an average diameter of 14cm were felled, including soft, medium, and hard woods: an average felling time of 7 minutes for a 14—15cm tree was achieved, though it is not stated what proportion of the whole were softwood

Table I Some experiments with axes

Author	Axe material	Axe size	Haft wood	Tree	Diameter (cm)	Time (mins)
Lepic (quoted by Evans 1897)	Flint	'8" long' (20cm)	Oak	Oak	20 (8")	?
Jacob-Friesen (quoted by Nietsch 1939; Clark 1945)	Flint			Fir	17	7
Jacob-Friesen *(ibid)*	Stone			Fir	17	5
Iversen (1956)	Flint	Medium	Ash	Various, oak	30	30
Semenov (1973)	Stone	?Medium		Pine	25	20
Stelcl & Malina (1970)	Stone	Small-medium		Various	14—15	Average 7

Table II Experimental tree-felling, 1976

Axe no	Material	Waft	Length (mm)	Width (mm)	Tree	Diameter (mm)	Time (mins)
1	Flint	Ash	190	73	Beech	150	28
2	Stone	Ash	103	55	Pine	120	19
3	Stone	Beech	156	60	Birch	120	15

trees. As far as we know, neither the relative merits of different materials for the axe, nor the relative time required for chopping different woods, have been studied in detail. The actual hafting method, on the other hand, has been exhaustively studied by Müller-Beck and Schweingruber (Müller-Beck 1965).

Since 1974 the Departments of Archaeology, Botany, and Geography at Durham University have been conducting a teaching experiment in which some of the work of the Danish team has been reproduced. With the kind assistance of the British Museum and the helpful advice of Dr J Troels-Smith, unprovenanced stone and flint axes of various shapes and sizes have been hafted and used by first-year students to colonize the 'virgin forest' of Great High Wood on the south-east side of the city. This work was undertaken with the cooperation of the Surveyor's Department and, in particular, of the groundsman, Mr J Wass. A small area (initially only some 400m^2) was set aside for a longer-term project, and in addition some spare land has been allocated for other agricultural experiments. Before felling started, a detailed survey was made of vegetation and soils, and the present pollen rain analyzed. It is intended to examine the ways in which the pollen rain may change with cultivation; to record the patterns of weed and shrub regeneration; and to detail yields and, in particular, yield fall-off with time. The pollen analytical side of the work, potentially the most important, has not yet reached a stage where any useful results can be quoted, and the felling has mostly been conducted with a view to instruction rather than experiment.

More recently we have attempted to provide a detailed comparison of axe chopping rates. Three first-year students made experimental hafts for three axes, two of stone and one of flint. Modem tools were used (we hope to progress to stone tools later): chisels for the perforation, spoke-shaves for the handle. The axes were sharpened on a modern Carborundum stone. We then set about felling three trees of roughly equal diameter (15cm) but of different species, To equalize the effects of their differing efficiencies, the workers were changed round from axe to axe, but the same axe remained at the same tree (Table II).

Axe no 1 was of flint, and of medium to large size. The edge was reasonably sharp, though sharpening was hampered by the tendency of the flint to flake or chip just when a keen edge was achieved. It was mounted in ash, from a young tree cut low down by the roots. The haft was heavy — heavier than was really comfortable — but this in itself caused the tool to achieve rapid results in the early stages. The tree felled was beech. After fifteen minutes a chip developed on the blade which caused us to suspend work with it, for resharpening would have taken an inordinate length of time. We preferred to finish felling the tree with another axe: total time 28 minutes.

Axe no 2 was of fine-grained stone, and rather small; it had an ash haft from a slender trunk; the tree felled was pine. The blade in this case was very sharp, and the tree came down in 19 minutes.

Axe no 3 was also of fine-grained stone, of medium size, rather worn and asymmetric in shape but quite sharp nonetheless. The haft was of beech – wood which had not been specifically selected and, therefore, was inclined to split. The tree felled was a young birch, and this was achieved after 15 minutes.

It is obvious from the above that the speed of felling depends very much on the type of tree and its diameter. Size is doubly important because larger trees have proportionately more of the hard inner wood represented. One can chop through the bark and outer rings very quickly; it is the inner wood that takes the time, and the older the tree the slower the work will get. It is also only to be expected that softwood trees will be much more easily felled than hardwood: oaks and beeches that we have felled in the past can be very stubborn.

Regardless of the relatively small time difference involved, however, it was quite clear to the workers that axe no 3 was much the most effective. No 2, though sharp, was really too small to make a great impression. No 1 was something of a liability because of its tendency to chip, and experience has shown that once a chip starts the axe must be laid aside, for the chip will only enlarge itself with continued use, thus greatly lengthening the time needed for resharpening, We do not know whether this flint axe can be considered typical but, if it can, then it is quite clear that stone would be a more useful material than flint for felling. If this conclusion is correct, and we are not the first to suggest it (Clark 1945, 68), we should look very carefully at the distributions of stone and flint axes to see in what ways, if any, a preference for stone can be detected.

A number of different problems present themselves in such experiments, which we will mention briefly. First, the axes must be sharp – in other words, they must be sharpened. Our use of a modern carborundum stone may be considered by some a significant deviation from prehistoric practice: but the method used undoubtedly involved constant rubbing back and forth on an abrasive stone. Large blocks used for this purpose are well known, and the visitor to Le Grand Pressigny Museum cannot miss them. One such stone was reused as an orthostat in the West Kennet Long Barrow (Piggott 1962, 19ff, with other references). On stone axes one can achieve a sharp edge with some ease; but flint appears to be much more difficult to sharpen.

The question of what wood is suitable for hafts has been exhaustively studied by Schweingruber on the basis of the Seeberg finds, but fulfilling these conditions in practice is more easily written than done (Müller-Beck 1965). In most cases we have used young trees, taking the whole diameter near the roots; but a segment of a larger tree, with the rings set at right-angles to the hafting and striking plane, would apparently be a better proposition. It is not easy to obtain ash in wood yards; it is virtually impossible to find it in the condition required, that is, neither splitting nor likely to split. Once obtained, it is essential that the wood is kept out of doors to avoid such mishaps. We have not experimented with one method that has been suggested – inserting an axe in a growing tree and letting the wood close round it – and we do not believe that this method would have been practicable: the length of time taken to achieve a tight fit, and the likelihood of loss render this method unsuitable.

Inexperience and the lack of suitable wood have resulted in a high casualty rate for the hafts we have made so far. The force brought to bear on the sides of the perforation is considerable (hence the use of antler sleeves); misdirected and glancing blows are very likely to damage both blade and haft. Iversen and Troels-Smith maintain that to avoid such damage it is necessary to mount the axe is such a way that there is room for play to either side, the haft not gripping the axe tightly (Iversen 1956, 37). There is a tendency to make the haft too narrow: the thickness of the wood at the perforation needs to be two to three times the width of the perforation. We have not used Neolithic wood-working tools to fashion the hafts, but we can believe that these were extremely effective. The initial stages of shaping were probably fairly rapid; the later stages slow and laborious as the perforation was fitted exactly to the shape of the axe. The use of antler as a sleeve, common on the Swiss lake sites, is not found in Britain. Even where it does appear, the size of the burr even of a Neolithic antler does not allow any very substantial axe to be hafted: we suggest that these tools were for carpentry, not tree felling. Modern antlers are very much smaller in overall size and diameter than Neolithic ones, so that the prospect of efficient mounting in antler sleeves is remote, unless a suitable source of imported antler can be found.

Several authors have indicated, and our experience bears out, that the best method of chopping is one in which the blow is struck from the elbow, not the shoulder, with the axe meeting the tree at as acute an angle as possible. A long vertical flake should be detached at the outset; then as the notch in the tree gets more V-shaped, the flake to be struck will slope further and further in. Criticism has been expressed of results that are based on the work of completely inexperienced personnel. Such criticism is, of course, valid, if otiose. The trouble is that 'experienced' personnel are a little thin on the ground these days, at any rate in Western Europe, so that one has no option but to proceed as best one can with available resources. In our case, we hope that the same team will be available for work for a further two years, and that the experience they will have gained will be as great as that of any 20th century Neolith.

We have so far talked of 'axes', but the function of these tools remains to be discussed. Here the study of wear patterns has been of crucial importance. It is clear from the archaeological material that 'axes' were sometimes mounted adze-wise; the wear, which should be symmetrical along the blade, is restricted to one side. It has sometimes been suggested – and the idea is not implausible – that 'axes' could have been used as hoes, that is, for breaking the gound. Ploughing with a bow- or crook-ard does not turn the soil over, nor does it break it up thoroughly; further work must have been necessary before the ground would have been anywhere near suitable for seed planting. Rock paintings in the Val Camonica are considered by Anati to indicate just this process (Anati 1965, 115, 117). Yet in most prehistoric agricultural assemblages there are few, if any, tools that are obviously hoes, certainly not in Britain. An adze-wise mounting of stone axes, as of shoe-last celts, might prove effective for hoeing.

This idea is plausible only in theory, for study of wear patterns has not borne it out in practice. Semenov's pioneer work (1973) has indicated that adzes could not be used as hoes if they were to continue effective as adzes. 'The combined functions of adze and hoe in one tool would be impossible, as the degree of wear on an earth-digging tool is very great. . . an adze after use as a hoe could not be restored merely by sharpening, and moreover traces of wear on a hoe are very characteristic and occupy a good part of the tool's surface' (Semenov 1973, 129). Experiments by Egon Hennig (1961) on 'shoe-last adzes' confirm this statement, and it has been found that the stone ard-shares of the second millennium BC in Orkney and Shetland show very great wear (S Rees, personal communication). None of our Neolithic pieces have anything like the amount of battering present on such objects. Any use involving contact with the ground produced massive scratching and abrasion of the blade, far greater than anything normally found on archaeological pieces. Hennig concluded that such tools were adzes used for wood working, just as Semenov did for comparable small pieces from the USSR. We should no doubt infer the same for our small stone axe. The criteria for distinguishing axes from adzes have also been laid down by Semenov (1973) and there can be no doubt that this piece is an axe.

Further study of the Swiss material quickly reveals that there is a considerable range of wooden and antler implements which might have served as hoes. Some, indeed, can hardly have been anything else (Müller-Beck 1965, 45ff). Plough shares are also well represented, so that we have to suppose that the absence of stone hoes and shares in the European Neolithic was more than compensated for by the presence of these implements in wood. Such a use re-emphasizes the need for many and effective wood-working tools.

In conclusion, we may confirm that most axes were used for wood working, the larger examples for tree felling, the smaller for carpentry; and we may suggest that different materials had different effects and, therefore, functions. The greater effectiveness of stone, as against flint, may well have considerable repercussions in the field of stone axe dispersal, and explain why axes from the great factories are so widely distributed. The position of flint axes is not yet certain, though it does seem that flint may have been less effective than stone. Our future work will be aimed at these and related problems.

Acknowledgements

We should like to express our thanks to the following, whose kind cooperation made our experiments possible: Dr Ian Kinnes and Mr Roger Miket for providing the axes from material in their care; Messrs Stephen Dickinson, Paul Gilman, and Nigel Jones of Durham University, who hafted the axes and felled the trees in the experiment described; Mr J Wass, the groundsman, who provided wood and allowed us to fell trees in woods in his care; and Miss Sian Rees, who allowed us to mention her work on the Scottish ard-shares.

Post scriptum

Mr Martin Kyllo, a participant at the Conference, wrote to the authors afterwards describing his memories of forest clearance in British Columbia in the late 1930s and early 1940s. As his remarks are of considerable interest, we quote them here in full:

> All work was done by hand with horses providing the only motive power. Only hardwood areas were cleared; softwoods do not create topsoil so the land they covered was not used. The lighter soils were put into production first as they were less densely wooded and could be cleared more quickly. Burning was not considered a suitable method of field clearance as it destroyed the topsoil. It was used to create pasture by burning underbrush.
>
> Cutting a tree above ground was considered valueless as the stump took up space. Large trees were ringed to kill them and left standing unless required for fuel. Small trees were cut off at ground level. The roots of larger ones were grubbed out with a mattock, then cut off. A rope was tied to the tree 20ft or so above the ground and the tree pulled down by a team of horses. This method could not be used for the very tall trees because of possible miscalculation and danger to the horses.
>
> Once felled, the large diameter trees were saved to be cut up for fuel. Branches and small diameter trees were piled in long rows. These piles were allowed to dry for a year or two, then burned. During the interim period, roots removed from the field were added to the piles,
>
> In retrospect, it is hard to estimate the time required to clear the land (at the time it seemed forever), At a guess I would say that one man and four boys aged up to sixteen years would work about one month to clear ten acres. This could be way off.
>
> Although I did not see it myself, my father enjoys telling of a man who had to plant a crop to retain his homestead (the rule was that the land had to be lived on and farmed). The man removed the underbrush and ringed the trees, then sowed his crop between the trees. He not only retained his homestead but harvested an excellent crop.
>
> Land in that area was considered of little value. No fertilizer was or is used. The crops were rotated, and, in the last twenty years, tractors have allowed deep ploughing, Some of the fields cleared about 35 years ago are producing very little now. How this equates with Neolithic hand-dug fields is anyone's guess.
>
> Partially dried hardwoods were the preferred fuel for several reasons. Primarily, softwoods bum too fast and too hot; they will not provide a steady heat for cooking. They are excellent for starting fires. Hardwoods will provide a steady fire and do not require continuous stoking. This reduces the time spent tending the fire and also means less wood needs to be cut. Hardwoods do not spark like softwoods so are less dangerous for open fires.

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An experiment with stone axes

John Coles

During excavations in the peats of the Somerset Levels in 1975 and 1976, the Somerset Levels Project exposed the first completely preserved Neolithic hurdles in Britain. These hurdles, made of multiple rods of hazel and alder, had been laid down on the surface of a marsh in order to provide firm footing for Neolithic traffic in the later third millennium BC (Coles & Orme 1977). In order to discover the technology involved in the manufacture of hurdles, which were 2.7m long and 1.1m wide, an experiment was mounted in which identical hurdles were made, using stone axes, flint flakes, and no modern equipment. The work was carried out in Bradfield woods in Suffolk, and three- or four-year-old coppiced hazel was employed; in age and in diameter of wood, this matched the ancient hazel rods used in the marshes of the Somerset Levels, but there were some differences in the lengths of the rods due to the dry summers of 1975 and 1976. The full details of the experiment appear in a report in Coles and Darrah (1977).

Three Neolithic stone axes were used, hafted in ashwood handles without binding or glue of any sort. The length of the hafts was 0.6m, as longer hafts tended to vibrate when used against a hard wooden stump or stool of hazel. The work of clearing the hazel rods from the stools was carried out by three men, and rates of work and of clearance were recorded. The use of stone axes in felling slender rods appeared to be rather different from their use against standing timber. In the experiment, the heavy weight of the wooden hafts, allied to the sharp edge of the axes, served to chop through the outer part of the hazel rods without much difficulty, and after several blows, the rods could often be bent down and twisted away from the stool. This breakage pattern was exactly that observed on the Neolithic hazel rods. On occasion, the rods were more intractable, and a number of blows were needed before the rod could be detached by actual severance. In these cases, the stool was left in a severely damaged state, with fragments of rod bases sticking up at various

1 Clearing of hazel stool with stone axe (note damaged rod-ends on stool base)

2 Rods woven around sails to form the hurdle. The bases of the hazel rods have been let in at alternating opposite ends, in order to maintain an even weave

angles. The experiment will continue to observe the regrowth patterns on the stools so cleared.

The actual timing of the operation of clearing has to take into account the unfamiliar use of stone axes, and the fact that no axes were sharpened for this operation. Nonetheless, they proved to be eminently suitable for the purpose, and the felling of sufficient rods for a large hurdle took only about 30 minutes. This figure is an adjusted one for two men, who presumably would have ensured that the axes did not fall from the hafts through inexpert aiming at the base of the stool; in the experiment, the slightest deviation from the rod centre tended to loosen the axe, and on occasion this caused the axe to fly off into the underbrush. None was lost.

The experiment continued with the cleaning of the hazel rods, by removing twigs and branches and leaves. Thereafter, the rods were dragged to the assembly position, in a clearing in the coppice, and the rods were selected for length and evenness of diameter. Some of their ends were cleaned up by stone axe and flint flake saw, the stouter rods were placed upright in the ground to act as the sails (transverses) of the hurdle. The weaving of the rods around these sails took only 12 minutes, by which time about 70 rods were in place. The hurdle was then laid flat, its ends evened up by axe and flake, and it was then carried out of the woods. It weighed 30kg complete. The entire operation for two expert men would have taken only 1.5—2 hours, and it may well be that a specialist team of Neolithic woodsmen could have completed the job in approximately one hour.

Although this experiment did not specifically set out to examine the character of stone axes, it was apparent to all that they were extremely effective implements when used correctly. Accuracy in directing the blow was essential, and the necessity for a hefty handle seemed apparent. Given these logical elements, the axes proved entirely suitable for the task, which can hardly be a surprise in view of their long popularity in Neolithic Britain.

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Stone axes in ethnographic situations: some examples from New Guinea and the Solomon Islands

Patricia Phillips

Abstract

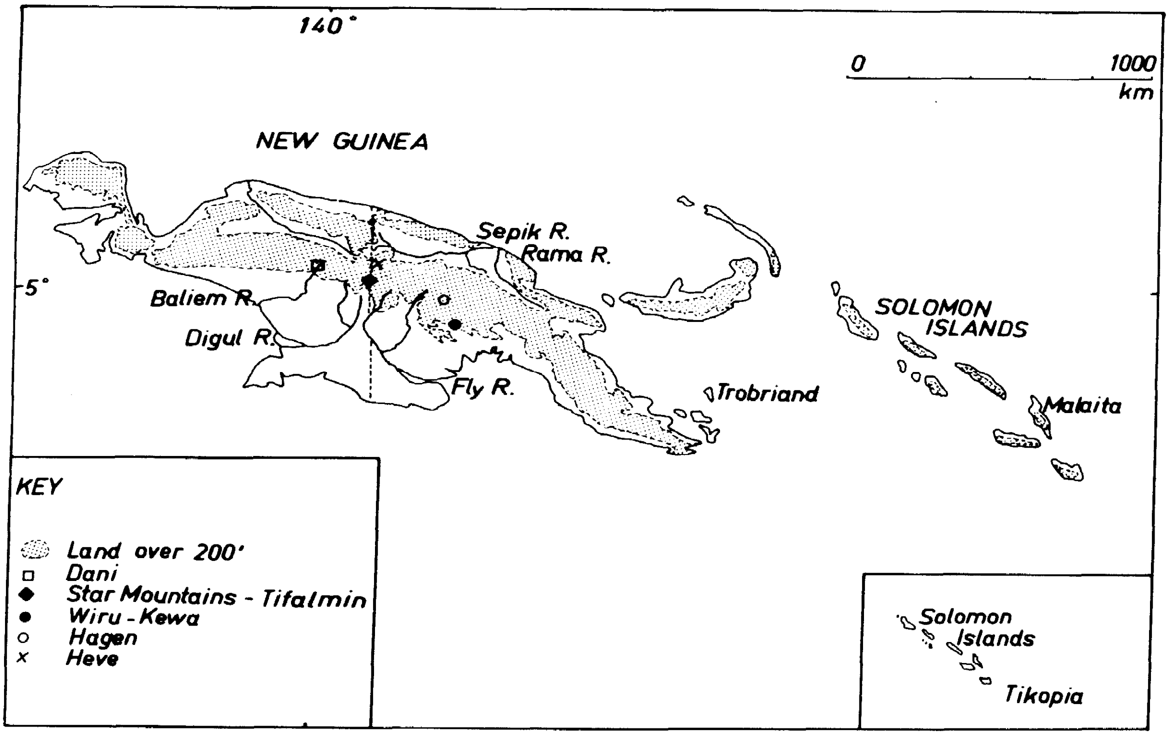
This paper examines anthropological evidence for the recent contexts of production, acquisition, and consumption of stone axes in New Guinea and neighbouring areas.

Introduction

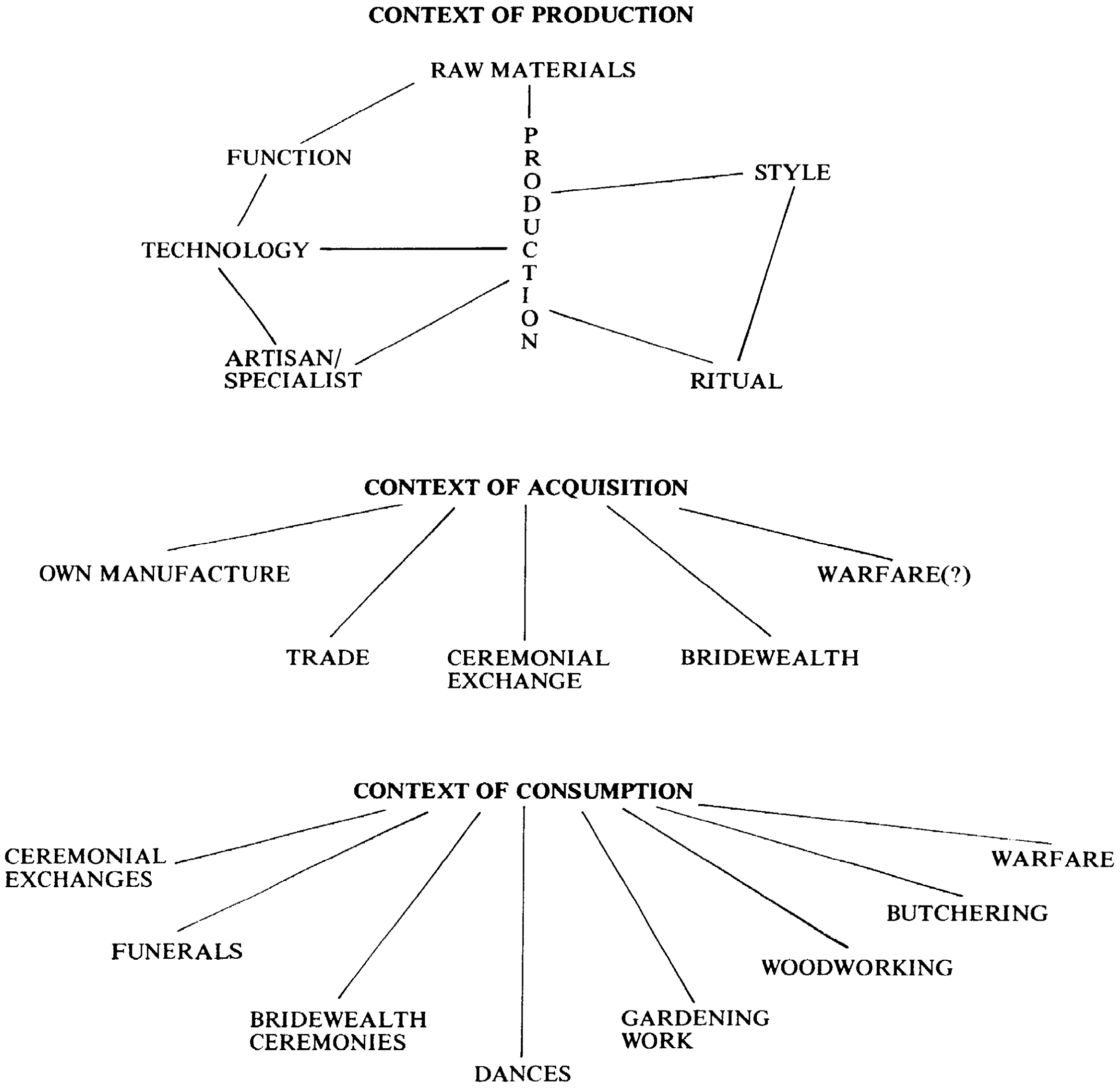
European overseas exploration from the 16th century onwards revealed the existence of peoples with completely alien technologies, economies, social, religious, and political systems, in the American, African, Asian, and Australian continents. For our purposes, the interesting aspect is the reliance of some of these societies on stone implements, which revealed to budding European archaeologists the likely role of similarly shaped stones found in their own countries. As Edward Lhwyd wrote in 1699, 'there are several stone hatchets found in this Kingdom, not unlike those of the Americans'. There are good data in the records of early explorers and anthropologists regarding the roles of stone axes and other ground stone implements in ethnographic contexts, but only in New Guinea have such implements been in use until recent decades.

New Guinea lies to the north of Australia, and forms part of the Pacific culture area (Fig 1). Along the centre of this large island run massive, deeply dissected highlands, only explored since about 1930 by Europeans and Australians. Much of the land is used for horticulture, with patches of secondary forest or thick grass being cleared for yam gardens. The varied resources between different ecological zones, plus an intensely competitive social life, led to lively trade and exchange of goods. Brookfield (1969) has described economic activity in the Pacific generally as being divided into socially derived 'prestations' and trading; within this great area, the most active trading took place in New Guinea and the Solomon Islands, and one such system, linking north-eastern New Guinea with New Britain and outlying islands, has been recently described by Harding (1967).

Research into stone axes and adzes was one of the



1 New Guinea and the Solomons, showing the location of the tribes mentioned in the article



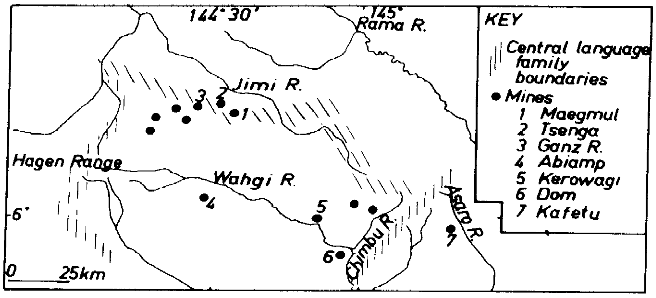
2 Contexts of production, acquisition, and consumption (the latter two are separated here following a suggestion made at the conference by A Selkirk, to whom the writer is grateful)

earliest aims of Pacific research; H D Skinner of New Zealand spent some 50 years acquiring and analyzing the Otago Museum collection of Pacific adzes. In 1959 Duff described the adze as the most important 'culture fossil' in Polynesia and Oceania, and he has used adze typology and distribution to test the theories of Pacific migration. Archaeological research is changing and filling out this picture, but there seems no doubt that in recent generations, and probably for long into the past, the 'polished stone work-axe was vital to subsistence' (Brookfield & Brown 1963, 61).

The most useful ways of studying axes in ethnographic situations are the contexts of production, acquisition, and consumption (Fig 2).

Context of production

Stone axes were replaced by metal in the Western Highlands of Papua New Guinea by at latest the mid-1950s, although poor quality axes are still being made for tourists. Chappell (1966) has made an exhaustive search of the area around Mount Hagen, and has identified thirteen source sites (Fig 3). The main material is a fine greywacke, but by petrological thin-sectioning, X-ray, and partial chemical analysis, Chappell has succeeded in distinguishing the products of the different sources. Hornfels comes from the Dom site where the technology employed is to set fires against the quarry or outcrop face, then to prise blocks loose with sharpened sticks, and wet-grind the resultant blocks. Only at Dom had the technique of sawing been used; here the hornfels



3 Western Highlands of Papua New Guinea: axe factory sites and boundary of Central languages group (after Chappell 1966, Strathern 1966).

was split into great flat slabs, each divided by grinding and sawing into rough-outs for two or three axes. Ceremonial blades from the recently exploited Maegmul mine, 300 m long, apparently took about three weeks to grind. Rarely, whole rock was traded from the quarry (eg from Abiamp to the Tuman people).

Stone from the majority of sources was made into axes of various sizes (Chappell wonders if this may be due to unpredictable splitting of the raw material) used for various functions. Most New Guinea axes can be divided by metrical attributes and hafting into work and ceremonial axes (Fig 4). The main interest was in serviceable working axes, and the Abiamp quarry, for instance, only produced work axes. Kerowagi only produced ceremonial axes, and the hornfels of the Dom site was made into the famous bride-price axes. Axe manufacture was not a fulltime occupation, and today only a few men continue the tradition.

The importance of petrographic features and technology in establishing sizes and shapes has not yet been assessed (but see Hughes 1977-Ed); there is a marked cross-sectional difference between axes from the majority of sites and those from the easternmost site at Kafetu. Cross-sections are 'planolateral' (round ended and flat sided) except at Kafetu, where they are lenticular. Bulmer and Bulmer (1964, 39) have suggested, on the basis of excavations, that the lenticular sectioned axes preceded the planolateral ones in the Highlands. Chappell and M Strathern do not report on any special ritual associated with the manufacturing process.

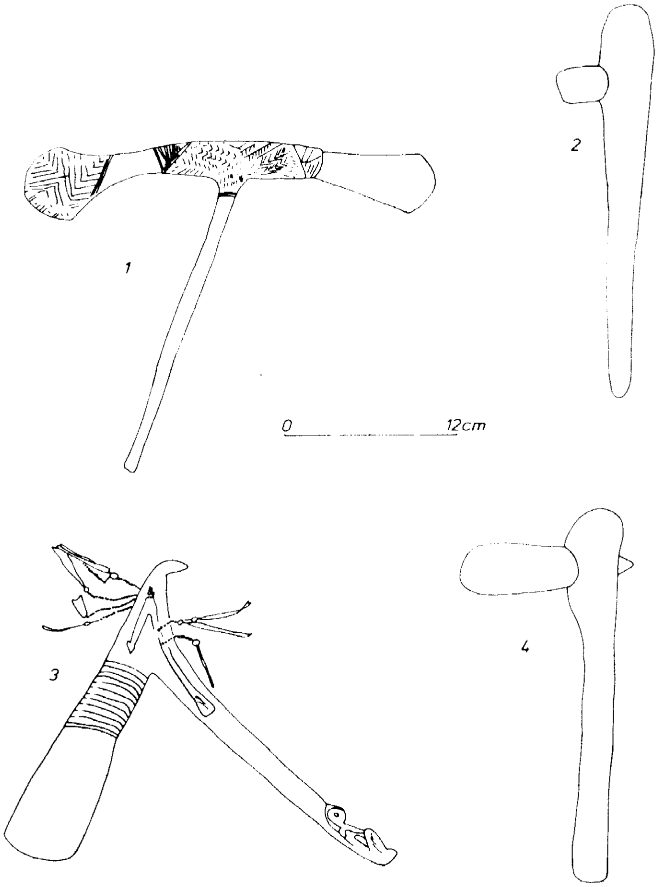
A contrast can be made between the people of the Western Highlands, close to the quarries, who can identify the sources of their axes with great accuracy and those of the Southern Highlands, who have to obtain their axes from the Westerners, and are only vaguely aware of their origins (M Strathern 1969). On Tikopia, the islanders are not aware of the sources of stone axes, although geology and petrographic analysis suggest that the island may contain sources of the volcanic raw material utilized (Firth 1959). On Malaita, Solomon Islands, stone axes ceased to be manufactured long ago, and any found are regarded as of non-human origin, 'the teeth of the thunderbolt' (Ross 1970).

Context of acquisition

Axes can be acquired by making them or obtaining them from their makers. Axe and pigs were highland products and feathers, plumes of the bird of paradise, and shells lowland products, in New Guinea. To obtain axes by direct trade with those who controlled the quarries, individuals or groups of men might travel to a source and trade a pig or cowrie shells for them. The Sibil of the Star Mountains acquired their adzes from a source some four days' journey away in exchange for tobacco (Kooijman 1962).

M Strathern (1966) has noted the difference in acquisition of Western Highlands axes by neighbours of the producers. The Western Highlands are occupied by speakers of the Central languages group. Despite the linguistic barrier, axes moved easily, at the western end of the area, to the Enga-speakers. Petrological analysis showed that, at the eastern end, the main Western Highlands sources, Ganz-Tsenga and Abiamp, were replaced by Kafetu source material. The mountains between the Chimbu and Asaro Rivers mark the break (Fig 3; Chappell 1966). M Strathern accounts for this difference in terms of the relative lack of exchange items to the east, whereas from the west, Enga-speakers traded with the Hageners, exchanging axes for pigs, salt, and palm-tree oil. Tree oil could be used for body decoration, and was important in bride-wealth payments.

Apart from direct trade, axes could travel via exchange partners, who would be friends or relatives by marriage. Here the mechanism was for an individual or



4 Work and ceremonial axes, Museum of Mankind, London: 1 Ceremonial axe, Upper Ramu River, nephrite blade, rattan bindings, 2 Work axe, Mimika River, hafted at junction of root with tree. 3 Ceremonial axe, D'Entrecasteaux Islands, greenstone blade, rattan binding, carved handle, beads, and pendants. 4 Work axe, Mimika River, greenstone blade in wooden haft.

group of men to take the time to visit neighbouring kinsmen or friends in the same or different language areas. Some men were involved through their clans in ceremonial exchange cycles, where large-scale down-the-valley exchanges of pigs and cassowaries — on long-term 'credit' — took place between 'Big Men' and their followers as the culmination of two or three years of initiatory gift movements (Meggitt 1973—4, discussing the Mae Enga). Such movements are illustrated in Fig 5. The acquisition of axes, the crucial agricultural tool, was a preliminary to the main exchanges; axes were at the basis of wealth, and wealth secured territorial integrity.

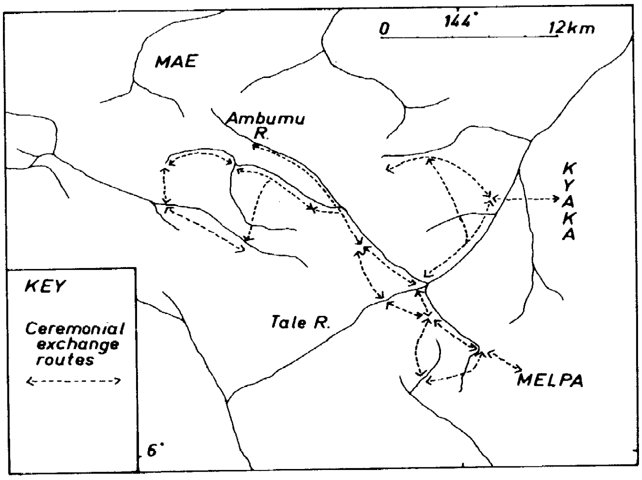
Axes were one of many items exchanged as bride-wealth. It has been calculated that they figured in about half the transactions of this nature prior to the coming of white men (Franklin 1965, discussing the Kewa in the Southern Highlands). By 1930—40 axes were less important proportionally among the Kewa and by 1940—50 had been entirely replaced, mainly by pearl shells, and to a small extent by steel axes and knives. In discussing bride-wealth, ethnographers emphasize that the exchanged commodity is not the woman, but gifts like pigs and shells going in opposite directions. Greater gifts go to the bride's family, who are losing her economic value and child-bearing potential. The usual social system in the New Guinea Highlands is of tribes organized into patrilineal clans, sub-clans, and lineages. Once a marriage has been arranged (and pressure may be exerted on the girl if a favourable bride-price is offered) the ceremony takes place on the dance ground of the bride's sub-clan (Franklin 1965). Payments are made by the clan of the groom to the bride's relatives, represented by her father. Among the Kewa, these may consist of four or five pigs, eight shells, and six other items; these gifts are redistributed to clan brothers and brothers of the bride. Then reciprocal payments of two or three pigs and three or four shells may be made to the groom's kin. Pigs, carrying bags, shells and axes, acted as bride-wealth in the Star Mountains (Pouwer 1964). The quality and contents of bride-wealth vary greatly within New Guinea, and according to the position of the bride's father and clan.

Historically, axes were used in warfare by some New Guinea peoples, and it seems theoretically likely, at least, that some may have changed hands on the battle-ground, as happened with arrowheads and spears (Gardner & Heider 1974, 140).

Context of consumption

M Strathern (1969) has given an excellent idea of the possible contrasts between two Papua New Guinea societies in their 'consumption' of axes. Because the Hageners live in the area of axe manufacture, they use axes in a wide range of practical applications, including garden clearing, cutting stakes for fencing, cutting timber for building, and roughing out wooden implements. M Strathern points to the use of chert flakes among the Wiru in the Southern Highlands, who had fewer axes; her impression was that here 'the axe tended to be reserved for the jobs only it could do' (1969, 319). Thus the Wiru, for example, used chert flakes for making wooden bowls and bamboo knives for butchering. Strathern gives a list of the basic horticultural, craft, and household uses of the axe.

Gardner and Heider (1974) have reported on a tribe only recently contacted by European culture, the Dani of the Beliem Valley, West Irian. The Dani still use axes for horticulture and wood working, and for splitting firewood (both the Hageners and the Wiru use wedges for this). The Dani also use axes for sharpening digging sticks, and butchering pigs. The Heve, on the Wogamus River, use diorite adzes for felling most timber, and a cylindrical diorite tool, the *ipe,* to cut down the fibrous sago palm (Townsend 1969).



5 Ceremonial exchange movements among the Mae Enga (after Meggitt 1973-4, Fig 2)

Other contexts of consumption of axes were in the ceremonial exchanges and bride-wealth ceremonies already mentioned; here axes acquired at previous ceremonies might change hands again. Axes could be offered to a sub-clan or lineage at death or illness (Meggitt 1973—4). Meggitt (1964, 215) also mentions the wearing of axes by young bachelors at dances during bachelors' festivals among the Mae Enga, and even in areas of New Guinea where use of stone axes has been abandoned for several decades, ceremonial or 'walk-about' axes of large size but poor quality are still worn at dances.

The dance ground or ceremonial ground in the Highlands usually lies in front of the cult house of the village; among the Tifalmin this is distinguished only by painted boards set before it (Cranstone 1971). Only men are allowed within it, and important ritual objects would be stored in it. Cranstone, discussing how little would be left of Tifalmin material culture for the archaeologist, mentioned that two stone club heads (never used) lay inside the Tifalmin cult house, and that other stone heads painted with red ochre were piled outside the district cult house. The Dani still keep sacred stones in the men's house, and these are displayed at funerals to placate the ghost of the departed. At the same funerals axes are used to cut joints from the fingers of the relatives of the deceased, likewise to placate his or her ghost. A series of finds from beside deserted ceremonial houses was made by Aufenanger: these include perforated axes, perforated club heads, bird figurines, and mortars. Their original role cannot be certain, but their burial in this context must be significant (Aufenanger 1960). Knobbed or 'pineapple' clubs occur in New Guinea and the Solomons (eg Starzecka & Cranstone 1974, Fig 6, a); morphologically there are resemblances to some Neolithic carved balls from Scotland. Bulmer and Bulmer (1964) have examined several hundred similar finds of ground stone tools and vessels from the Highlands; most are of volcanic stones and probably of local manufacture, since half-finished examples are known. They are used today as magic charms in fertility and prosperity cults, but were probably originally used for both practical and cult purposes, for example clubs in warfare, mortars for grinding poison to put on arrowheads, grinding ochre, or preparing cult medicines.

In the Solomons axes were used for tree cutting, canoe building, and warfare in earlier days (Starzecka & Cranstone 1974). Today axes are only used in ceremonies. On Malaita social and priestly leaders carry them as badges (Ross 1970). On Tikopia stone axes are full of *tapu* or sacred importance, and are carried at ceremonies, sometimes hafted, sometimes unhafted in baskets. However, the most important and sacred axes on Tikopia were made of clam shell (Firth 1959).

Conclusion

Within the context of production, there are good data on sources, raw materials, and technology from the Western Highlands of New Guinea. The axes seem to have been made by non-specialists. Functionally. the most marked division is between the work axe and the ceremonial axe. Style, which can be expressed as the culturally determined or traditional element in manufacture, cannot yet be defined until the limitations imposed by the raw material and technology have been identified. Equally, ritual, which may oblige the craftsman to follow certain rules of manufacture, or enact magical rites during manufacture, is not identifiable from the ethnographic literature.

Constraints on acquisition of axes are linked to social factors; to the availability of local materials or products to exchange against axes; and to the presence of other materials which could be used in ‘axe’ functions, for example, clam shell and chert. The possible effects of language barriers in limiting movement are also interesting.

Within the context of consumption, the practical applications of the axe or adze are similar, though not identical, throughout New Guinea. The variability apparently relates to local availability of the implements. Stone axes functioned as wealth in various exchanges and ceremonies. Both work and ceremonial axes might also be used in warfare.

More data are needed on the contexts of production, acquisition, and consumption of axes in New Guinea; study of recently contacted groups is particularly important. Much of the data obtained so far is the work of a very few ethnographers. The information presents a scanty if provocative glimpse of geographical variation in production or acquisition of stone axes, and of their consumption. The data emphasize the individual nature of each society’s view of the axe in solving problems of subsistence, territorial integrity, and personal or group success, and in warding off threats of religious or magical origin.

For archaeologists it is significant, if unsurprising, that variability in stone implement form and finish reflects variations in production behaviour. We can test the proposition that this applied in the past by, for instance, experimental manufacture of axes in the same materials and in the same forms as prehistoric ones. The subtleties of acquisition and consumption behaviour would be harder to test, but might be suggested by inter-regional distribution of particular implements, or the distribution of implements within the settlement or cemetery. However, while data from ethnographic situations are of interest to the prehistoric archaeologist, the following limitations must be borne in mind: that there can be no one-to-one comparisons between the recent past of New Guinea and the Solomons, and the Neolithic and Early Bronze Age of Europe; that the role of ethnography is to stimulate questions to be asked of archaeological data; and that even a very extensive knowledge of ethnographic data will never provoke all the possible questions that could be asked.

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Petrology and prehistory: lithic evidence for exploitation of stone resources and exchange systems in Australia

Isabel McBryde

(with an Appendix on the petrology of the greenstone quarries and their products by Alan Watchman)

Abstract

In Pacific and Australian studies at present both prehistorians and anthropologists are devoting considerable attention to exchange systems, aware of their vital role in culture. This paper surveys current archaeological investigations in these regions concerned with exchange systems and the distribution of goods. In Melanesia much work has concentrated on entire trading systems, often combined with ethnographic research, as well as studies of the distribution of individual components such as axe stone. Melanesian and Polynesian obsidian sources provided valuable exchange items carried over great distances by sea; the tracing of this movement in time and space has stimulated important studies involving sophisticated geochemical characterization analyses.

In Australia archaeological studies of exchange are recent developments. They include studies of the lithic resource bases represented in the assemblages from excavated occupation deposits, and petrological analysis of collections of ground edge artefacts to identify quarry sources and the distribution networks based on them. The results and research strategies of two projects of this kind are discussed, both aimed at greater understanding of the exploitation of material resources, and of lithic technology and exchange between communities. One study was based on axe collections from the New England region of New South Wales, the other on investigating the greenstone quarries of south-east Australia including the well-known site at Mt William, Victoria. Both produced evidence for spectacular distribution of stone material, with important implications for the interpretation of prehistoric exchange systems and social inter-relationships.

The island worlds of Melanesia and Polynesia

Throughout Australia, Melanesia, and Polynesia there is growing awareness amongst prehistorians that exchange may play a vital role in culture, and a concern to investigate this, combining ethnographic studies of existing trading and exchange systems with the use of archaeological techniques to probe their past. For example, trade and exchange in Oceania and Australia was the theme chosen for a symposium to celebrate the sesquicentenary of the Australian Museum, Sydney, in August 1977. In recent studies of trading networks in Melanesia, where they are extensive and may be investigated ethnographically, the approach is geared to analysis of the entire system, rather than of single components within it (Lauer 1970; Hughes 1977). Such work is in progress on the island trading centres of southern Papua, by Irwin (1974) on Mailu, and Allen (1977) on Motupore. Yet valuable results have come from studies of single elements of the systems, such as Chappell's work (1966) on axe quarries in the New Guinea Highlands and the distribution of their materials and Ambrose's investigation (1976) of New Guinea obsidian sources and trade. Chappell used thin-section identification. Obsidian, being a glass, is not amenable to thin-section study, and Ambrose has employed a variety of methods of trace element analysis to determine the chemical characteristics of the various sources. In the same programme Ambrose is studying hydration layers of specimens from various sites and their use in establishing chronologies for the exploitation of the different sources. Five major obsidian sources seem to be involved and the distribution of their products (widespread in both time and space) is of significance for the interpretation of Melanesian prehistory (Key 1969; Ambrose & Green 1972; Smith 1974; White & Specht 1973; Specht 1974; Ambrose 1976).

Obsidian occurs in relative abundance also in the volcanic islands of Polynesia. Studies of source areas here are adding considerably not only to our knowledge of obsidian and the problems of source characterization but also to the developing picture of Polynesian prehistory. New Zealand scholars have been prominent in this work, which involves sophisticated geochemical studies and computer analyses (Reeves & Armitage 1973; Ward 1974a; 1974b; Reeves & Ward, forthcoming; Green *et al* 1967; Armitage *et al* 1972; Leach, work in progress). The distinctive New Zealand greenstones favoured for making ceremonial objects offer scope for significant contributions to prehistory by petrological analyses in this part of Polynesia (eg Orchiston 1975).

Australia

The volcanic glasses on which most of the recent source characterization and trade studies have concentrated in the island worlds of Polynesia and Melanesia are relatively rare on the Australian continent. Different cultural contexts for trade and exchange may also be created in the hunter-gatherer societies of a large continent as compared with those of sea-going, island-based horticulturalists. Yet for Australia recent ethnography records the existence of extensive exchange systems. In these the economic aspects of the transfer of materials were often subordinated to ritual and social needs, while large ceremonial meetings and inter-tribal gatherings could provide the opportunities for barter. The distances over which goods travelled frequently rival those involved in the sea-trade networks of Island Oceania. These exchange systems provide vital clues to understanding the development of culture in the present, and the diffusion of certain cultural traits. Their past history is therefore of considerable interest.

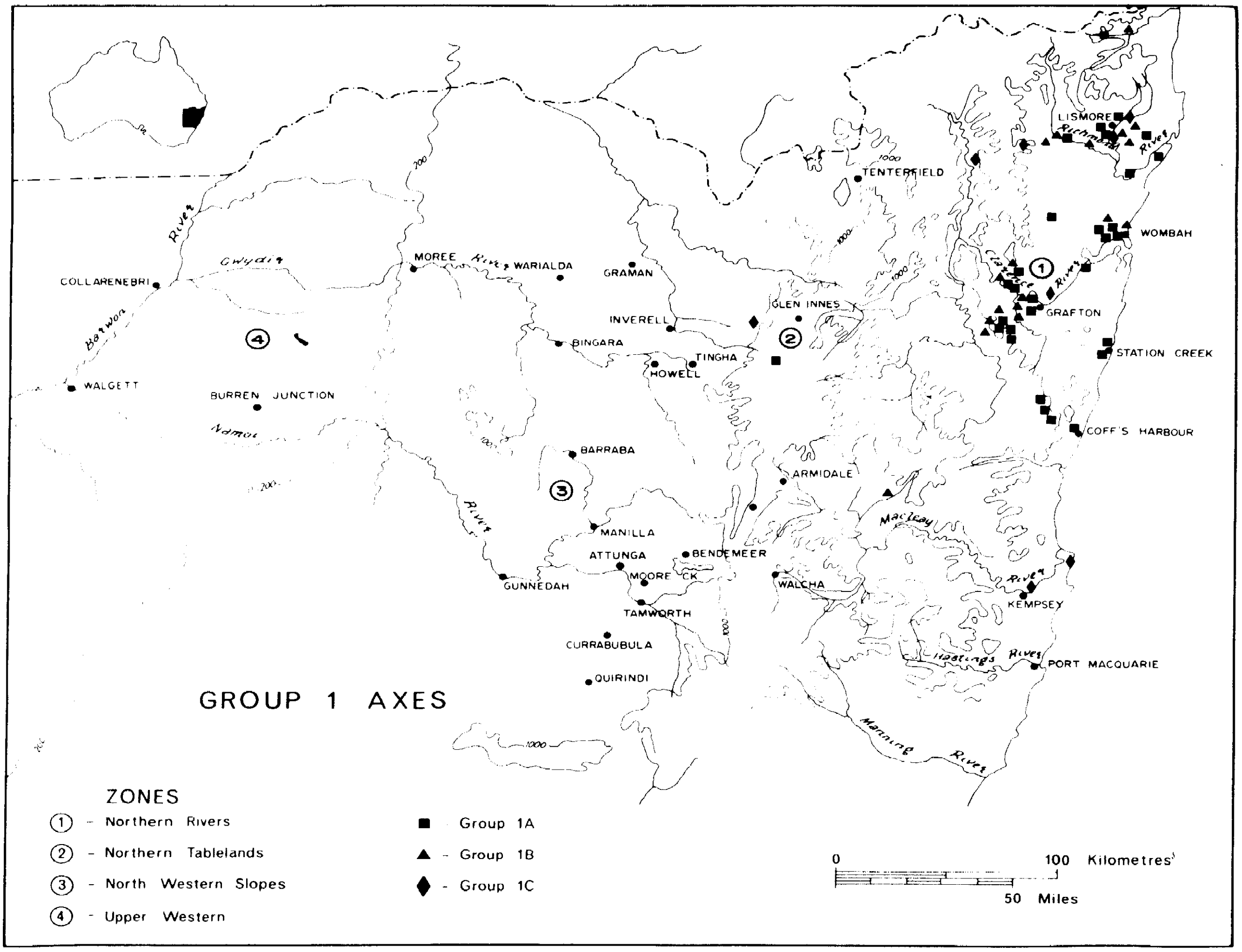
Combined petrological and archaeological studies of the evidence for past dispersal of stone material are still new in Australia. Yet McCarthy published (1939) a survey of the historical and ethnographic evidence, which raised many questions to which such techniques could contribute, as does Mulvaney's recent discussion (1976) of similar evidence. Thomson's (1949) analysis of ceremonial gift exchange cycles in Arnhem Land demonstrated much of relevance to prehistorians, but was paid insufficient attention. Certainly this is understandable, given the concerns of Australian archaeology in its pioneer decades with chronology and culture sequence. It has meant, however, that economic prehistory, directed to studies of trade and exchange, and making use of petrological techniques, is only beginning here. Yet such studies could contribute significantly in documenting the movement of certain classes of goods, certain components of a wider range of exchange, the less durable elements of which have not survived in the archaeological record. Recent ethnography cautions us to view the distribution of lithic material as but part of wider exchange systems involving many classes of goods, not as a single entity, as 'axe trade' (or spearhead or grinding slab) developed in isolation to meet specific technological needs. The needs no doubt existed, and were catered for, but in the context of an exchange network of greater complexity than is envisaged in our concept of an axe trade and the exploitation of certain quarry sources to supply a specific demand for one class of raw material.

The studies that have been undertaken so far in Australian archaeology fall into two categories. In the first, analyses of the lithologies of excavated site assemblages provide clues to the movements, contacts, and exchange sources of the human groups responsible. In the second, more far-reaching petrological analyses of large artefact collections concentrate on certain classes (such as groundedge tools), which may require raw materials of a specialized kind not found in all geological environments and so necessitating movement of goods. These may provide clues to wider patterns of exploitation of resources to sustain lithic technologies and to the existence of exchange or trade systems. It is important that both approaches be developed, as they can yield valuable and often complementary evidence. Limitations are imposed by the need for more detailed geological field mapping in many parts of the continent, and the widespread occurrence in many quite extensive regions of the rock types used for tool making, Identification of exact source outcrop may involve intensive field and laboratory work. Time and continuing geological research should gradually minimize these limitations, but at present they often create an inevitable area of imprecision where precision is essential. That dated assemblages with sure archaeological context are still few (considering the size of the continent) imposes further limitations, while additional restrictions arise from the fact that, as yet, for many regions our knowledge of the antiquity and associations of artefact types is insufficient. Studies based on large museum artefact collections, mainly composed of surface finds, at present lack both time depth and cultural context. So, though similar in many aspects to the study of Neolithic axes in Britain, they lack the control that investigation could impose on a sample the date and cultural context of which could be derived from its typology. So far studies both of excavated assemblages and of museum collections have been developed mainly in south-eastern Australia. Here the available ethnographic data on traditional culture are less satisfactory than for Central Australia or the north; even for the recent past there is greater dependence on archaeological evidence to reconstruct aspects of material culture.

Analyses of the lithologies represented in excavated assemblages have been made by Branigan and Megaw (1966) for the Curracurrang rock shelter near Sydney, showing the lithic resource base for hunter-gatherer groups occupying that shelter over a considerable period of time. Work on coastal sites south of Sydney, and in the southern uplands dating to the last 5000 years has shown the importance of silcrete in the backed blade industries of the middle phase of the three-part industrial sequence documented on the sites. The decline in the use of silcrete for tool making coincides so neatly with the decline in the use of backed blades, together with an increase in the use of quartz and of the number of quartz bipolar pieces, on sites of the last millennium, that Flood (1973) named the last phase of prehistory in the area 'The Quartz Period' and used the relative frequencies of quartz and silcrete in assemblages as 'cultural markers'. Sources of silcrete are widespread along the coastal strip south of Sydney; the material would have been available in the local environment for most areas throughout the periods involved (Hughes *et al* 1973). In Tasmania, an island isolated by post-Pleistocene sea-levels from the technological changes expressed in the backed blade tradition, Jones (1971) still found changes in technology associated with changes in favoured raw materials. In the assemblages of the Rocky Cape caves he recorded increased use of fine grained exotic raw materials in the period after 8000 BP (Jones 1971,441).

Detailed examination of lithologies of the assemblages from the Seelands rock shelter near Grafton on the Clarence River in New South Wales (Fig 1) (McBryde 1974, 347—52) revealed interesting changes in the use of raw materials, both locally available and imported, during the 6000 years of occupation (McBryde 1974, 234, 261). In the pebble-tool component of the flaked-tool industry there was a complete change in the range of rock types selected at the nearby gravel beds of the Clarence from the earlier levels of the site to those of later occupation. In levels dating to the present millennium there appears for the first time a range of banded cherts used to make the small scrapers, adze flakes, and backed blades. This material comes from mountain ranges on the northern fringes of the Richmond River valley 128km distant (Fig 1). The distribution of lithologies used for groundedge tools in the Richmond and Clarence valleys showed movement of greywackes obtained from the Clarence gravel beds to the Richmond valley, perhaps as part of the same exchange system (Binns & McBryde 1972, 9—16). Tribes from both valleys often met in the Copmanhurst-Seelands area for ceremonies (Binns & McBryde 1972, 82). Axes of greywacke reached the estuaries of both rivers, though this may betoken seasonal movements of local populations as much as barter or exchange between coastal and inland groups (McBryde 1976).

Similar examination of the lithologies of the assemblages from the Graman rock shelters on the western slopes of the Great Dividing Range (Fig 2; McBryde 1968; 1977) revealed a contrasting situation.



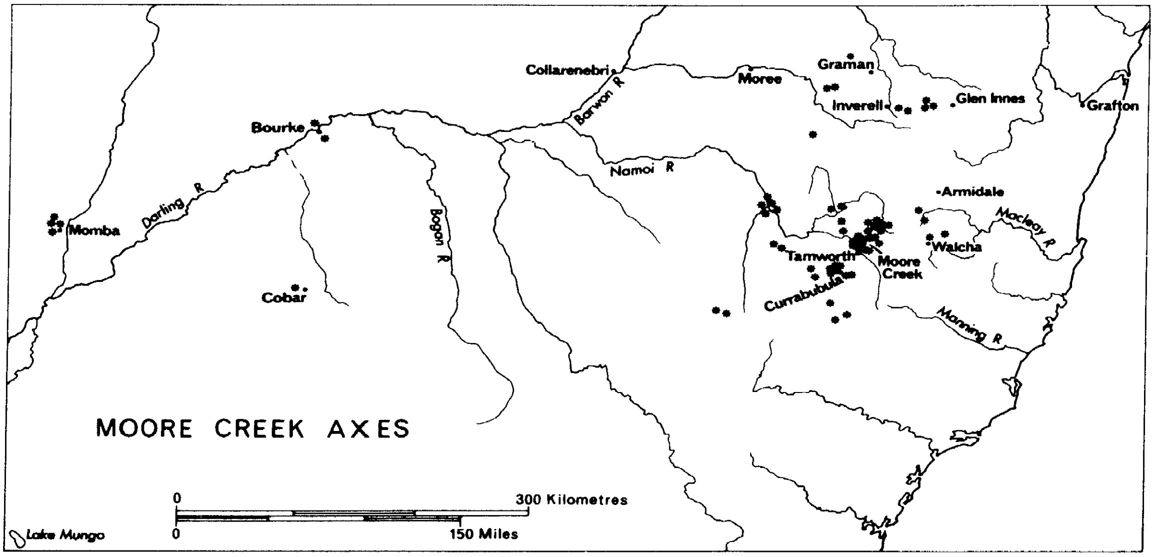
1 Distribution of edge-ground artefacts of Group 1 greywackes in north-eastern New South Wales. Each symbol represents a specimen. The source area for these greywackes would lie in the uplands north-west of Coffs Harbour. These rocks form the bulk of the detritus carried by the Nymboida and Mann Rivers, and tributaries of the Clarence (after Binns & McBryde 1972)

In the flaked-tool component of the industry there was consistency over time (some 4000 years) in the use of locally available quartzites, chalcedonies, and quartz. Ground-edge tools included exotic material, from the Moore Creek quarry near Tamworth, 160 km away (Fig 2). Axes found on the surface of the deposit are made of a distinctive pyro-metamorphosed bole, derived from a contact zone on Gragin Peak 8 km to the south-west. None of this material occurred in earlier occupation layers. Presumably therefore use of this source post-dates the most recent occupation layers belonging to the early first millennium AD.

In the Perth district of south-western Western Australia field surveys have shown a consistent appearance on certain sites of flaked tools manufactured from a distinctive fossiliferous chert. Local outcrops of this material must occur west of the present coastline; their exploitation therefore should belong to an early phase of local prehistory, in the Pleistocene or early Holocene (Glover & Cockbain 1971; Hallam 1972, 14—15). Tools in this chert have not been found in excavated sites dating to the recent period in that area. Its appearance on sites in the region might well be taken as a chronological marker. Confirmation of the hypothesis may be seen in recovery of tools in this chert from levels of the Devils Lair cave site near Cape Leuwin dated between 12000 and 19000 BP. Quartzite artefacts occur throughout the deposits which date from 12000 to beyond 25000 (Clover 1974; 1975).

Petrological studies of ground-edge tools from northern New South Wales

More extensive investigations were undertaken by Binns and the writer (1969; 1972) for northern New South Wales, analyzing available collections of edge-ground tools. In inspiration and methodology this research project owed much to the classic British study of museum collections of Neolithic axes. Indeed it began as a pilot project testing the applicability of that investigation's approach to Australian problems, within the general context of the writer's regional survey of



2 Distribution of edge-ground artefacts derived from the quarry on Mt Daruka at Moore Creek (Group 2B, andesitic greywacke). Each symbol represents a specimen

New England (McBryde 1974). It was the first project of its kind in Australia. Like the British study it aimed at information relating to the exploitation of raw materials, the use of quarry sites, and the dispersal of their products as clues to trade in the prehistoric economy. Our approach was to identify the lithologies represented in a sample (over 500 specimens) of ground-edge tools from the area under review. The majority of ground-edge tools was designed for use as the heads of short-handled tomahawks rather than of long-handled axes, though often for convenience in the literature referred to as axe heads. Some ground-edge chisels and knives are also known from ethnographic collections of hafted specimens. However all have similar and specific requirements in terms of raw material, that it be fine-grained, hard, and tough, and capable of withstanding continual impact. Suitable material may well be rare, and form the basis of exchange or trade networks. In our study identification of the lithologies was based on thin-section work, adequate for sourcing the rock types represented. The collection comprised ten major groups of lithologies, which we attempted to trace to their source, locating specific quarried outcrops where possible. Distribution maps were built up for each to show patterns of dispersal or concentration.

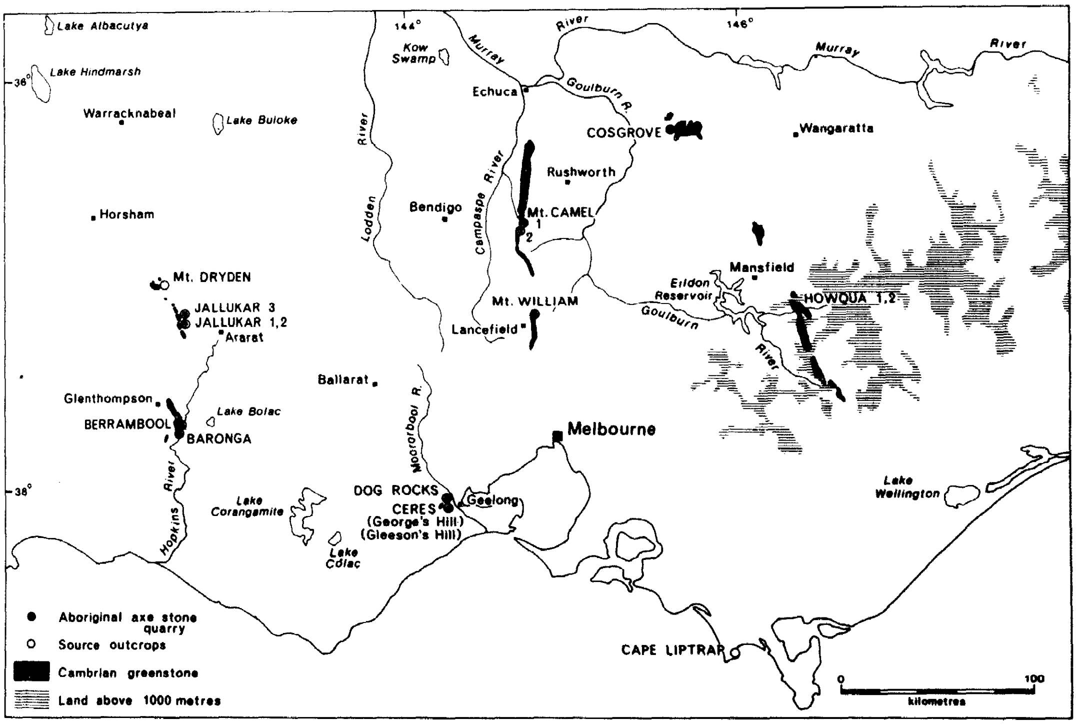
As this study has already been published (Binns & McBryde 1972) there is no need here to give detailed discussion of its results. However it may be appropriate to indicate the main trends which emerged, and also some of the problems encountered; they may well be relevant to the planning of research designs for such studies. Sample size and sample selection are obvious sources of difficulty in such investigations. Our sample could be considered large but, in terms of the geographical area involved might well be considered inadequate: furthermore it was impossible to gain an even coverage for the area as a whole. Sample selection was hardly in the control of the investigators, given the material at our disposal. We studied all available collections in state and local museums, as well as artefacts acquired from the writer's own field reconnaissance and excavations. The majority of specimens, however, had come to the museums from amateur collectors; it had little documentation and its archaeological context was uncertain. Indeed several large collections could not be included because they were inadequately provenanced. These factors also denied to the project any time depth within which to assess the spatial dispersal of artefacts; very few specimens in our sample came from dated contexts. Interesting changes in the observed patterns of dispersal over time would therefore be masked. Given the nature of the sample, its size, and the size of the geographical area involved, the presentation of distributional data was kept at a very simple level. The sample was insufficient to support the more sophisticated analyses one would wish to apply to larger samples with tighter control of selection.

The aim of the project was to test the feasibility of such an approach, given limitations which only many years of archaeological and geological research would remove. It showed that such studies could yield useful data, even using the somewhat inadequate evidence available. The fact of dispersal was fully documented in the New England study; its interpretation of course raises many other questions. The distributions of the ten lithological groups distinguished combined to create consistent patterns of concentration and dispersal across the geographical area investigated. For several groups there was widespread distribution from the northern tablelands along the courses of the westward-flowing rivers to the Darling Basin, 800 km distant. Central to this pattern was the spread of tools derived from the outcrops of andesitic greywacke on Mt Daruka at Moore Creek (Fig 2). In contrast the valleys of the Richmond and Clarence Rivers on the adjacent coastal plain seem to have been cut off from the exchange systems or contacts which distributed these resources of the plateau (Fig 2). These two valleys form an isolated entity; stone material is exchanged between them, but not acquired from outside, nor distributed thence. Illustrating this is the distribution of artefacts of Group 1, greywackes of acid volcanic provenance outcropping on the eastern margins of the central complex, near the headwaters of streams flowing into the Clarence (Fig 1). Geologically their source lies in the uplands, but in terms of human exploitation their source is the gravel beds of the middle Clarence to which they are carried in river detritus. However, human agencies alone account for their distribution to the Clarence estuary and to the Richmond valley 120 km to the north.

Of the known quarry sites in the region we may distinguish those such as the Moore Creek site the products of which reach distant areas (Group 2B; Fig 2) from those which seem important only for more local markets such as that near Wilson's River, Tia (Group 8C axes; Binns & McBryde 1972, 44–50, 66). An intermediate range seems involved for the Mt Foster and Mt Harris quarries , on the Lower Macquarie River, whose material is found from Dubbo to Brewarrina (McBryde, work in progress). This poses interesting questions since these sites are near the Barwon, in territories crossed by the distribution routes of the materials that travel from New England to the Far West (eg Groups 2, 5, and 10; for the dispersal of Group 2B, see Fig 2). Certainly the western river systems seem vital to this pattern, especially in the arid western plains. Dated examples of ground-edge tools of Moore Creek stone suggest that the use of this quarry has an antiquity of some millennia (Binns & McBryde 1972, 65, 78–9).

Mt William and other quarries in Victoria's greenstone belts: distributional studies

Recent investigations by the writer on the distribution of groundedge tools derived from quarries in the greenstone belts of southeastern Australia (Fig 3) invited different strategies (McBryde & Watchman 1976) . Rather than taking a collection of artefacts, defining the lithologies present, and tracing their sources, the thrust has been reversed. Starting with a large quarry site known from ethnographic accounts to have been an important source, we defined its material, and then traced its products in the museum collections, thus building up data on their distribution. The catalyst for the investigation (which began at the conclusion of the New England project in 1972) was the ethnographic record. It documents the quarry site on the slopes of Mt William north of Melbourne (Figs 3 and 8) as a major source of stone for tomahawks, being greatly prized and traded over hundreds of miles to areas of New South Wales and South Australia (Blandowski 1855, 7–8; Guthridge 1910, 6; Smyth 1878 , **I,** 181, 359; **II,** 298-9). The quarry was still in use when Melbourne was first settled in the 1830s, its operation controlled by strict conventions. The outcrops were owned by a group of the Wurundjeri tribe, and only members of a certain family were permitted to work them. The last man responsible for working the quarry, Billi-billeri, died in 1846 (Howitt 1904, 311–12; Fison 1890, 53). This ethnographic evidence and its indication of the date when the quarry was last used gave new dimensions to the archaeological study, and added some chronological control. This aspect justifies extensive use of available ethnographic data on exchange, trading centres and trade routes, tribal territories and traditional patterns of contact or hostility between groups, in assessing the final distribution data. It is hoped that future archaeological work in Victoria will add depth to the time perspective, allowing us to see the antiquity of any patterns that may emerge. At present there are too few excavated assemblages of ground tools from sites in south-eastern Australia to permit investigation of this aspect.

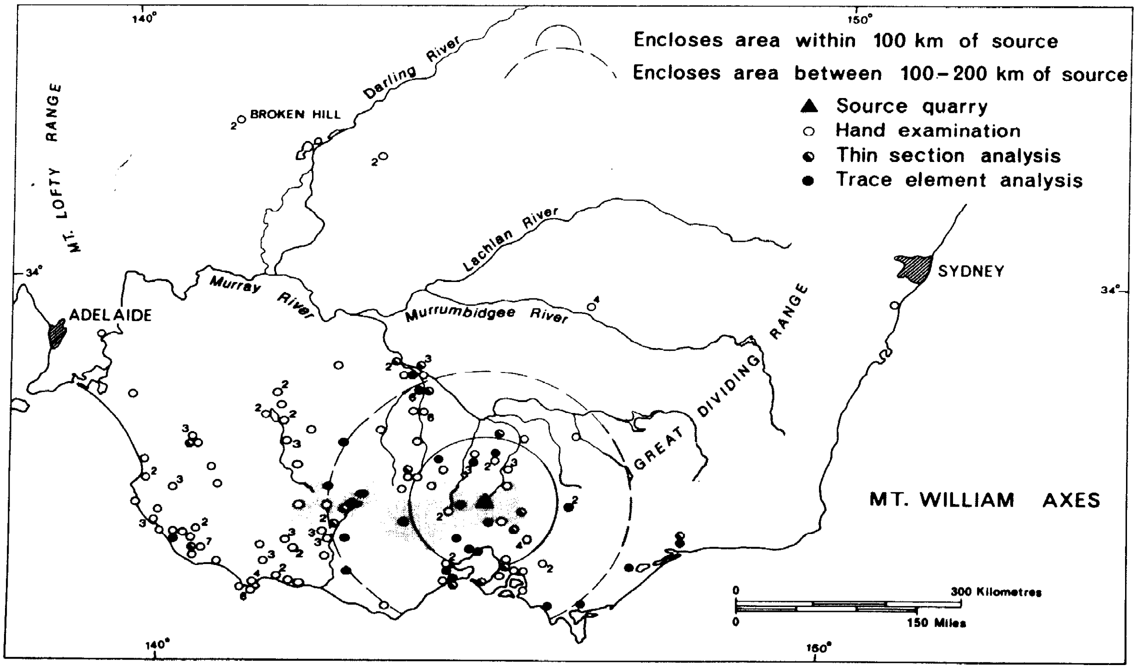


3 Quarry sites in the greenstone belts of Victoria

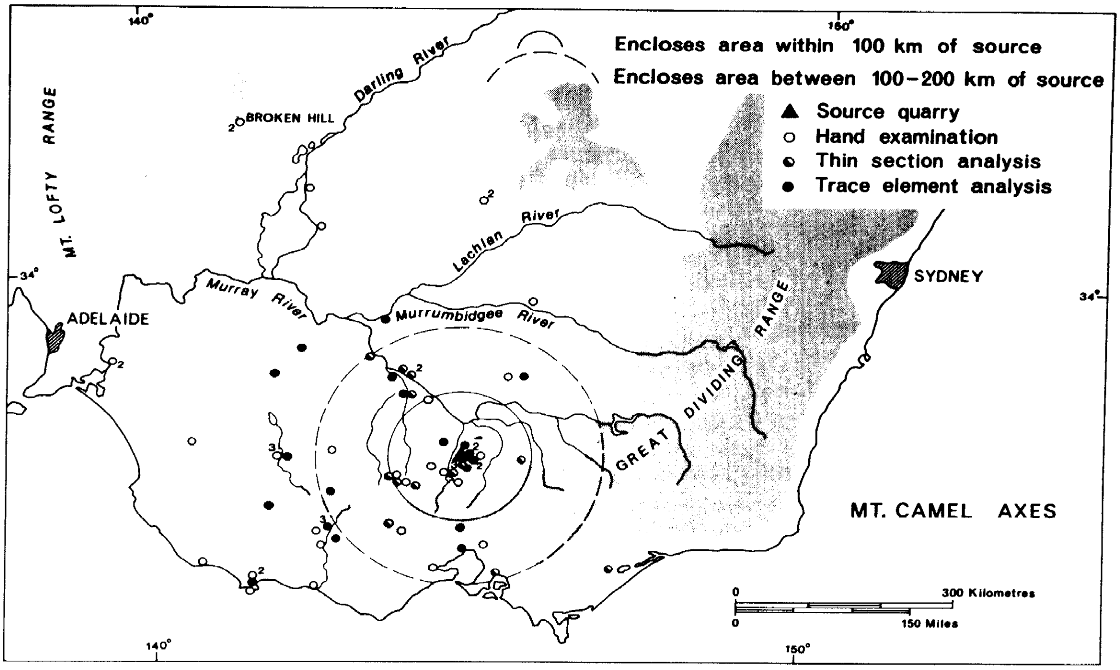
The outcrops quarried at Mt William are of altered and metamorphosed igneous rocks, often referred to in the literature as diabase but best described as hornfels (for a full description of this material and that from the other major greenstone quarries, *see* Watchman, Appendix). The Mt William stone is fine-grained, hard, and tough, superb raw material for a tool to be subjected to heavy use. In the greenstone belts of Victoria outcrops of similar stone are relatively frequent (Fig 3). We found that though the early ethnographic record stressed only one quarry, others did exist. Had they been exploited at an earlier period, or were the 19th-century writers on Aboriginal culture unaware of their existence? So, what had begun as a straightforward project defining the distribution of artefacts quarried from Mt William and then assessing the importance of this site in 19th-century exchange systems became a more complex investigation. It became more complex not only in terms of the archaeological and ethnographic implications, but also in terms of the petrological studies involved. The other quarries in the greenstone belts, at Mt Camel, Howqua, Geelong, Jallukar, and on the Hopkins River (Fig 3), produced material in some instances indistinguishable from that of Mt William in hand examination or thin section (Fig 9). So we were dealing with distributions to which all quarries could have contributed, and their individual role had to be assessed. This necessitated exact characterization and identification of each, posing problems of considerable complexity for the petrologist as the parent material and the processes of alteration for the rocks of most quarries were identical (Watchman, Appendix). Unlike the New England study, the main technique of identification could not rest with thin-section analysis, much less hand examination. Only the Berrambool site on the Hopkins River had material sufficiently distinct to allow safe sourcing by thin-section and macroscopic examination. For the stone from the central Victorian quarries (Mt William and the two Mt Camel sites) geochemical analyses were needed to match artefact with quarry source. These involved both major element and trace element studies (McBryde & Watchman 1976, 166—8). In the trace elements, plots of proportions of yttrium against strontium and yttrium against zirconium provided useful discrimination between Mt William and Mt Camel material, but neither trace element work nor that on major elements was fully conclusive. X-ray diffraction studies were made, but provided little definitive data. These problems are discussed in full by Watchman (Appendix).

The petrological aspects of the project involved more than laboratory identification of quarry material and archaeological specimens. Field studies were made of all quarries, to assess their geological context, and to collect data for reconstruction of the formational process responsible for the alteration of the parent igneous rock (Watchman 1977).

The archaeological aspects of the project included field investigations of the quarry sites, sampling them, as well as mapping and recording their worked outcrops and features as clues to the methods of exploitation. The artefact collections were also analyzed, in metrical and typological studies aimed at determining the inter-dependence or otherwise of design features which may relate to local stylistic preferences, to function, or to the qualities of the raw material used. The sample at present numbers over 1400, culled from major collections in the state museums of Victoria, New South Wales, and South Australia, the National Ethnographic Collection in Canberra, and numerous private, university, and local collections. This sample was selected after



4 Distribution of edge-ground artefacts derived from the Mt William quarry. The different bases of identification are indicated, also the number of specimens from a particular locality if there is more than one



5 Distribution of edge-ground artefacts from the Mt Camel quarry. The basis of identification is indicated, also the number of finds from any one locality

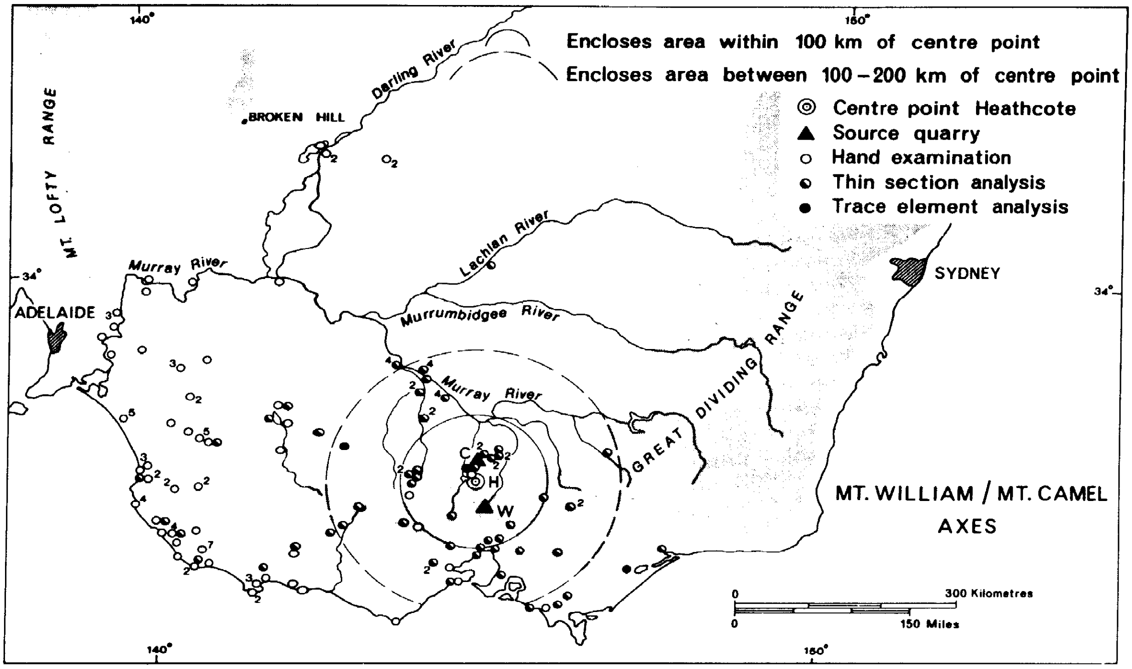
examining collections from the total area of the three states involved, thus covering all of south-eastern Australia, casting our net wider than the area indicated as relevant by the ethnographic record. This seemed a wise precaution. Numbers of non-greenstone axes were also noted, so there are some data on the relative proportions of the total composed by different lithologies for all regions.

The distributions of specimens now firmly identified for three of the greenstone quarry groups, Mt William, Mt Camel, and Berrambool, are shown in Figs 4, 5, and 7. Given the problems of distinguishing between material from the greenstone quarries in general, and Mt William and Mt Camel in particular, the basis of identification for each specimen plotted is indicated, whether this be hand examination, thin-section study, or trace elements analysis. The presentation may seem over-elaborate, yet it does highlight significant variations in the quality of the evidence offered. In the writer's view these cannot be ignored. Unfortunately it was not possible to section or take samples for trace elements analysis from all the collections used in the investigation, hence this variation. Even with detailed analyses many specimens could not with certainty be assigned to either Mt William or Mt Camel outcrops; these are plotted on a separate distribution map (Fig 6). Variation in the chemical composition of the rocks across the outcrops concerned contributes to this problem, especially for the Mt William site where quarried areas extend for over a kilometre (Fig 8).

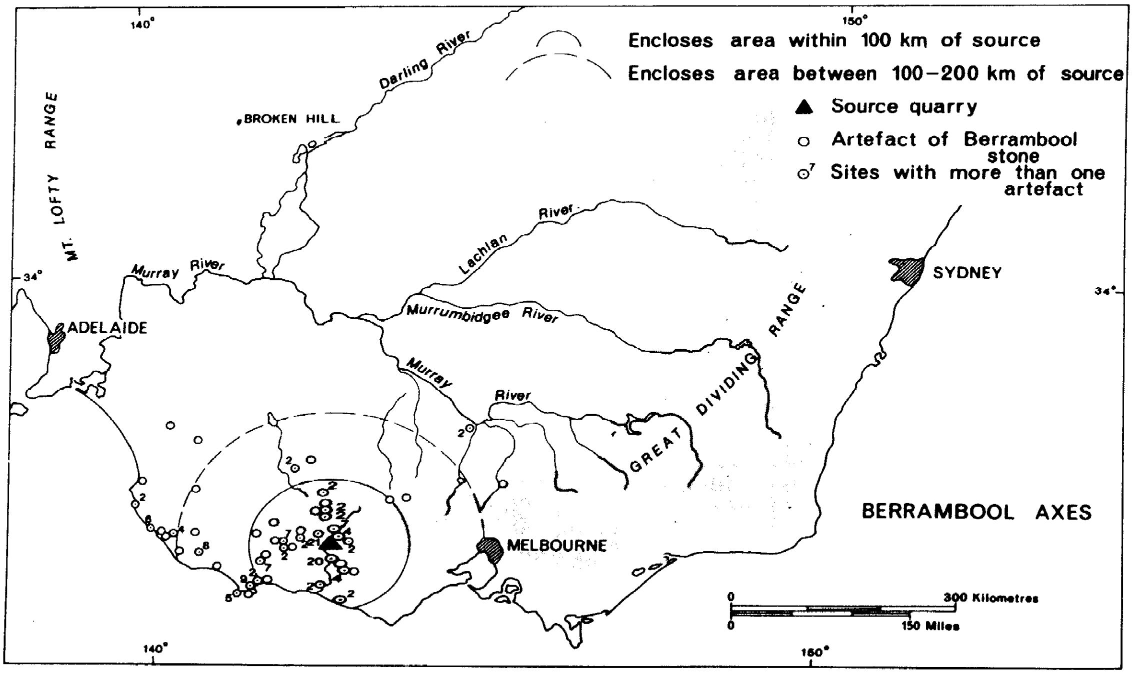
The maps demonstrate clearly the extent of dispersal for material from these three major quarries, some specimens being nearly 700 km from their source. For all quarries the distribution lies west of the main Dividing Range, and east of the lower Murray and Mt Lofty Ranges. There are also interesting variations: the slightly differing pattern for Mt Camel examples and for those of Mt William, and the spread north and west of Mt William and Mt Camel (Figs 4, 5, 6) examples while those from Berrambool are locally confined with spread to the south west (Fig 7). Some 66% of this latter group lie within 100 km of the quarry source, none beyond 300 km. In contrast, of the Mt William examples 22% are within 100 km of the source, 29% beyond 300 km. Similarly, for the Mt Camel group the figures are 29.5% and 20.5% respectively; for the Mt William/Mt Camel group 13.9% and 50.3% respectively. The other quarries in the greenstone belts seem to have been locally used resources, distributed within one group or tribal territory. Examples from the Baronga and Geelong sites however are found on locations in South Australia within the distribution network for the Berrambool quarry.

There is clear statement of the fact of movement of goods. The processes of exchange or distribution to which this movement bears archaeological witness may not be so easily discerned. Much work remains to be done to interpret the emerging patterns. In this stage of the project I plan to apply the usual studies of spatial distribution, of distance clustering, and regression analysis, relating these not only to the source locations but also to the ethnographic information available on trade and exchange in south-eastern Australia, known trading centres and communication routes, as well as data on tribal territories and the relations between the various tribal communities.

The spread of Mt William artefacts (Fig 4) does match expectations based on the ethnography, with its record of wide dispersal for Mt William stone (eg Blandowski 1855, 7—8) and its exchange for reeds used in spear making brought by Aborigines from the reed beds of the Goulburn and Murray Rivers (Fig 3) (Guthridge 1910, 5; Smyth 1878, I, 181, 359; II, 298—9). The examples



6 *Distribution of artefacts derived from either Mt William or the Mt Camel quarries where exact source identification is not possible on the analyses indicated. Each symbol represents one artefact unless otherwise indicated*



7 *Distribution of edge-ground artefacts derived from the Berrambool quarry on the Hopkins River*

8 The Mt William quarry near Lancefield, Victoria. The quarried outcrops extend over 1km along the ridge; flaking floors show up as crop marks where pasture dries out above them in early summers. Photograph: Isabel McBryde from New South Wales recall the comment of an Aboriginal near Hay in the Riverina in 1862 that their axes came from 'the Melbourne country' (Guthridge 1910, 6). The ethnography however does not alert one to the spectacular south-western distribution of Mt William and Mt Camel material. Areas in which Mt William and Mt Camel artefacts are poorly represented (Figs 4, 5, 6) are Gippsland in the extreme south-east, and the north-western parts of Victoria. Traditionally the Kurnai tribes of Gippsland regarded themselves as distinct from and hostile to the Kuhn group of central Victoria. They did not participate in the inter-tribal gatherings and activities of those tribes living to the west. Axe distributions fit this 19th-century model based on traditional tribal alliances and hostilities. In the north-west of the state other sources of high-quality axe stone may have been dominant in a separate exchange system. One possible source is a quarry at Charlotte Plains near Bendigo (mentioned by Howitt's informants [1904]) the material from which was taken to tribal gatherings at which exchange took place on the distant Wirrengren Plains in the Mallee (Massola 1973; Mulvaney 1976). The site of this quarry may now lie submerged beneath the large reservoir at Cairn Curran. The Wimmera/Mallee regions as a whole may not have been intensively or permanently occupied, but were probably used on a seasonal basis, as they lack permanent surface water. Distribution maps for axes of all lithologies might well show 'blanks' for this part of Victoria.

The distribution of artefacts from central Victorian quarries to the north and to the west seems to follow routes based on the rivers which flow into the Murray. In the south-west there is a more open pattern and a representation of material from several sources. This could well reflect the existence of exchange networks in the area, patterns of seasonal movement within tribal territories, and the regular meetings at locations such as Mount Noorat in the western district known to have operated as trading centres in the 19th century (Dawson 1881, 78). Significantly, the distribution of artefacts from the various major quarries do differ, yet they are never exclusive. This would suggest the incorporation of their products into an existing and complex network of exchange rather than the independent establishment of an 'axe trade' or separate market and supply route to distribute the high-quality stone or finished products from one distinct source. There may have been variations in the distributions over time which at present remain elusive, but on existing evidence, archaeological and ethnographic, this hypothesis is attractive.

Appendix:
Petrology of the greenstone quarries and their products

Alan Watchman

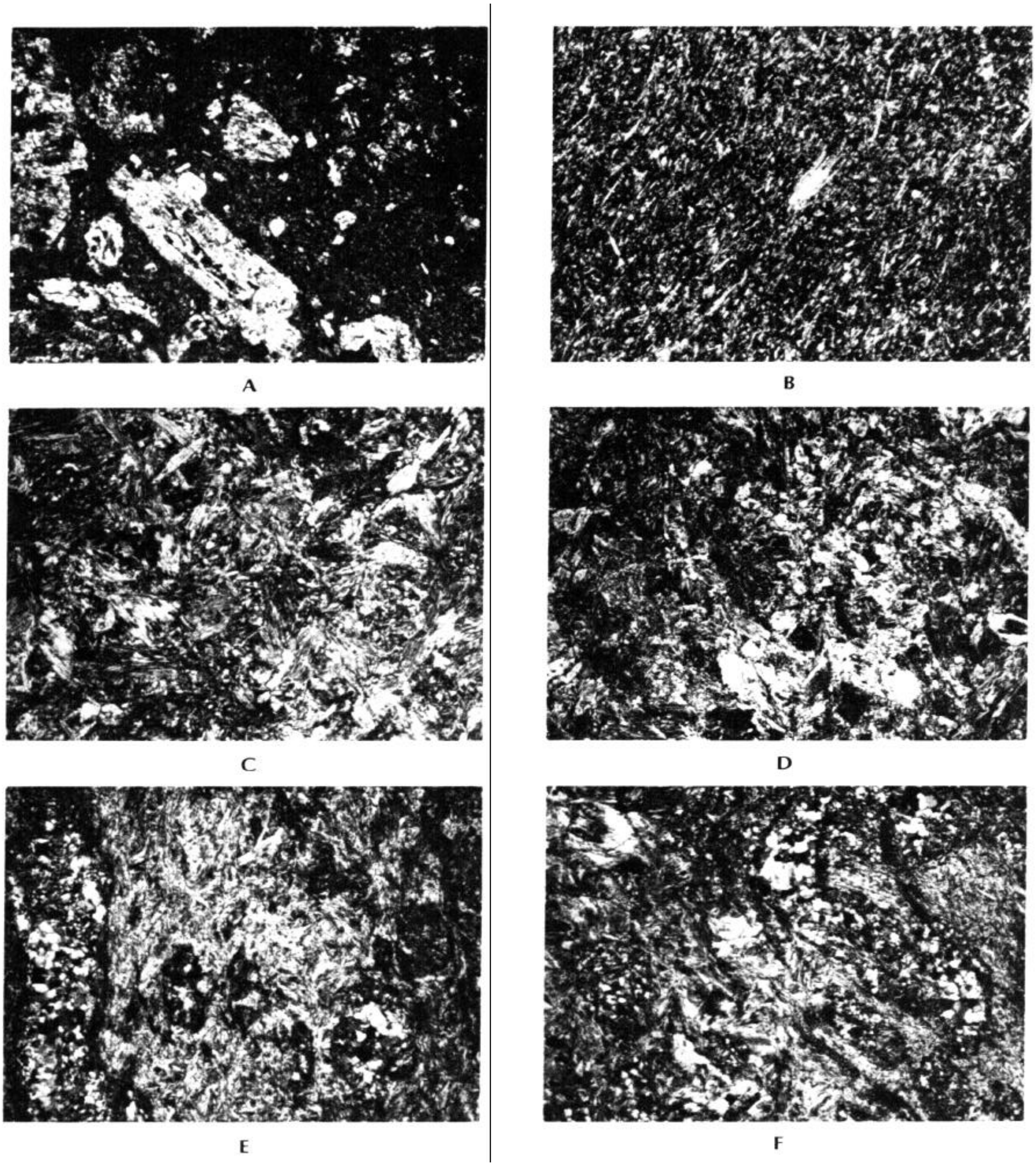
Major sources of Aboriginal axe stone in Victoria are found in Cambrian greenstone belts (Fig 3). These belts form long narrow ridges with sparse outcrops of altered and metamorphosed volcanic rocks and minor diabase. The petrology of stones obtained from each quarry was studied in detail to define the rock types. Axe stones were quarried at Berrambool, Baronga, Jallukar, Mt William, Mt Camel, Cosgrove, Howqua, and near Geelong and consist of andesite, diabase, porphyry, hornfels, volcaniclastics, altered pyroclastics, and metagabbro respectively. These rocks all share qualities of fine grain, hardness, and toughness, which make them excellent axe stones.

Most of the quarry materials are readily recognized by their mineralogy and textures, but hornfels from Mt Camel is barely distinguishable from that at Mt William. We have concentrated our efforts on finding the best way of distinguishing between axe stones derived from these quarries. Axe stones from other quarries, for example Berrambool, are easily recognized in hand specimen by their minerals and textures and therefore do not present problems of source determination.

At the Berrambool site an easily recognized rock type was quarried for axe stones. The altered andesite with microporphyritic texture consists of sericitized plagioclase and prismatic pyroxene phenocrysts, and microphenocrysts of these minerals and magnetite in a chloritized cryptocrystalline groundmass (Fig 9, a). Plagioclase is altered preferentially and indicates primary zoning, whereas pyroxene is relatively fresh, being only marginally altered to amphibole. Though cryptocrystalline, the groundmass shows irregular patches of granular albite. Light-coloured plagioclase phenocrysts microporphyritically enclosed by a dark groundmass are an easily recognized feature in hand specimens. The minerals and textures of axe stone from Berrambool are different from other axe stones quarried in Victoria and therefore a problem does not exist in determining the source of altered andesite axes.

At Mt William exploitation of outcrops and stone-working activity was carried out diagonally across the Lower Unit of the Cambrian Heathcote Greenstone. The Lower Unit is almost vertical in the quarry area and consists essentially of actinolite-cummingtonite hornfels up to 500m thick. In the basal parts, the unit is characterized by spheroidal patches of quartz, carbonate, and albite (Fig 9, e). Long thin actinolite needles penetrate into these spheroids and the interlocking amphibole needles result in a decussate texture. Pseudomorphs and relict textural features are rare because of the strong recrystallization. Minor magnetite forms dust-like patches and small euhedral grains, In the central part of the unit is a fine-grained compact amphibolite consisting of actinolite, cummingtonite, and minor iron oxides (Fig 9, c). In some places there is a white-spotted amphibole hornfels formed by small concentrations of cummingtonite bounded by actinolite. Irregular patches of altered fine-grained amphibolite are characteristic of the upper parts of the unit where chlorite, actinolite, and iron oxides are common and the rocks are weakly foliated as a result of structural deformation. Green-black and strongly recrystallized axe stones were quarried across the full width of the Lower Unit so that petrographic and geochemical variations are to be expected in the axes. Contact metamorphism is thought to be isochemical.

Two small quarries near Mt Camel were worked in outcrops of the Heathcote Greenstone along strike for 200m over a width of 30m and on a knoll about 100m in diameter. In the Mt Camel area the Heathcote Greenstone is not easily subdivided into units, and small lenses of chert, metavolcanics, and diabase comprise this formation. Axe stones were quarried in altered metavolcanics and consist predominantly of actinolite, cummingtonite, and quartz with minor amounts of albite, carbonate, and epidote. Hornfels, formed by metamorphism of lavas, contains spheroidal patches of quartz and albite, strongly resembling similar features found in rocks at Mt William (Fig 9, f). Green-brown hornfels



9a Photomicrograph of altered andesite from the Berrambool quarry. Phenocrysts of sercitized plagioclase and augite, and microphenocrysts of these minerals in a dark cryptocrystalline groundmass. The long feldspar lath is 3mm in length. Plane polarized light

b Characteristic and common rock type found at Mt Camel. The photomicrograph shows thin amphibole needles in microcrystalline albite and quartz. Actinolite needles are 0.3mm in length. Plane polarized light

c Actinolite-cummingtonite hornfels at Mt William. Blades and needles of the amphibole minerals form a decussate texture. The length of amphibole grains is less than 1 mm. Plane polarized light

d Actinolite-cummingtonite hornfels at Mt Camel. Actinolite and cummingtonite interlock in a decussate texture which is remarkably similar to rocks at Mr William. Mt Camel amphibolites are less recrystallized than those at Mt William and the grain size is slightly less, being up to 0.6mm in length. Plane polarized light

e Spheroids and patches of granular albite and quartz within amphibolite at Mt William. Actinolite and cummingtonite interlock forming a mass of unoriented needles which are up to 0.2mm in length. Plane polarized light

f Hornfels from Mt Camel showing spheroids of granular albite and quartz. Amphibole needles form interlocking clusters around the spheroids. The length of the needles is about 0.2mm. Plane polarized light consists of actinolite and cummingtonite arranged in a decussate texture (Fig 9, d). Useful attributes for sourcing Mt Camel axe stone are the presence in some rocks of small plates of diopside, amphibole pseudomorphs, relict tuffaceous texture, and fine amphibole needles in a granular albite and quartz groundmass (Fig 9, b). Carbonate and epidote veins are abundant in some places, indicating mobility of calcium and suggesting metasomatic metamorphism.

Approaches to source characterization of Mt William and Mt Camel axe stones

Slight differences between stones from Mt William and Mt Camel are colour, texture, and mineral assemblages. There is an apparent visual distinction between axe stones from these sources, but as a continuous colour spectrum is represented by all materials colour is only used as a guide to the possible source of an axe. Pale brown axe stones are more likely to come from Mt Camel than Mt William. Finely ground black axe stones are almost certainly derived from Mt William. This broad classification scheme is an initial aid in determining the source of an axe.

In hand specimen the texture of the hornfels is of little assistance in determining their source. Most axe stones are fine grained and compact, generally without any features which are diagnostic of material from a particular quarry. The exception is the white-spotted amphibole hornfels which is found only at Mt William. Its outward appearance is similar to spotted hornfels developed in pelitic rocks in contact metamorphic aureoles.

Thin sections reveal additional textural differences between hornfelses from these sources. Some axe stones from Mt Camel contain amphibole pseudomorphs after pyroxene, relict tuffaceous texture, or a mass of minute amphibole needles in microcrystalline albite and quartz. These features are not observed in quarry samples from Mt William and are therefore useful attributes for identifying axe stones from Mt Camel.

The range of hand-specimen and petrographic features makes source discrimination impossible in many cases because hornfelses quarried from Mt William and Mt Camel are not uniquely characterized and distinguishable from each other. After carrying out petrographic studies our approach therefore was to determine trace element contents of axe stones and quarry materials so that we could establish an effective characterization scheme for all hornfels axes.

Trace element analysis was selected because the method is relatively simple and less time consuming than major element analysis and because similar techniques have been successfully used to solve other archaeological problems (Hodson 1969; Ward 1974a; 1974b; Bieber *et al* 1976). Trace element concentrations were determined by X-ray fluorescence analysis of pressed powder pellets, using the method of Norrish and Chappell (1967).

Table I lists major and trace element contents of several geological samples from Mt William and Mt Camel. These specimens were collected from unquarried exposures and studied as part of a thesis by the writer (1977). They do not represent archaeological material. The analyses of hornfels from Mt William and Mt Camel indicate bulk chemical similarities between host rocks of quarry materials. Trace element concentrations for geological samples suggest that their use may not be effective for source characterization.

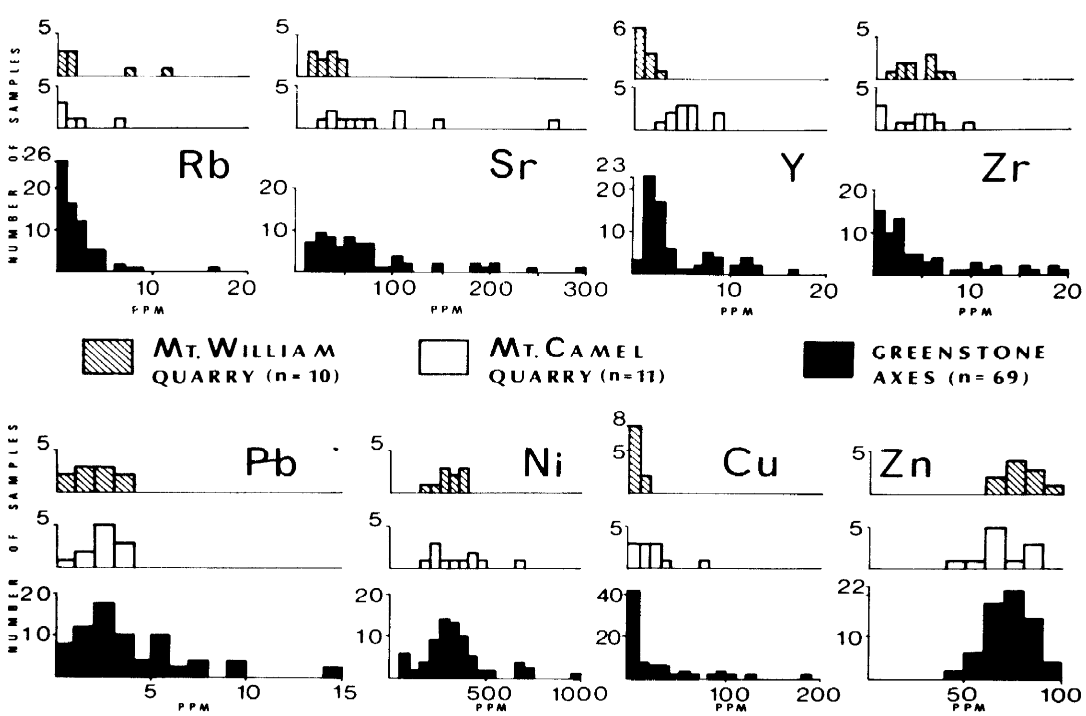
Values for the trace element contents of 69 axe stones are presented elsewhere by Watchman and Freeman forthcoming, and illustrated here in the form of histograms (Fig 10). With the exception of yttrium there is little difference in the trace element concentrations of quarry samples, suggesting that hornfelses from the two quarries are geochemically indistinct. As discrimination between sources is dependent upon homogeneity within a source and heterogeneity between them, yttrium is the only element analyzed which can be used to classify sources of hornfels. However, inspection of the content of yttrium in axe stones shows a lack of bimodal distribution which coincides with values of quarry samples. Therefore effective source characterization is not possible using this individual trace element. Covariance between two trace elements, in particular Y-Sr and Y-Zr, is slightly more useful for source characterization but does not effectively overcome the problem of geochemical similarity (Watchman & Freeman, forthcoming).

A statistical method which takes into consideration all trace elements is better at source characterization than single element classification. We thus set out to use two statistical procedures which utilize all the trace element data together. These methods are similarity coefficient calculation and the evaluation of a linear discriminant function.

Similarity coefficients were calculated by following the method of Sigleo (1975). Two calculations were made for each axe, against average contents of trace elements in samples from Mt William and then from Mt Camel. High values for the coefficient indicate excellent correlation between axe stone and quarry

Table I Major and trace element contents of quarry material from Mt William and Mt Camel

WT%	Mt William			Mt Camel		
SiO_2	54.47	55.84	51.20	50.08	56.28	50.12
TiO_2	.03	.03	.01	.12	.21	.22
Al_2O_3	3.26	3.08	1.29	5.83	8.00	9.28
Fe_2O_3	5.20	3.04	6.13	2.17	2.78	2.14
FeO	7.25	8.73	4.85	5.47	8.82	6.61
MnO	.18	.17	.24	.24	.19	.18
MgO	22.85	23.75	24.12	11.06	15.83	14.37
CaO	3.92	2.29	5.80	22.05	5.16	14.54
Na_2O	.19	.20	.22	.35	.38	.59
K_2O	.07	.02	.01	.26	.04	.07
P_2O_5	.01	.01	.01	.07	.04	.03
S	–	–	–	.01	–	.01
H_2O+	2.39	2.42	3.67	1.09	2.15	1.77
H_2O-	.05	.07	.08	.07	.08	.05
CO_2	.05	.04	1.65	1.07	.22	.09
Total	99.92	99.69	99.28	99.93	100.18	100.07
PPM						
Rb	5	2	2	1	3	2
Sr	348	52	72	277	30	46
Y	7	6	6	6	2	1
Pb	5	5	5	3	3	3
Zr	29	14	18	27	9	11
Nb	–	–	1	–	–	–
Ni	522	272	398	479	312	491
Cu	2	45	4	3	2	3
Zn	114	93	82	109	89	91



10 Trace element concentrations in geological samples of hornfelses from quarries at Mt William (sample n = 10), Mt Camel (sample n = 11), and axe-stones (n = 69)

whereas results less than 0.56 show poor correlation between axes and possible sources. Relative differences between coefficients calculated from both quarries enable selection of the appropriate source of each axe stone. However, for some axes, values of both coefficients are approximately the same, in which cases possible sources cannot be determined, thus pointing out further the geochemical similarity of the quarry materials.

A linear discriminant function was devised to classify axe stones into one of several populations; either P_1 (Mt William) or P_2 (Mt Camel), or P_{new} (a new group which is not P_1 or P_2). Essentially the method follows Rao (1973, 577) in which the means of trace element contents are used to calculate the covariance sums of squares matrices so that a complex quadratic equation can be evaluated and tested for significance at the 5% level. When the results of each test between axes and one of the populations are significant the sample is assigned to that population. Raw trace element values were used initially and then the procedure was repeated after carrying out logarithmic transformations. Results of both sets of calculations still fail to classify all axes (Watchman & Freeman, forthcoming).

From the histograms of trace elements and the two statistical methods it is concluded that hornfelses from the two quarries are not sufficiently distinct to allow classification of all axes. The problem is the similar range of trace element contents in hornfels from both quarries. Trace element contents from Mt Camel fit the variation in trace element geochemistry across the width of the Lower Unit of the Heathcote Greenstone at Mt William, thereby making effective source characterization difficult.

Major element analyses of geological samples from the quarries of hornfels were made by the writer (1977). Actinolite-cummingtonite hornfels at Mt William and Mt Camel contain different amounts of Al_2O_3, Fe_2O_3, MgO, CaO, Na_2O, and P_2O_5 (Table 1), possible attributes for course characterization. We have not analyzed axe stones to determine their major element concentrations mainly because the X-ray fluorescence analytical technique is time consuming. Variation in major element contents in hornfels from the two areas is expected from the geological history of the rocks but the range of values may not overlap between quarries. Additional work is needed before axe stones can be sourced using major element analyses.

Conclusion

Our work has established several essential conditions for provenance studies of artefacts which may be relevant to other archaeological studies. It is important to understand the geological aspects of artefact material before embarking on elaborate and expensive analytical programmes. Some material may be characterized readily by features observed in hand specimen whereas others could be sourced by petrography. The geology of source locations of artefact material is worthy of study because it indicates the range of minerals, textures, and geochemistry which can be expected in a given artefact population.

Analytical techniques should involve minimal sample preparation prior to analysis and a simple, rapid, and accurate method is preferred to complex and arduous approaches. There seems little chance of overcoming the problem of inhomogeneity of data within a source because of geological parameters but, nevertheless, the simplest effective attribute should be the aim of source and artefact characterization. After elimination of all simple attributes a combination of features may be the most effective means of sourcing artefacts.

From our study of hornfels at Mt William and Mt Camel we are able to source 96% of all axe stones analyzed for trace elements. Some of these were classified by hand examination and petrographic features whereas the others were sourced by combining these aspects with trace element data.

Acknowledgements

The figures illustrating this paper were drawn by Joan Goodrum of the Australian National University to whom we offer grateful thanks. Fig 1 was based on an original map prepared by Bruce Whan of the University of New England, Fig 2 on one by Win Mumford of the Australian National University. Dragi Markovic prepared the microphotographs in Fig 9. The research projects on axe lithologies in northern New South Wales and South-east Australia have been supported by grants from the Australian Research Grants Committee; with pleasure I acknowledge this debt.

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A Table of British Implement Petrology Groups

PPS = *Proceedings of the Prehistoric Society*

Group I Uralitized gabbro, epidiorite, or greenstone. Source in Mount's Bay area, near Penzance, Cornwall. Widely distributed and abundant. Keiller, Piggott, and Wallis, *PPS,* **7** (1941), 51.

Group Ia Close to Group I. Stone and Wallis, *PPS,* **17** (195l), 105.

Group II Epidiorite or greenstone. Source near St Ives, Cornwall. Rare. Keiller *et al, PPS,* **7** (1941), 55.

Group IIa Close to Group II. Stone and Wallis, *PPS,* **17** (1951), 106

Group III Epidiorite or greenstone. Source near Marazion, Cornwall. Rare. Keiller *et al, PPS,* **7** (1941), 55.

Group IIIa Close to Group III. Stone and Wallis, PPS, **17** (1951), 106.

Group IV Altered picrite. Source near Callington, Cornwall. Locally abundant in the south-west. Keiller *et al, PPS,* **7** (1941), 56. Redefined by Evens, Grinsell, Piggott, and Wallis, *PPS,* **28** (1962), 215.

Group IVa Sheared greenstone, close to Group IV. Stone and Wallis, *PPS,* **13** (1947), 49. Defined by Stone and Wallis, *PPS,* **17** (1951), 114. Redefined by Evens et al, *PPS,* **28** (1962), 215.

Group V Calc-silicate hornfels. Source said to be probably near St Ives, Cornwall. Very rare. Keiller *et al, PPS,* **7** (1941), 56.

Group VI Epidotized intermediate tuff. Factories in Great Langdale and Scafell Pike area of the Lake District. Widely distributed and very abundant. Keiller *et al, PPS,* **7** (1941), 58.

Group VII Augite granophyre. Factories in the Penmaenmawr area, Caernarvonshire. Widespread and abundant in some areas. Keiller *et al, PPS,* **7** (1941), 61.

Group VIIa Stone and Wallis, *PPS,* **17** (1951), 121. Later given full group status as Group X *(qv).*

Group VIII Silicified tuff. Source in south-west Wales. Widely distributed and locally abundant. Keiller *et al, PPS,* **7** (1941), 63. See also Stone and Wallis, *PPS,* **17** (1951) 122.

Group VIIIa Close to Group VIII. Evens *et al, PPS,* **28** (1962), 217.

Group IX Porcellanite. Factories at Tievebulliagh and Rathlin Island, County Antrim, Ireland. Widespread but relatively uncommon outside Ireland. Keiller *et al, PPS,* **7** (1941), 63.

Group X Fine dolerite. Factories near Sélédin, Brittany. Rare in Britain. Evens *et al, PPS,* **28** (1962), 218. Equivalent to Dolerite Type A. See Le Roux, *Antiquity,* **45** (1971), 283. An earlier Group X (Stone and Wallis, *PPS,* **13** (1947), 52) and Group Xa (Stone and Wallis, *PPS,* **17** (1951), 127) have been superseded.

Group XI Fine silicified tuff. Source in Great Langdale area of the Lake District. Rare. Stone and Wallis, *PPS,* **13** (1947), 52. See also Stone and Wallis, *PPS,* **17** (1951), 124, 126, and Plint, *Trans Cumberland Westmorland Antiq Archaeol Soc,* **62** (1962), 6, 7.

Group XII Picrite. Source near Hyssington, on the Shropshire-Montgomeryshire (Powys) border. Axe hammers and battle axes only, Abundant in the west Midlands. Shotton, Chitty, and Seaby, *PPS,* **17** (1951), 159.

Group XIII Spotted dolerite or preselite. Source in the Preselau Hills, Pembrokeshire (Dyfed). Rare, but important as 'Blue Stones' of Stonehenge. Stone and Wallis, *PPS,* **17** (1951), 128. See also Group XXIII.

Group XIV Camptonite. Source near Nuneaton, Warwickshire. Rare. Shotton, *PPS,* **25** (1959), 135.

Group XV Micaceous sub-greywacke. Source in southern Lake District. Widespread and locally abundant (particularly as axe hammers). Shotton, *PPS,* **25** (1959), 137.

Group XVI Epidiorite or greenstone. Source near Camborne, Cornwall. Locally abundant in the south-west. Evens *et al, PPS,* **28** (1962), 220.

Group XVII Epidiorite or greenstone. Source near St Austell, Cornwall. Rare. Evens *et al, PPS,* **28** (1962), 223.

Group XVIII Quartz dolerite. Source in the Whin Sill, northern England. Widespread and locally abundant (particularly as axe hammers). Evens *et al, PPS,* **28** (1962), 224.

Group XIX Greywacke. Source probably in Cornwall. Rare. Evens *et al, PPS,* **28** (1962), 226.

Group XX Epidotized ashy grit. Source in Charnwood Forest, Leicestershire. Widespread and locally abundant. Shotton, *PPS,* **25** (1959), 141.

Group XXI Baked shale. Factory at Mynydd Rhiw, Caernarvonshire. Rare. Houlder, *PPS,* **27** (1961), 113 ff.

Group XXII Riebeckite felsite. Factory in Shetland. Unknown outside Shetland, though possible examples from mainland Scotland await thin-sectioning. Ritchie in *Studies in Ancient Europe* (eds Coles & Simpson) (1968), 128 ff. Group number allocated after publication.

Group XXIII Ranges from graphic pyroxene granodiorite (Group XXIIIa) to quartz dolerite (Group XXIIIb). Source area between Preselau Hills and St David's Head, Pembrokeshire (Dyfed). Group XIII is an individual rock type which falls within the petrological and geographical range of Group XXIII. It might have been classed as a subgroup of XXIII but for its prior publication as a group in its own right. Rare. Shotton in *Prehistoric Man in Wales and the West* (eds Lynch & Burgess), (1972), 89.

Group XXIV Calc-silicate hornfels. Factory near Killin, Perthshire. Ritchie in *Studies in Ancient Europe* (eds Coles & Simpson) (1968), 126 ff. Group number allocated after publication.

Group XXV Altered quartz diorite. Source south-west of Douglas, Isle of Man. Locally important but as yet unknown outside Isle of Man. Coope (publication in preparation).

A glossary of the petrological terms used in this volume

Acicular: Needle shaped. A term applied to the crystals of certain minerals.

Acid: A term applied to igneous rocks with a high proportion of light coloured minerals (quartz, feldspar, muscovite) and over 65% silica.

Acmite: A sodium iron silicate mineral of the pyroxene group (brown).

Actinolite: A hydrous calcium magnesium iron silicate mineral of the amphibole group. *Actinolitic* (adj).

Aegirine: A sodium iron silicate mineral of the pyroxene group (green).

Albite: A sodium aluminium silicate mineral of the feldspar group.

Alkaline: A term applied to igneous rocks containing a high proportion of sodium and potassium.

Altered: A term applied to rocks or minerals which have been changed, generally by the growth of new, fine-grained minerals, due to the action of chemical solutions. The alteration is too slight to justify the term metamorphism.

Amphibole: A group of hydrous silicate minerals of variable composition, but generally containing iron and magnesium.

Amphibolite: A metamorphic rock composed largely of hornblende and plagioclase.

Andesite: An intermediate volcanic rock. *Andesitic* (adj).

Arsenopyrite: An iron arsenic sulphide mineral.

Ashy: Containing volcanic ash. A term generally applied to sedimentary rocks.

Augite: A calcium sodium iron magnesium aluminium silicate mineral of the pyroxene group.

Aureole: The zone of metamorphic rocks surrounding an igneous intrusion.

Baked: Heated by an igneous intrusion. A term applied to sedimentary rocks adjacent to small intrusions, which have supplied insufficient heat to result in metamorphic mineral growth.

Basalt: A basic volcanic rock. *Basaltic* (adj).

Busanite: An alkaline basalt.

Basic: A term applied to igneous rocks with a high proportion of dark minerals (hornblende, augite, olivine) and less than 54% silica.

Biotite: A hydrous potassium iron magnesium silicate mineral of the mica group (brown mica).

Bole: A red, earthy, or waxy decomposition product of basaltic rocks, containing iron oxides and hydrous silicates.

Calc-silicate: A term applied to metamorphic rocks, composed largely of calcium-bearing silicate minerals, which originated as impure limestones.

Camptonite: An intrusive igneous rock in which the essential components are plagioclase feldspar and brown hornblende.

Chalcedony: A fine-grained fibrous mineral, composed of silica (silicon oxide).

Chert: A compact, fine-grained siliceous rock of sedimentary origin, composed of varying proportions of opal, chalcedony, and cryptocrystalline quartz.

Chlorite: A hydrous iron magnesium aluminium silicate mineral.

Chloritized: A term applied to rocks which have suffered alteration involving the development of chlorite.

Chloromelanite: A sodium iron aluminium silicate mineral of the pyroxene group.

Contact metamorphism: Metamorphism of the rocks surrounding an igneous intrusion.

Contact zone: The zone of metamorphic rocks close to the igneous intrusion responsible for the metamorphism.

Cristobalite: A microcrystalline mineral composed of silica.

Cryptocrystalline: A term applied to rocks which are so fine-grained that their crystalline character cannot be clearly distinguished under the microscope.

Cummingtonite: A hydrous iron magnesium silicate mineral of the amphibole group.

Decussate: A term applied to the criss-cross arrangement of the minerals formed during contact metamorphism.

Diabase: An altered dolerite.

Diopside: A calcium magnesium iron silicate mineral of the pyroxene group.

Dolerite: A basic intrusive igneous rock, composed largely of augite and plagioclase feldspar. *Doleritic* (adj).

Dyke: An igneous intrusion in the form of a vertical, or steeply inclined, parallel-sided wall of rock.

Corundum: An aluminium oxide mineral, the hardness of which is exceeded only by diamond.

Eclogite: A dense metamorphic rock, formed under very high pressure and temperature, composed largely of garnet and omphacite.

Emery: A granular natural abrasive, the principal component of which is corundum.

Epidiorite: A metamorphosed gabbro, in which the augite has been replaced by hornblende.

Epidote. A hydrous calcium aluminium silicate mineral.

Epidotised: A term applied to a rock which has suffered alteration involving the formation of epidote.

Erratic: A rock fragment removed from its place of origin by glacial action.

Eruptive: A synonym for igneous, though sometimes restricted to extrusive rocks, Not widely used in English, but equivalent to the French term *eruptif:*

Euhedral: A term applied to minerals whose crystal faces are well developed.

Extrusive: A term applied to igneous rocks formed at the earth's surface, either as lavas or as volcanic ashes.

Feldspar: A mineral group consisting of potassium aluminium silicates (orthoclase) and sodium calcium aluminium silicates (plagioclase).

Feldspathoid: A mineral group consisting mainly of potassium and sodium aluminium silicates, but containing less silica than the feldspars.

Felsite: A fine-grained, tight coloured, acid igneous rock.

Fibrolite: Sillimanite occurring as a mass of fine fibrous crystals.

Fissility: The capacity of a rock to split readily in one direction.

Flint: A fine chert with a conchoidal fracture, generally grey or black when fresh.

Foid: A short alternative name for the feldspathoid group of minerals,

Foliated: A term applied to metamorphic rocks which have a planar fissility due to the parallel orientation of platy minerals. *Foliation* (noun).

Gabbro: A basic intrusive igneous rock, composed largely of augite and plagioclase feldspar. Coarser than dolerite.

Garnet: A group of silicate minerals of variable composition, but generally containing aluminium, iron, magnesium, or calcium.

Glaucophane: A hydrous sodium magnesium aluminium silicate mineral of the amphibole group.

Glaucophane schist: A metamorphic rock containing glaucophane and a variable assemblage of other minerals.

Glaucophanite: A synonym for glaucophane schist.

Gneiss: A coarse-grained banded metamorphic rock. Gneissic (adj).

Granite: A coarse-grained intrusive acid igneous rock, composed largely of quartz and orthoclase feldspar, with some mica and amplibole.

Granodiorite: A coarse-grained intrusive acid igneous rock, composed largely of quartz and orthoclase feldspar, orthoclasc feldspar, and hornblende.

Granophyre: An intrusive acid igneous rock, characterized by graphic intergrowth of quartz and feldspar.

Graphic texture: An intimate intergrowth of quartz and feldspar. giving rise to a pattern resembling cuneiform script.

Greenstone: A general term applied to a variety of altered basic to ultrabasic igneous rocks.

Greywacke: An impure sandstone, in which the sand grains are bound together by an altered clay matrix.

Grit: A hard coarse sandstone.

Hornblende: A hydrous calcium magnesium iron aluminium silicate mineral of the amphibole group.

Hornblendite: An ultrabasic igneous rock, composed almost entirely of hornblende.

Hornfels: A hard even-grained metamorphic rock produced by contact metamorphism.

Igneous: A term applied to rocks which have formed at high temperature, by crystallization from molten material such as lava.

Ilmenite: An iron titanium oxide mineral.

Intermediate: A term applied to igneous rocks which are intermediate in composition between acid and basic, with between 54% and 65% silica.

Intrusion: A body of igneous rock which has been injected into the surrounding rocks at some depth below the earth's surface. *Intrusive* (adj).

Jade: A semi-precious stone largely composed of either jadeite or nephrite, two quite distinct but superficially similar minerals.

Jadeite: A sodium aluminium silicate mineral of the pyroxene group.

Jadeitite: A rock largely composed of the mineral jadeite.

Leucite: A potassium aluminium silicate mineral of the feldspathoid group.

Leuocratic: A term applied to igneous rocks composed mainly of light coloured minerals.

Lithology: The general character of a sedimentary rock formation.

Mafic: A term applied to the dark coloured minerals (biotite, hornblende, augite, olivine), and to rocks rich in these minerals.

Magnetite: An iron oxide mineral.

Meta-: A prefix used to indicate that a rock has undergone metamorphism; eg *meta-gabbro, meta-volcanic.*

Metablasts: Large crystals, in a finer grained matrix, formed during metamorphism.

Metamorphism: Alteration of the mineral composition and texture of rocks as a result of changes in temperature and pressure. *Metamorphose* (verb). *Metamorphic* (adj).

Metasomatism: Alteration of the composition of rocks through the action of migrating chemical solutions. *Metasomatic* (adj).

Mica: A group of hydrous potassium aluminium silicate minerals, some of which contain other elements, such as iron and magnesium. *Micaceous:* A term applied to sedimentary rocks containing abundant mica.

Microcrystalline: A term applied to rocks which, though definitely crystalline, are so fine-grained that the individual grains cannot be seen with the naked eye.

Microporphyritic: See under porphyritic.

Mineral: A naturally formed crystalline chemical compound.

Mylonitization: The process whereby rocks may be crushed and flattened by shearing under great pressure.

Nephrite: A hydrous calcium magnesium iron silicate mineral of the amphibole group.

Obsidian: An acid volcanic glass.

Olivine: An iron magnesium silicate mineral.

Omphacite: A green sodium rich variety of augite.

Opal: An amorphous hydrous silica mineral.

Orthoclase: A potassium aluminium silicate mineral of the feldspar group.

Pelitic: A term applied to rocks originating as muddy sediments. Most commonly used for metamorphic rocks.

Penetrative deformation: Deformation producing structural changes in all the rocks of an area, not merely the weaker strata.

Petrogenesis: The mode of formation of rock types.

Petrography: The descriptive study of rocks. *Petrographic* (adj).

Petrology: The study of rocks. A general term embracing petrography and the study of petrogenesis.

Phenocryst: A relatively large crystal in a fine-grained matrix in an igneous rock.

Picrite: A coarse-grained ultrabasic intrusive igneous rock, mainly composed of olivine, augite, and plagioclase feldspar.

Plagioclase: A sodium calcium aluminium silicate mineral of the feldspar group.

Polarizing microscope: A microscope which makes use of polarized light to study the optical properties of minerals as an aid to their identification.

Porcellanite: A general term for a variety of hard, close-textured rocks with a dull lustre. The Group IX porcellanite is a metamorphosed soil.

Polphyry: An igneous rock having large crystals in a fine-grained matrix. *Porphyritic* (adj), or *Microporphyritic,* if the phenocrysts are too small to be distinguished except under the microscope.

Pseudomorph: A term used for a secondary mineral which has retained the crystal form of an earlier mineral which it has replaced.

Pyrite: An iron sulphide mineral.

Pyroclastic: A term applied to the deposits resulting from explosive volcanic eruptions.

Pyrometamorphosed: Altered by very high temperatures along the actual contact with an igneous intrusion.

Pyroxene: A group of silicate minerals of variable composition, but generally containing iron or magnesium.

Pyroxenite: A rock composed largely of pyroxene.

Quartz: The pure crystalline form of silica (silicon oxide),

Quartzite: A sedimentary or metamorphic rock composed largely of quartz.

Relict texture: A texture in a metamorphic rock preserving some trace of its pre-metamorphic origin,

Retrograde metamorphism: Metamorphism during which high temperature minerals are altered to lower temperature forms.

Rhonite: An iron aluminium calcium magnesium titanium silicate mineral.

Riebeckite: A hydrous sodium iron silicate mineral of the amphibole group.

Sandstone: A rock formed from sand.

Sedimentary: A term applied to rocks originating as sediments.

Schist: A metamorphic rock containing a high proportion of platy minerals, such as mica, whose parallel arrangement gives rise to foliation. *Schistose* (adj).

Sericite: A hydrous potassium aluminium silicate mineral of the mica group, occurring in minute crystals as an alteration product of feldspar. *Sericitized:* a term applied to a mineral which has suffered alteration involving the formation of sericite.

Serpentine: A hydrous magnesium silicate mineral.

Shale: A fine-grained sedimentary rock, originating as mud or silt, which splits easily parallel to the stratification.

Silcrete: A siliceous crust formed at the surface in a semi-arid climate.

Silicified: Altered by the introduction of silica.

Sill: A parallel sided igneous intrusion following the stratification in a sedimentary rock formation.

Sillimanite: An aluminium silicate mineral.

Siltstone: A sedimentary rock originating as silt.

Sphene: A calcium titanium silicate mineral.

Spilite: A basic volcanic rock. A type of basalt rich in sodium.

Subgreywacke: An impure sandstone.

Titan-augite: Augite containing titanium.

Titano-magnetite: Magnetite containing titanium.

Tremolite: A hydrous calcium magnesium iron silicate mineral of the amphibole group.

Tridymite: A microcrystalline form of silica.

Tuff: A rock originating as a volcanic ash deposit. *Tuffaceous* (adj).

Uralitized: Altered, with green fibrous hornblende (uralite) as one of the main alteration products.

Volcanic: Originating in a volcano.

Volcaniclastic: A term applied to a rock or sediment containing grains or particles of volcanic origin.

Weathering: Alteration of a rock by processes acting at, or near, the surface.

Zoning: Compositional layering in a crystal.

Index

Page numbers in italics refer to Figures and Tables only; those in roman type may refer to Figures and Tables as well as text. Numbers such as 42..44 denote text interrupted by other matter; *n* means footnote. For ‘Group’, please read ‘petrological group’ in cross-references such as *‘see also* Group IX’ (Eds).