UNIVERSITY OF SOUTHAMPTON

FACULTY OF ARTS

ARCHAEOLOGY

<u>Doctor of Philosophy</u>

THE BRONZE CASTING INDUSTRY IN LATER PREHISTORIC SOUTHERN BRITAIN: A STUDY BASED ON REFRACTORY DEBRIS

by Hilary Howard

I dedicate this thesis to

Michael Pitts Michael Holliday Martin Kilmer

and to my grandmother

Jane Smith Smith Smith

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ABSTRACT

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THE BRONZE CASTING INDUSTRY IN LATER PREHISTORIC SOUTHERN BRITAIN: A STUDY BASED ON REFRACTORY DEBRIS

by Hilary Howard

Industrial organisation is a vital aspect of the organisation of society as a whole. This study aims to investigate the organisation of a particular industry during the later prehistoric period (1st millennium BC) in southern Britain. The focal archaeological data set comprises those refractory artefacts - crucibles, moulds, tuyères and furnaces - used in the bronze casting process. However, a wide range of ethnographic, historical, technological and geological literature has been quarried in the course of this integrated study, to construct predictive organisational models, and to assist in the interpretation of archaeological remains.

Following a theoretical examination of the concepts 'industry' and 'specialisation', Part I sets out and discusses the evidence for metalworking organisation in ethnographic contexts. The concluding chapter of this Part consists of a series of generalisations drawn from the ethnography-based discussion, and the implications of these generalisations for the understanding of prehistoric bronze casting are outlined.

Part II examines the overall constraints on refractory production and investigates the manufacture of refractories in a range of recent historical and ethnographic contexts. The potential contribution a study of refractories can make towards the understanding of the casting industry is discussed here. Part II concludes with a description of the methods selected to analyse archaeological refractory artefacts.

Part III consists of a series of individual studies of prehistoric casting sites. The metalworking evidence and locally available materials for refractory production are described, and analytical results are presented and discussed. Catalogues of bronze casting sites and non-ceramic moulds form the final chapter in this Part.

The concluding Part IV attempts to set the archaeological data presented and discussed in Part III within the organisational and technological frameworks considered in Parts I and II. Prehistoric refractory technology is assessed, and organisational models are proposed for the bronze casting industry during the age of bronze, and during that period when man had become economically dependent on iron for the production of most tools and weapons.

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INTRODUCTION

Most metal-related studies in Britain have focussed on the typology and distribution of specific classes of bronze artefact. Although such studies have been invaluable for refining prehistoric chronology and postulating inter-regional contact, many seem to imply (to paraphrase Cunliffe, 1978a, 9) that the bronze age was peopled solely by animated metal objects, endowed with all the characteristics of living creatures, and capable of evolution and parthenogenetic reproduction. The bronze is all. Questions are frequently restricted to the single class of artefact under study, and attempts to relate material data to the broader contexts of production, dispersal, use and deposition, are conspicuously rare.

Two main factors may be held responsible for the constant research emphasis throughout the 20th century on bronze metalwork and its morphology. The first concerns the nature of the archaeological record. Bronze artefacts constitute by far the largest category of evidence for the period of economic dependence on that metal. The great majority of these artefacts, however, have been discovered by accident, either in hoards without other material associations, or as single uncontexted finds. Until the last decade or so, very little settlement evidence was available from the bronze age in Britain, and hence those interested in that period of prehistory tended to rely on the vast collection of bronze artefacts in our museums as the sole basis for interpretation.

The second factor concerns the progress of archaeological thought, and here additional reference may be made to the field of ceramic studies. Prior to the development of radiocarbon dating, prehistoric chronology was dependent on stratigraphic relationships and changes in artefact style. Increasingly complex chronological schema were constructed, based on minor variations in bronze implement shape or ceramic decoration (eg Burgess, 1968a; Hawkes, 1959). The identification of 'cultures' popular during the first half of this century again relied exclusively on typological data (eg Childe, 1940; Piggott, 1954). Finally, since the demise of the 'culture concept', and the corresponding growth in interest in exchange systems generated by the 'new archaeology' of the 1960s, stylistic elements have again been emphasised to define trade zones and networks (eg Ellison, 1980; Hodder and Orton, 1976).

A direct consequence of the developing pattern of archaeological thought in relation to material evidence ('chronology' through 'culture' to 'exchange'), has been an almost total neglect of technology and industry. In this context, 'industry' is considered to be synonymous with 'production system' as defined by Udy. "Any production system involves a technological process carried on by a production organisation, with a reward system, in a social setting" (Udy, 1959, 3). Here Udy defines production as the "purposeful alteration and combination of physical material until it reaches some desired empirical state", and a production organisation as "any social group engaged in carrying out one or more technological processes" (Udy, 1959, 2). Thus, the structure of any production system (industry), depends both upon the technological processes involved and the social setting in which it exists. The 'social setting' of prehistoric Britain has received considerable attention of late, most especially that time period known as the late bronze age. Settlements have been located and excavated, and settlement evidence considered in relation to land use and subsistence patterns. Here, the work of Richard Bradley merits particular attention (eg Bradley, 1978). For the period which witnessed increasing dependence on iron as the raw material for tool and weapon, the work and syntheses of Cunliffe and Champion perhaps best exemplify the investigation of social organisation (Champion, 1979; Cunliffe, 1978a).

However, although many recent studies have provided thoughtful analysis of the subsistence basis of societies, other aspects of economic organisation, principally the craft industries, are often ignored or appraised without consideration of their broader social setting. I would contend that the understanding of craft technology and the organisation of production are vital to the understanding of society as a whole. This study is offered as an <u>attempt</u> to achieve this basic understanding.

Period of study

The study concerns the organisation of the bronze casting industry during the 1st millennium BC, that is, through that period conventionally known as the later bronze age into the time when man was chiefly dependent upon iron for the production of his tools and weapons. Although the terms 'later bronze age' and 'iron age' are unfortunate in that they imply an illusory rift in cultural development, they will, nevertheless, be retained here in the absence of more accurate terminology defined by absolute chronology.

Careful fieldwork during the last decade, stimulated by a growing interest in social organisation and change, has provided for the first time a series of well-excavated and recorded later bronze age settlement sites. Many of these sites have yielded evidence in the form of ceramic refractories (crucibles, moulds, furnaces and furnace furniture) for the process of bronze artefact manufacture. It is thus now possible to study the bronze industry by examining actual production sites, rather than inferring manufacturing locales from type distributions, and technological processes from finished implements.

During the thousand years or so covered by this study, the economic emphasis shifted from dependence on bronze to exploitation of, and eventual dependence on the more readily available and easily worked iron. It is hoped to show in these pages, through consideration of the production evidence, how the bronzeworking industry was affected by this shift in metal dependence. The study of a single industry through the bronze-iron age transitional period should contribute to a wider understanding of the technological change and social development which took place at the time.

Area of study

The present study considers archaeological material from southern Britain. In the present context, 'southern Britain' is defined as the entire mainland area south of the Scottish border, including Wales and the southwest peninsula. The recent recovery of large and well-contexted assemblages of bronze casting debris has allowed the detailed appraisal of metalworking at a single site (Foster, 1980; Needham, 1980a; Spratling, 1979). However, in order to explore variation in casting technology between metalworking groups, and investigate the inter-regional and diachronic organisation of this specialist craft, it is necessary to consider production systems at a wide range of settlement types in different areas through time.

The ideal data set for such a study should be derived from well-contexted manufacturing debris from a series of well-excavated and -recorded sites of different size, complexity and perhaps function. These sites should represent both the bronze and iron ages, and, ideally, be located in regions of diverse physical resources.

Although the number of excavated later bronze age settlements has increased dramatically during the last ten years, sites providing good industrial evidence are still relatively scarce, and are scattered throughout Britain. Evidence for settlement during the 1st millennium iron using period has a longer history, but here excavation has been biased in favour of the more obvious hillforts, and other site types have rarely been subject to detailed study (Champion, 1979, 355). Furthermore, many early iron age excavations were poorly recorded, and much potentially valuable information has been lost.

The archaeological record, therefore, is erratic. Thus, in order to obtain a sufficient sample of well-contexted material from an adequate range of sites, it has been necessary to study an extensive geographical area.

Sources of evidence

The main body of archaeological evidence examined comprises those refractory accoutrements used in the bronze casting process. These include the crucibles in which metal was melted, the moulds in which it was cast, the hearths or furnaces wherein melting took place and furnace equipment such as tuyères or blowpipes used to induce forced draught. Although refractories of other materials are considered within the overall study of production, attention is focussed upon the ceramic and refractory-sand artefacts associated with bronzeworking.

The reasons for this concentration on ceramic debris are outlined below (II.1.2). Ceramic refractories from fourteen production sites have been analysed petrologically and in detail to determine the level and range of technical expertise operative at each site, and the knowledge displayed by the metalworkers of suitable refractory resources. The ceramic resource ecology (II.3.2) of most production sites studied is examined via selective raw material sampling and analysis. The results of these single assemblage analyses are set out and discussed in III.2-15. Refractories from a further fourteen sites have been analysed to provide additional data, and the results of these analyses are included in a 'production site corpus' (III.16).

Until the present study, minimal interest has been taken in refractory fabrics and the potential wealth of information they contain. Although occasional analyses of crucible materials have been published (eg Crossley, 1967; Hodges, 1968; Lamm, 1973; Proudfoot, 1955; Wood, 1965), little attempt has been made to interpret the results in the broader context of metalworking organisation. Most studies of refractories have, in fact, focussed exclusively on slag residues adhering to interior and exterior surfaces (eg Hencken, 1950; Moss, 1927; Richards and Aitken, 1959).

As already emphasised above, this is a study of production organisation. Although ceramic refractories provide the focal dataset, a wide range of additional sources has been consulted within this essentially integrated study to construct predictive organisational models and assist in the interpretation of the archaeological data. These include ethnographic accounts of bronze, iron and rare metal working, historical treatises on metalworking, documentary records of organised industrial casting (bells, cannons), documentation concerning glassworking, evidence from present-day foundries, modern industrial literature and economic geology.

PART I

THE SMITH AND HIS CRAFT

I.1 INDUSTRY AND SPECIALISATION: A THEORETICAL EXPLORATION

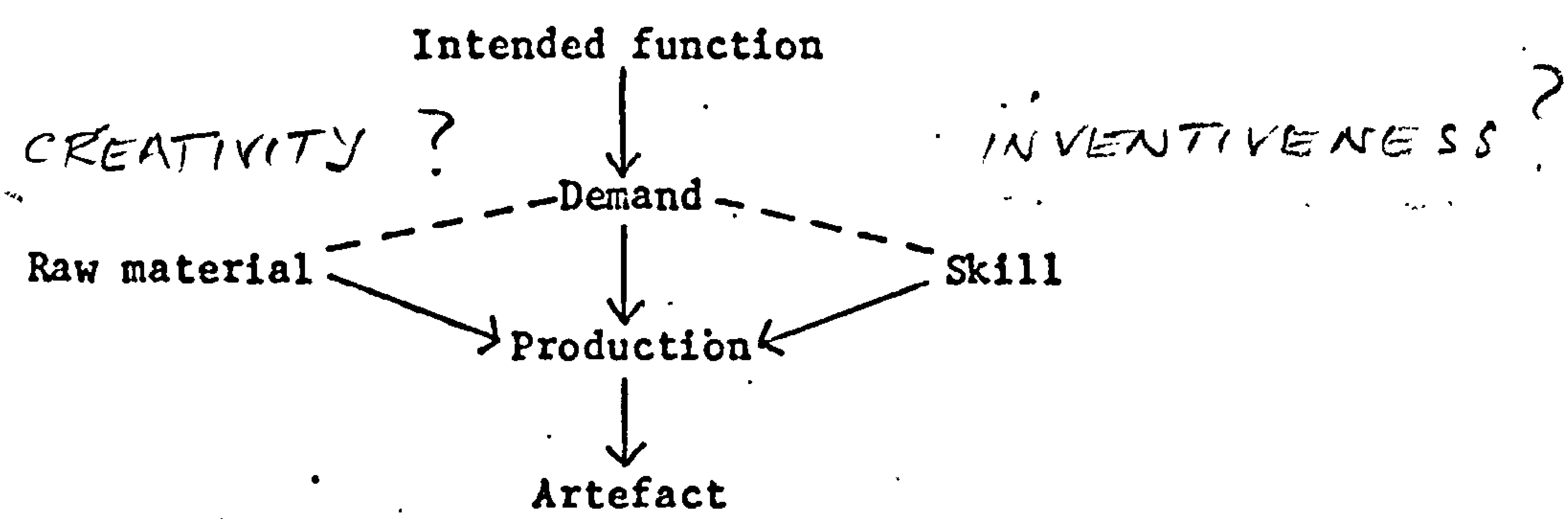
I.1.1 Industry and demand

As a prelude to this study of bronze casting it is important to emphasise two basic truisms the implications of which have rarely been considered by archaeologists. Firstly, any industry, including that organised for the production of bronze artefacts, is necessarily embedded in the society in which it exists. Secondly, bronzeworking is by nature a specialist industry carried out by craftsmen with a sophisticated range of skills which would never have been developed by all.

Following Childe, archaeologists have defined 'industry' in terms of groups of typologically related artefacts. Childe defines 'cultures' as recurrent assemblages of associated archaeological types, but stresses that "a recurrent assemblage of stone tools [for example], never found in any recognisable type of dwelling or grave, nor even associated with broken bones of game indicative of a distinctive selection of menus, should not be termed a culture, but an industry" (Childe, 1956, 33). Objects of a given material, produced by generally similar processes, showing similarities in form and decoration, have subsequently been described as representing an 'industrial tradition' (eg Britton, 1963). 'Industrial stages' have been claimed to correspond to typological developments in single artefact categories (eg Burgess, 1974, 191).

These restricted uses of the term emanate in the main from the nature of archaeological data, and attitudes to those data. Finished objects generally constitute the only closely scrutinised material evidence of a production organisation. In the only thoughtful, in-depth study of prehistoric industrial organisation to date, Rowlands operationally defined an industry as "any form of productive work that is carried out as a specialist activity, whether full- or part-time, by an individual or group of individuals" (Rowlands, 1976, 115). Although this broader definition is relevant in the present context in that it extends beyond artefact attributes and relates to the production process, it fails to emphasise the relationship between this process and the society in which it takes place. In these pages, the term 'industry' will be taken as synonymous with Udy's 'production system' (p 2 above). Here, 'industry' encompasses a social setting, a production process and organisation, and a range of finished products.

The relationship between any industry and its parent society, together with those criteria upon which specialisation depends, are usefully summarised in the following simple model.



The production of any artefact is both stimulated and limited by demand for that artefact. Demand in its turn is an active response to functional needs, either utilitarian, symbolic, or both. The nature of such functional needs will be determined by the social, economic and ritual organisation of the group in which they are manifest.

Taking utilitarian need as an example, the production of pottery vessels for food preparation and storage, takes place in some societies in response to individual periodic demand. Among the Cape Hottentots of South Africa, pots are produced by the women of each household as and when required (Schapera, 1930). Pottery is made by all Lango (Zaïre) males when needed by the family (Driberg, 1923, 86) and among many southern African Bantu groups pots tend to be produced by individual families according to their requirements (Colson and Gluckman, 1951; Smith, 1974, 116). In the Maghreb, under the traditional rural system, each family provides its own pottery, replacing all broken vessels and increasing stocks during an annual workshop session (Balfet, 1966). In these cases, the consumer who demands and the producer who supplies are one and the same person. DEVELOPMENTAL CREATIVITY

At the other end of the spectrum, in complex societies, demand is generated by a potentially limitless range of functional requirements. For example, during the past few years, Chinese cooking in the home has become very fashionable in Britain. This popularity stems partly from the proliferation of Chinese restaurants along every high street, partly from a more adventurous attitude to cooking and entertaining, partly from the availability of a wide range of hitherto unobtainable ingredients, and partly from a trend towards healthier eating. The massive ramifications of each of these factors need not be pursued here - suffice it to describe them as the 'social setting'. The desire to cook in the oriental fashion has generated a demand for culinary utensils specifically designed for the purpose, principally the Chinese wok. Thus woks are produced in response to this demand and reach the shelves of every department store through a chain of complex marketing mechanisms. Thus, in ranked and stratified societies, producers and consumers may never make contact other than through one or a series of intermediaries (Renfrew, 1977, 9).

In prehistory, bronze artefacts were produced to satisfy demands related to land clearance, agriculture, warfare, and ritual or symbolic expression - all integral to the operative social system. However, a local chief or farmer, unless a trained bronzesmith, would be incapable of satisfying his demands for tools, weapons and ornaments himself, but would have recourse to a specialist producer. It is time to turn to the second basic truism cited above, namely the invariably specialist nature of the bronzeworker's craft.

Although ethnographers and ethnoarchaeologists enumerate specific criteria for the identification of economic specialists, archaeological definitions of craft specialisation have been little developed (Rice, 1981). Archaeologists frequently allude to 'specialised' producers or industries, but the precise implication of these terms seems generally ill-considered, and is rarely clear from the context. One reads, without further explanation of the terminology involved, of "at least semi-specialist potters ... manufacturing particularly high-quality vessels" (Shennan, 1977, 56); that "the existence of the specialist involves exchange of services for goods or other services" (Burgess, 1980, 275); of "incipient specialisation inherent in the practice of copper metallurgy" (Renfrew et al, 1974, 382); and that "iron extraction had in part become a specialist skill in south-east Britain by the second century BC" (Cunliffe, 1978a,295). Renfrew, drawing heavily on the work of Service and Sahlins to define the characteristics of chiefdom societies, appears to ascribe a range of meanings to the term 'specialisation'. Neolithic flint-mines are defined as evidence of specialist activity on the basis of the sheer scale of labour involved. "In the case of the flint-mines ... it may be appropriate to speak of regional specialisation associated with redistribution" (Renfrew, 1973, 555). "Improving craft specialisation" (Renfrew, 1973, 543) is seen embedded in the extensive trade in stone axes and neolithic gabbroic pottery. "Religious specialisation" is discussed in relation to the stone circles of Avebury and Stonehnge. "Specialist observers or 'seers', in effect a priesthood, were a feature of the society ..." (Renfrew, 1973, 555).

Cunliffe equates 'specialisation' with "small-scale manufacturing", and further defines the former in terms of full-time, prestige-good production carried out by exceptionally skilled artist-craftsmen and supported by individual or community patronage (Cunliffe, 1978a,296). This assumed relationship between specialisation, full-time craftwork and community support, is frequently manifest in the archaeological literature, and stems from Childe's lifelong tenet that metalworkers were the first full-time specialists supported by social suprlus SURPLUS (eg Childe, 1930, 4-5, 10; 1940, 163; 1951, 35).

So what is specialisation? Two recent attempts to explore specialisation in archaeological contexts have been largely based on ethnographic and ethnoarchaeological constructs. Pierpoint enumerates five forms of specialisation (Pierpoint, 1980, 39). These 'forms', which cross-cut a variety of social and economic systems, describe different individuals or groups involved in production. By implication, specialisation is thus defined as a range of activities limited (socially and/or politically and/or economically) to certain elements of society. Pierpoint then claims (without producing supportive evidence) to demonstrate that specialist goods command high social and economic esteem, and are of vital significance in trade networks. This view of specialist products is somewhat restricted.

Rice's trial model for the development of ceramic complexity reflects a broader consideration of specialist activity (Rice, 1981). Criteria relevant to the identification of economic specialists are: the relationship between time spent in craftwork and time spent in subsistence activities; the proportion of income derived from craftwork relative to that obtained from subsistence activities; the explicit recognition of the craft by the society in which it operates; a reward system for work performed. Specialisation is identified as "an adaptive process in the dynamic interrelationship between a non-industrialised society and its environment" (Rice, 1981, 219). Rice's exploration of the evolution of specialist pottery production as a concomitant of increased societal complexity takes account of the wide variety of social and economic parameters that underlies specialisation.

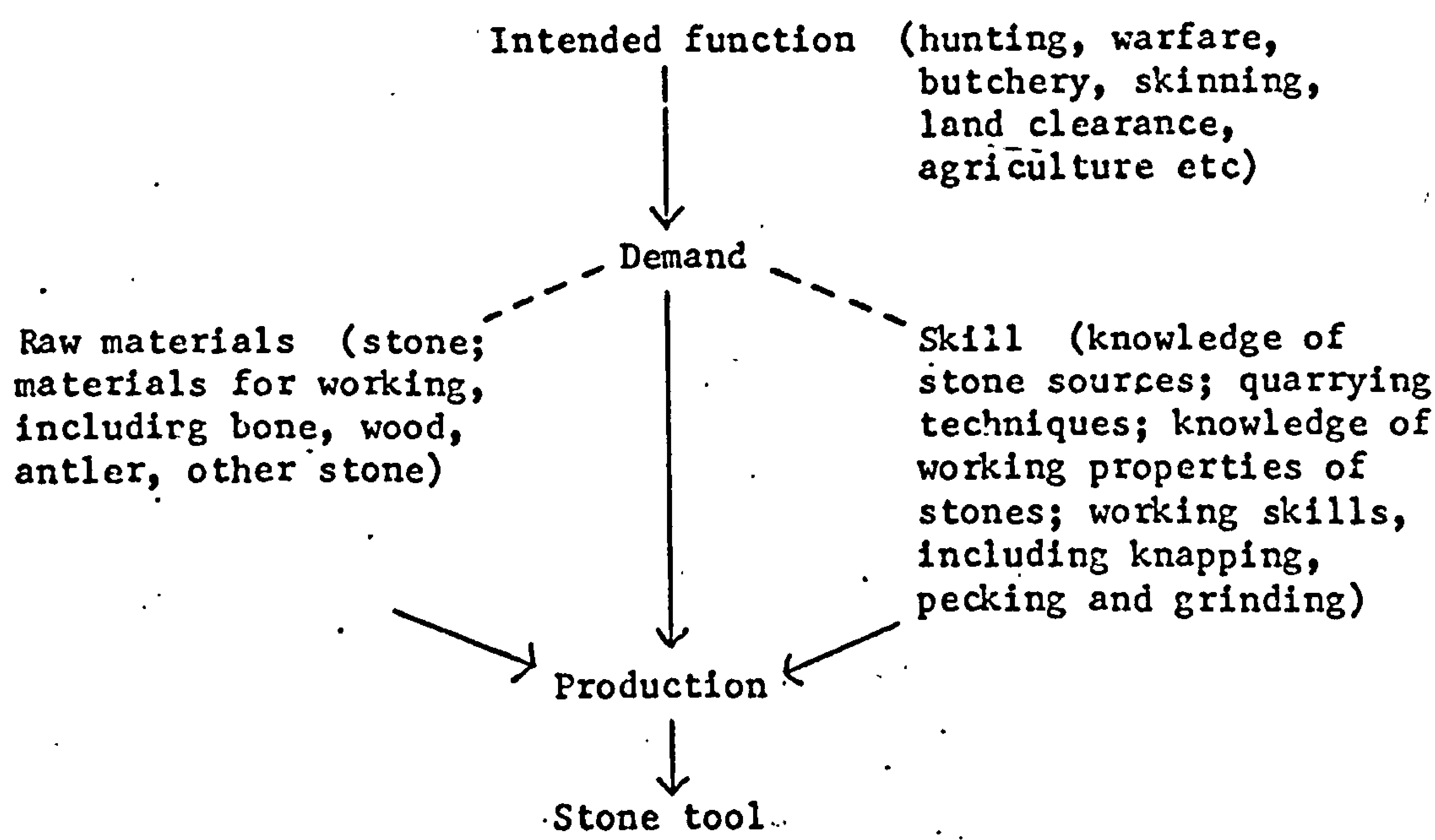
In sum, it is clear that specialisation is a complex phenomenon and cannot be defined simply in terms of whether certain individuals perform certain tasks from which others are barred; whether certain craft products find favour over a wide territory; or indeed whether a tribesman is a full-time or part-time farmer. Specialisation represents myriad aspects of a society's organisation and beliefs.

Until recently, Childe was alone in having considered prehistoric bronzeworking as a specialist activity; others chose to focus on the typology of the smiths' products. Now, however, in his investigation of the middle bronze age metal industry, Rowlands has discussed (albeit briefly) the implications of the specialisation concept and the relationship between the specialist and his society. Basically defined, specialisation involves differential access to and development of a wide range of spohisticated skills (Rowlands, 1976, 116). I would add to this definition the equally fundamental issue of differential access to raw materials both for the products themselves and for equipment required in the manufacturing process (Howard, 1981). It is here proposed first to explore this differential access to skills and raw materials in some detail, thereby emphasising the essentially specialist nature of the bronzeworker's craft, at this basic level of definition.

I.1.2 Bronzeworking is a specialised craft

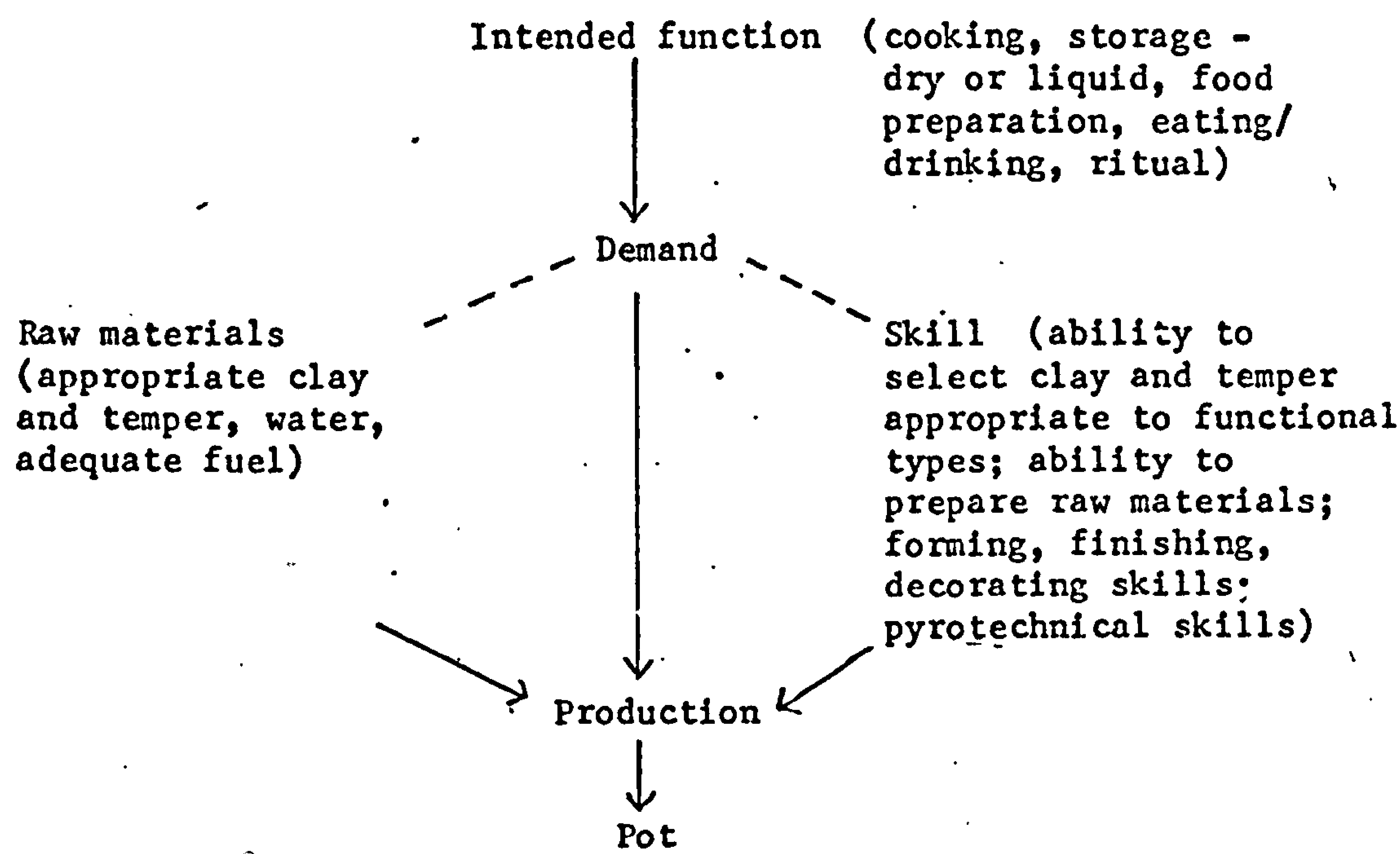
In the domestic mode of production, raw materials necessary to produce a limited range of artefact types are generally available to all, and there are few social restrictions on the development of skills required to exploit these sources (Sahlins, 1972). Specialisation implies differential access to skills and raw materials. Here, instructive comparisons may be made between the making of stone artefacts, the ceramic production process and the casting of objects in bronze.

Generalised model for the production of stone tools



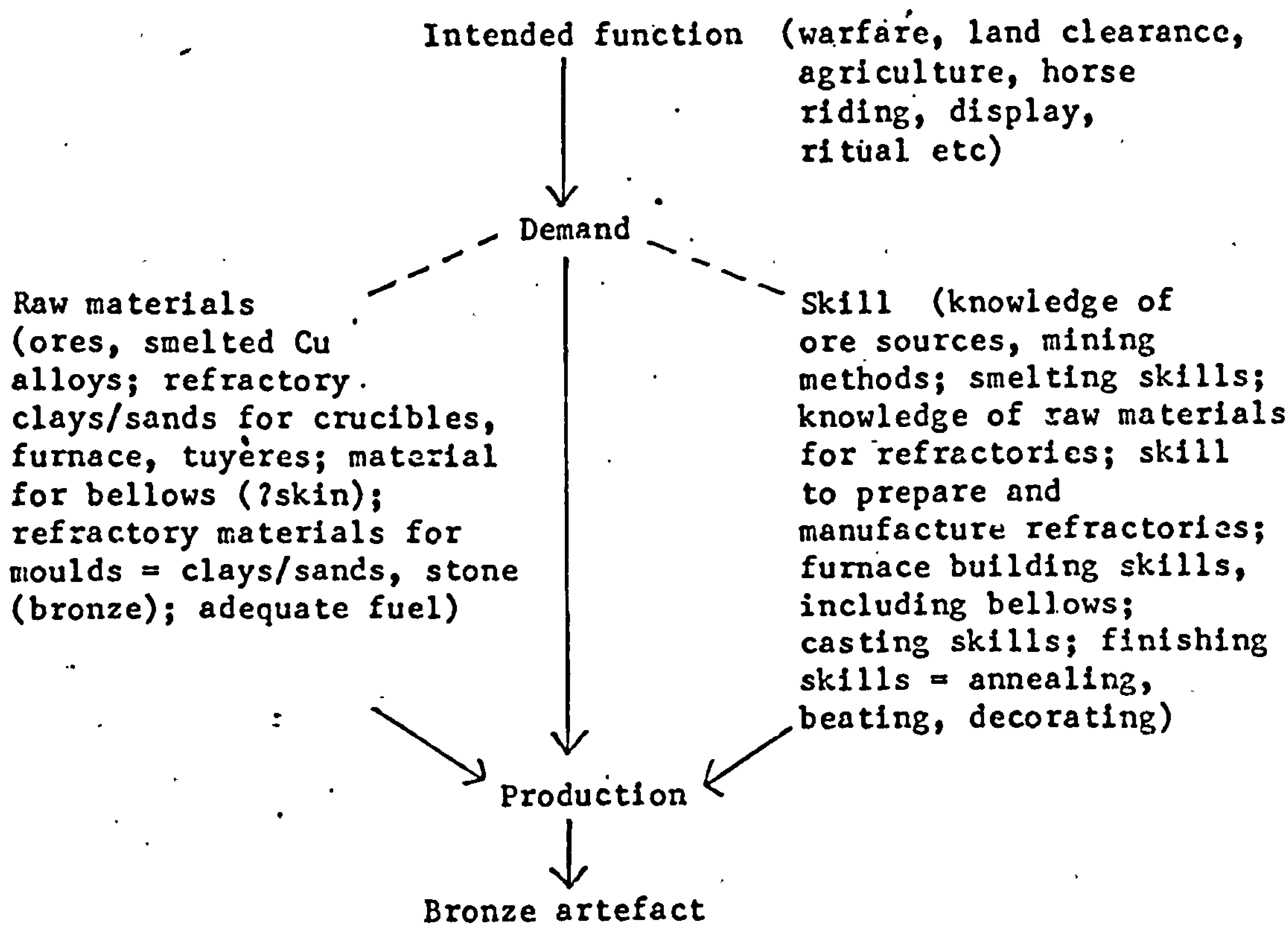
The above model illustrates the possible range of complexity inherent in lithic artefact manufacture. In some societies, the production of stone celts is a highly specialised craft restricted by social factors (for example, taboo and heredity), and by access to the requisite skills and raw materials, to a limited number of individuals (McBryde and Watchman, 1976). By contrast, in many hunter-gatherer groups, all members have free access to stone and possess the basic skill to produce simple single purpose flake tools (Gould et al, 1971; Hayden, 1979). Flakes are struck and used without further refinement for butchering and skinning a single animal, and are discarded at the kill site.

Generalised pottery production model



This model summarises the range of raw materials, and skills required to exploit and manipulate these materials to produce pots to perform specific socially determined functions. Like stone tools, the manufacture of pottery vessels can be, and is shown to be organised at different levels of complexity involving different levels of specialisation (Rice, 1981; Peacock, 1982). At the simplest level, as was seen above, individuals make and fire pots for food preparation as and when needed. The ubiquitous raw material, clay, is freely available to all, and minimal skill is required to form and bake a basic cooking or storage vessel. Such a pot will be used by its maker until it breaks, when it will easily be replaced. Beyond this level, the range of variation in production organisation is limitless, but invariably involves some form of specialisation. Perhaps no suitable clay or temper is available (differential access to raw materials); perhaps access to clay pits is limited (economically or socially) to a certain caste or clan; perhaps an individual has not developed the skill to produce a vessel which will not crack in the cooking fire (differential access to skill); or perhaps he or she chooses (an economically and/or socially determined choice) not to make pottery. In each of these cases, individuals will seek to have their demand filled elsewhere, by specialist potters.

<u>Generalised bronze artefact production model</u>



The diversity of raw materials and range of skill needed to cast a single bronze object far exceed those required for pottery production or the shaping of lithic tools. The bronze caster must not only be familiar with the properties of the metals he is casting, and have access to these comparatively rare raw materials; he must also know intimately his ancillary materials, and possess the skills to manipulate these within rigidly controlled technological constraints. The manufacture of crucibles, moulds and tuyères, for example, allows little technological latitude. To function successfully, this equipment must be produced to high refractory standards. The smith must be aware of these standards and possess the necessary skills and knowledge to exploit suitable raw materials to meet them. Additionally, the smith must be an expert in pyrotechnology, able to set and control a draught-assisted fire up to the temperature of molten bronze. The delicate skills of casting must also be his, and he may also be proficient in a plethora of finishing techniques. All these skills require prolonged and intense learning and practice, and can neither have been available to nor developed by all.

I.1.3 Specialisation in action

The ramifications of specialisation, thus basically defined, and the factors affecting the organisation of specialisation, are manifold and vary according to the social system within which the specialisation exists. It has already been stressed that it is not sufficient to define 'forms of specialisation' (pace Pierpoint, 1980) on the basis of a single criterion, be it time spent in the craft, hereditary affiliation of craft operators, or presence/absence of patronage. To understand the organisation of a specialist industry, it is necessary to consider a range of aspects of specialisation, and to investigate their independent or combined mode of variation within a particular social system. The complexity of the specialisation concept commands a study in its own right, and thus a selective approach must be adopted here. The following list is confined to those elements I consider most relevant to the understanding of prehistoric metalworking.

1. Specialisation according to metal: a smith manipulates a restricted range of metals.

2. Specialisation according to activity within the metalworking process: a craftman's expertise is confined to mining, smelting, casting or smithing, or a limited combination of these.

3. Specialisation according to products: a smith produces a limited range of items.

These three types of specialisation (which can operate independently or in combination) may be manifest by individuals or groups of smiths; the craftsmen may be involved in metalworking for greater or lesser proportions of their time; and they may be earning more or less income from their industrial activities. Examples of these various facets of specialisation; the social, economic, political and belief factors which limit or encourage their development; and the inter-relationships between them, will be presented and discussed within the following chapters.

I.2 UNDERSTANDING METALWORKING: THE RELEVANCE OF ETHNOGRAPHIC AND HISTORICAL DATA TO ARCHAEOLOGICAL INTERPRETATION

The limitless variety of social contexts within which demand for functional categories of bronze artefacts takes place, coupled with the complexities of the production process, preclude the formulation of universally applicable, comprehensive, organisational models. Pertinent areas of interest such as location of production, full-time vs part-time specialisation, number of groups or individuals involved in the production process, number of individuals involved at each stage of production; the status of the smith in society, and pattern of work, specifically whether the smith was permanently located, or peripatetic serving a restricted or unlimited area; are all dependent upon those factors of social and economic organisation which engender demand for particular artefact categories. Although holistic models are not practicable, it is however desirable to examine production organisation in different social contexts, and use the data so acquired in three ways:

1. To appreciate the overall organisation of metallurgical industries in varied settings, and to examine the relationship of the craftsmen to their parent societies.

2. To identify, within this overall picture, those aspects of production organisation which appear to have broad application, but which are not necessarily direct functions of technology. The distinctive social position of the smith, and the generally hereditary nature of his craft (see below) may be cited as examples. The identification of such universals can aid in the formulation of predictive models of prehistoric industrial organisation (for a recent review of the use of ethnography by archaeologists, see Orme 1981).

3. To identify and examine those aspects of production which are directly dependent on technology. This category of data includes the material evidence of bronze casting. The technological constraints operating on the casting process are constant, irrespective of location or time period, and hence it is possible to make direct comparisons between the material residues of ethnographic and historical industries, and casting debris in archaeological contexts. Such comparisons can assist in the interpretation and reconstruction of prehistoric technology.

With these three levels of inference in mind, an extensive study was undertaken of the literature concerning metalworking in ethnographic and historical contexts. Before discussing the evidence, however, it is necessary to describe the nature of the data, and to stress the problems inherent in using these data in a comparative study.

Following Rowlands, archaeological information "must form the controlling factor by which the evidence from ethnography [and history] can be organised to form relevant models" (Rowlands, 1971, 210). It must be recalled that for part of later British prehistory, man was dependent on bronze for the provision of his tools, weapons and ornaments. After the adoption of iron, bronze lost its utilitarian function, and today, in no part of the world is man dependent on any metal other than iron. There is thus no direct equivalent for the bronze age smith, nor for the society within which he worked.

Rowlands (1971) explored the organisation of production within iron using societies, and examined commonly held beliefs concerning metalworking in the north European bronze age. However, caution must be exercised in applying complex iron-based models to bronze-based social systems. The technological constraints operating on non-ferrous casting differ substantially from those relating to the working of iron. Raw materials for bronze making are geographically limited, whereas workable iron ores are ubiquitous and abundant; ironworking requires less skills, equipment and control of varied raw materials, and is thus easier to master; iron is more versatile than bronze in that objects of any size and shape can be made by the same process. These factors are necessarily reflected in some aspects of the production organisation associated with each metal.

However, at a general level, valid comparisons may be made between bronze dependent man and iron dependent man. Such aspects as the status of the smith in his society, his pattern of work, or his activity specialisation are not necessarily direct functions of specific raw material exploitation: a smith is always a smith. Information may thus be used concerning both ferrous and non-ferrous metalworking in diverse iron-based economies to formulate general predictive models to elucidate the organisation of the bronze casting industry throughout prehistory. The same information may be used to gain an appreciation of the possible variety and complexity of specialist activity in a range of social contexts.

Once iron was generally available for tool and weapon production, bronzesmiths became rare metal workers and have remained so to this day. Thus, a comparative assessment of bronze casting in the ethnographic and historical record should aid directly in the interpretation of that industry during the iron age. In practice, data relevant to bronze casting are both rare and difficult to locate in the ethnographic literature, and accounts which do exist vary dramatically in approach and quality. Most information is of a technological nature; industrial organisation and the role of the smith have received but scant attention. Copper alloy casting is everywhere a dying art (see Table I.10, Appendix I.1), and it is essential that comprehensive, methodical studies of the remnant practitioners and their work should be undertaken before a wealth of valuable information is lost forever. Neaher's work with the itinerant Awka metalworker (Neaher, 1976) is a rare and classic example in its field, and should be emulated in other areas before it is too late.

Three main factors may be held responsible for the notable dearth of information concerning metalworking - be it bronze or iron - in its social context. Firstly, anthropologists' mid 20th century reaction against the study of material culture may be cited. Everywhere this reaction seems to have extended to the social behaviour of smiths (a point made by Vaughn, 1973, 162, and Brown, 1980). Secondly, in the 19th and early 20th centuries, although material culture found favour, travellers and ethnographers were generally preoccupied with techniques and processes, and scant attention was paid to the organisation of work (both Udy, 1959, and Spier, 1973, have commented on this bias towards technical description). According to personal preference, accounts contain either expanded descriptions of activities such as smelting or forging; or mere allusions to the existence of a particular industry, without further detail. Isolated statements such as "they cast bronze" occur with tantalising regularity. Thirdly, the lack of detail in the literature, concerning industrial organisation and pattern of work must in part reflect the intense magic and secrecy which invariably surrounds the metalworking arts (Table I.2, Appendix I.1). Nowadays, as the cloud of mystery lifts and old taboos are gradually forgotten, information is becoming easier to acquire. It is significant that two recent major studies were undertaken by females (Neaher, 1976; Brown, 1980) who, in the past, would never have been allowed near the craft.

Cline's masterly study of metalworking technology (Cline, 1937), which encompassed such organisational aspects as the status of the smith and the role of ritual in the craft, remained, until very recently, the only extensive comparative study in this area. However, Cline's work, which relies entirely on published material, inevitably reflects the uneven nature of the ethnographic record. Now, to complement this classic account, there exists a pioneering study of ironworking in Kenya, based upon methodical fieldwork (Brown, 1980). Dr Brown's data are consistently collected, allowing comparative analysis of the metalworking systems of a range of tribes with varying social organisations. Like bronze casting, traditional ironworking is a rapidly dying art in most parts of the world. Cheap, mass-produced goods have largely supplanted the native product (Table I.10, Appendix I.1). Again a plea must be made for further detailed recording whilst the data are still available.

Turning now to the historical literature, little reference can be found to small scale metallurgical industry. For the Roman period in Britain two solitary inscriptions barely hint at the organisation of what must have been a prestigious and prolific craft (C.I.L. VII.265).

Inscriptions on medieval bells trace the peregrinations of their founders and provide clues to the general organisation of that branch of bronzeworking, but virtually nothing is known of the crafting of ornaments or everyday household items such as bowls and cauldrons. Although the technology of gunfounding has been subject to close scrutiny (Ffoulkes, 1911; 1937; Jackson et al, 1973) the identity of the founders and their work systems is unknown. More information is available for the early industrial period, but this generally applies to manufactory or factory based industries, and is thus of limited value in prehistoric interpretation.

At the third level of inference, the historical literature, like the ethnographic, yields a considerable body of technological data. Metallurgical treatises written during the Roman and medieval periods contain detailed accounts of each stage of the casting process, including careful descriptions of the manufacture of ancillary equipment such as moulds. As technological constraints are constant, the information contained in these accounts can be compared directly with information derived from archaeological material.

At the beginning of this chapter, I stressed the desirability of studying metalworking in different social contexts, and of using the data so acquired to gain an appreciation of organisational variety; to identify 'universals' concerning the smith and his craft; and to aid in the interpretation of prehistoric technological processes. I have described the uneven quality of information in the ethnographic and historical literature, and have outlined the problems inherent in relating this information to prehistoric societies. Despite these problems, it will be demonstrated in the following chapters that provided a <u>large, geographically and chronologically wide ranging and varied sample</u> of societies is considered, the literature, appropriately questioned, can greatly enhance understanding of the <u>essential characteristics</u> of metalworking.

The data

The data set out in Tables I.1-10 (Appendix I.1) are drawn from an extensive, but by no means exhaustive survey of the ethnographic and historical record. Data concerning almost 200 pre-industrial societies are presented, both to illustrate the potential range of social and organisational variety, and to draw attention to facets of the metalworking industry rarely considered by archaeologists. Generalisations concerning the smith in society (Ch I.3), specialisation (Ch I.4), industrial organisation (Ch I.5) and transactions (Ch I.6) are all based upon these data.

Information concerning technical processes (the third way of using the ethnographic data), other than when directly relevant to the broader aspects of organisation, is not included here, and instead is presented in Part II.

The data appear in tabular form to facilitate comparison and avoid unnecessary repetition. Furthermore, this mode of presentation frees the general discussion from overwhelming lists of examples, and also allows the data to be consulted with ease. Examples included in Chs I.3-6 have been carefully selected from these data to illustrate the range of variation relevant to each general point being made. Examples illustrating the complexity of variation within that range may be found in the appropriate tables.

Information is thus grouped into ten operational categories corresponding to the individual tables:

Table I.1 The smith's position is society: includes information concerning the relationship between the smith and other members of his social group; his caste, clan or group affiliation; and his status.

Table I.2 Magic, ritual and taboo: describes the air of secrecy and mystery which envelopes the smith and his work, and the varied rituals and taboos associated with all aspects of the metallurgical crafts.

Table I.3 Organisation of work: includes information on specialisation by metal, activity or product; individual or community specialisation; full- or part-time work; the seasonality of the craft; itinerant or resident activity; and co-operative or individual work patterns.

Table I.4 Becoming a smith: relates to the hereditary or open nature of the craft; selection of smiths within defined lineages; apprenticeship, and initiation rites.

Table I.5 Output: describes the smith's products and product specialisation.

Table I.6 Supply of metal: describes the nature of the smith's raw materials (scrap or smelted ore) and the means by which these materials are obtained.

Table I.7 Supply of non-metal: describes the means by which the smith obtains the non-metal raw materials, such as charcoal, refractories and wax, essential to his craft.

Table I.8 Location of activities: contains information on the location of smelting and smithing activities, and the social and practical factors determining these locations.

Table I.9 Transactions: describes the manner in which the smith disposes of his products, and includes information on trade, tribute and commissions.

Table I.10 Change: describes recorded changes in the crafts, the nature and cause of such changes, and the smith's attitudes to change.

The ethnographic texts from which these data derive vary both in quality and in date. In some cases, 'tribes' have been confused with lingusitic groups, clans or lineages. Nomenclature often reflects political or ethnic affiliation as understood by the individual ethnographer. A vast literature now exists devoted to the elucidation of tribal and ethnic grouping in each region considered. A detailed review of this literature is beyond the scope of this study. I have therefore decided to use the 'tribal'/'group' designations adopted in the references consulted, despite the inevitable discrepancies resulting from such a procedure.

The various 'peoples' are alphabetically arranged in the tables within their different country groups. Countries in turn are grouped by continent, and appear in a standard order. When examples are cited in the text, the country is always given, and thus acts as a key to the tables where fuller information and the source may be found. The present tense is used throughout the tables and preceding discussion, except where a 'then and now' situation is specifically documented. The brief nature of many of the entries is a reflection of the content of the original sources rather than selective quotation.

I.3 THE SMITH IN HIS SOCIAL SETTING

I.3.1 The position of the smith

Throughout Africa, Asia and northern Europe, smiths, whatever their social status, are set apart within the societies in which they work. Distinctivenes is manifest in the attitudes of their fellow group members (be it tribe or community) towards them. A smith may be feared, despised, loathed, held in contempt or awe, admired, respected or honoured; but never regarded as 'just another' group member. Mixtures of favourable and uncomplimentary attitudes are common, again irrespective of the smith's status.

Four main factors account for the smith's distinctive social position.

1. Smith groups

Most smiths are set apart from their fellow tribesmen by exclusive group affiliations. Smiths generally belong to separate clans, kin groups, castes, or craft associations with hereditary membership. In 80% of cases included in this study, metalworking is a closed hereditary occupation; in 14% the craft tends to be hereditary, although outsiders may join, usually after participating in complex ceremonies (eg Kamba of Kitui (Kenya)); in only 6% of cases is metalworking an open profession.

In Kenya, blacksmithing is not restricted to one clan, although some clans are forbidden to work iron. Certain clans are famous for their smiths. Smithing is usually the jealous preserve of individual families within the various clans (eg Peul, Laobes (Senegal); Fouta (Guinea); Bavenda smiths among the Balemba (Zimbabwe)). In Ndebelé territory (Zimbabwe), smithing is restricted to the indigenous Kalanga, who enjoyed a high reputation for their craftmanship prior to the Ndebelé incursion.

Smiths frequently belong to distinct castes with membership restricted to certain clans. Thus Masai (Kenya) smiths all belong to the el-Konono, the serf clans; smithing is restricted to a few clans among the Swazi (Swaziland); and Luyia smiths (Kenya) are drawn from leading clans.

Alternatively, smiths may form distinct castes or classes irrespective of clan affiliation. Each Nandi smith (Kenya) is a member of the clan in which he resides, but together the smiths form a submerged class. Members of the ŋkyagu caste (which includes smiths) among the Marghi (Nigeria) are drawn from various clans.

In some societies, metalworking is restricted to certain kin groups. Agulu village, part of Awka township (Nigeria), is composed of seven exogamous smithing kin groups. Among the Ovambo (Namibia), all smiths are drawn from low class families. In Dahomey (Benin), brassworkers belong to individual family groups related by blood and interest to the blacksmiths' castes.

Finally, metalworkers may be set apart by their membership in craft-exclusive guilds. Bagam (Cameroon) and Benin City (Nigeria) blacksmiths and brass casters belong to separate guilds, and in Korhogo City (Ivory Coast) copper smelters and casters form separate restricted craft associations. Among the Kikuyu (Kenya), all ironworkers belong to an exclusive blacksmiths' guild.

The psychological and often physical separateness afforded by the caste-clan-kin structure is frequently reinforced by the worship of deities exclusive to the particular craft. In Dahomey (Benin), holy days celebrate Cú, the god of iron. Bronze and brass smiths in Benin City (Nigeria) worship their founding ancestor Eguchae, and share in worship of the blacksmiths' deity Ogun. Awka smiths (Nigeria) call on the powers of Akputakwa, the god of metalworkers and their families, to protect them on their travels.

2. Mystery and magic

All aspects of the metalworkers' art, from the collection of ore to the final casting or smithing, are surrounded by magic and ritual. Ore gathering is the task of women among the Mbawara smelters (Nigeria), and is shrouded in secrecy. It is taboo for a man to observe a woman gathering ore and heavy fines must be paid by any who break this taboo. Mining is highly ritualised among the Fauta (Guinea), and is preceded by sacrifice and dancing in special costume. Among the Angas (Nigeria), charcoal making and smelting are accompanied by complex ritual involving the cutting of a special tree by a tribal religious leader. The Marghi (Nigeria) wear traditional ornaments throughout the iron smelting process, which is preceded by ritual beer drinking and chicken sacrifice. Among the Ba-Ila (Zambia), the success of the smelt is said to depend on the purity of the workers (observing taboos), the ancestral spirits, the special power of the 'iron doctor' and the efficacy of the 'medicines' (objects and potions used in smelting rituals). The building of the smelting furnace is accompanied by complex ritual among the Achewa (Malawi), and involves sacrifice and use of a human foetus.

The Suk smith (Kenya) chants prayers during forging, and no woman may see him at work. To break this taboo would induce madness and, eventually, death. Among the Buganda (Uganda), smiths may not eat or talk with others whilst working. The Gwembe Tonga smith (Zambia) must remain sexually continent during the night before smithing, and must not wash before going to the forge. Among the Gude (Nigeria), brass casting is preceded by elaborate ritual. A 'medicine' is prepared from special leaves mixed with wormcasts, and rubbed over the newly made moulds to prevent leakage. It is believed that the power of the 'medicine' will suck back any escaping metal.

The smith also surrounds his tools with mystery, magic, ritual and ceremony. The Bakitara (Uganda) sacrifice a sheep and a fowl when a new anvil is installed. Great power is invested in the Evhe smith's hammer (Togo), and among the Ondulu (Angola) hammer making for a novice smith is accompanied by lengthy and complex ceremonies. Batak (Indonesia) smiths' tools are worshipped, and tool spirits are believed to protect the smith and his family.

The atmosphere of secrecy and ritual which envelopes the metallurgist's craft is, perhaps, partly responsible for the widespread belief that the metalworkers themselves are endowed with magic powers. In his society, the smith is often called upon to act as mediator between his fellow tribesmen and the spirit world. His magic powers are vital to many aspects of social, religious and even economic life. Yakuts smiths (USSR) rank alongside shamans, giving council, making predictions and curing sickness. Awka metalworkers (Nigeria) act as doctors and purveyors of cults both at home and whilst travelling. Nuba smiths (Sudan) are rainmakers and sickness experts. Among the Gola (Liberia), smiths perform ceremonies accompanying initiation into the Poro - the tribal secret society. Gurage smiths (Ethiopia) too act as ritual specialists in circumcision and other ceremonies. The Kikuyu smith (Kenya) acts as arbiter in disputes. Fear of his magical powers ensures compliance with his decisions.

Whilst the smith requires ritual and ceremony to ensure the successful functioning of his tools and equipment, his fellow tribesmen often believe the tools themselves to be magical. The Bari (Sudan) swear oaths on the smith's hammer, the Fouta (Guinea) on his anvil, and the Tiv (Nigeria) on his tools. Among the Moro and the Nuba (Sudan) iron implements are powerful in curing sickness. A variety of iron objects is used in Marakwet (Kenya) ritual and as protection against the repurcussions of a premature death within the family. In many parts of north Africa, the smith's tuyère is a powerful charm. The Marghi (Nigeria) and the Kikuyu (Kenya) place tuyères in fields to protect property, and the Tiv (Nigeria) use them as cult emblems.

3. Craft and craftmanship

Metalworkers are often set apart because of their technical skills. Conversely, they are distinguished by the extent to which practising their craft prohibits or limits their involvement in other activities. Luyia smiths (Kenya) are noted for their intelligence, skill, wisdom and mystical powers. Among the Gola (Liberia) and the Pangwe (C African Republic) smiths are admired for the skill and physical difficulties involved in their craft. On the other hand, the Kanembu (Nigeria) despise all forms of industry, and smiths are held to be effeminate by the warlike Gala (Sudan).

4. Products

The smith's distinctive position in society is often grounded in the functional and symbolic significance of his output. Artefacts produced by the smith are inextricably bound with all aspects of social, economic and ritual life. The Kpelle smith (Liberia) is distinguished because he makes vital agricultural tools and implements for ceremonies. Among the Gola (Liberia) agricultural tools, weapons and currency are essential to the social and economic framework. Dahomean society depends on the blacksmith's products for agriculture, other productive crafts, and burial. Copper and brass castings in Dahomey (Benin) are a valued portion of the King's wealth. Labwor smiths (Uganda) are famous for their hoes and spears which are widely traded among the neighbouring tribes. Among the Wachagga (Tanzania), smiths are both honoured and feared because they make deadly weapons. Yoruba (Nigeria) mythology stresses the divine origin of the smith and the revolutionary role of iron in agriculture and the common good.

I.3.2 The status of the smith

As Rowlands has observed, archaeologists, following Childe, have tended to ascribe high status to smiths in prehistoric Europe. Reviewing the ethnographic evidence, Rowlands showed that in fact "no particular status can be automatically assigned to the smith ... simply on the basis of assumed prestige for his particular skills and knowledge (Rowlands, 1971, 217). However, although Rowlands' observations are borne out here, a more extensive survey of the literature reveals that the smith almost invariably enjoys a distinctive status, be it high or low. Information was located describing the status of the smith in 89 of the tribes and communities included in this study. Metalworkers among 45 peoples are of low status, 39 smithing groups are of high status, and in only five cases is it said that smiths are of no special standing within their social milieu.

So, how is status defined in society? Differences in status are reflected in the extent of the metalworker's participation in the social, political and religious life of his community.

Low status is accompanied by specific restrictions relating to marriage and/or residence patterns, physical contact with non-smiths, and ownership of land or animals. Dinka (Sudan) smiths can own no cattle, Nandi smiths (Kenya) may not marry non-smith members of Nandi clans, and their cattle may not breed with Nandi cattle. Marriage with smiths is barred among many peoples (eg Rendille (Kenya); Fouta (Guinea); Naman (Zimbabwe); Kois (India)). Among the Masai and Wandorobbo (Kenya), smiths are held in profound contempt. Smith clans are endogamous, confined to separate quarters, and all physical contact is avoided. No hospitality is accorded the smith and none is expected from him. Smiths have no legal rights and can be murdered without redress. Although a submerged class, the əŋkyagu smiths among the Marghi (Nigeria) are important members of society and enjoy a certain measure of social parity. They live amongst, and enjoy amicable relations with the Marghi, but are nevertheless endogamous and are barred from eating and drinking with non-əŋkyagu tribesmen. Low status smiths are often associated with other unsavoury occupations. Badditu smiths (Ethiopia) form an inferior caste with weavers, tanners and potters. In central India, brass workers belong to the most degraded of untouchable castes which also includes grass-cutters and horse-tenders. Amongst tribes in north east Nigeria, smiths are often the grave diggers.

High status implies participation in tribal or community life, and is often accompanied by social, economic, political and/or religious privileges. On some occasions smiths achieve positions of power. Luyia smiths (Kenya) are treated as peers of the tribal leaders. They are allowed to wear high prestige garments during ceremonies, and sit with the elders in council. The Kaffir (South Africa) brassworkers' living compound is adjacent to that of the chief. In Ashanti (Ghana), the craft chief is often the village chief, and the goldsmith's wife is privileged to bedeck herself with ornaments otherwise worn only by the wives of the chief. Benin brass and copper workers (Nigeria) are rewarded by food, women, slaves, and help in house-building. They are sometimes permitted to plant new settlements in the bush and farm with slaves supplied by the King. Blacksmiths' clans of Buganda (Uganda) are attached to royal households and enjoy free land, tax exemption and freedom from compulsory labour. During the Kingdom period in Java, the blacksmiths filled honoured positions at court, were addressed as priests and often acted as ambassadors.

Neaher has observed that negligible attempts have been made to explore possible causes of status differentiation between separate smithing groups (Neaher, 1976, 71). In a more recent study of Kenyan smiths, Brown (1980) has examined the question of status differentiation in some detail. Her conclusions stress a strong correlation between status and the relative importance of the smith's output to the economy of the society. Smiths are vital to the livelihood of agricultural groups, providing tools for intensive cultivation, weapons for hunting and defense, and protective 'medicines' to maintain the good health of the community. Among agricultural groups in Kenya, smiths are usually of high status, and often hold official positions. By contrast, pastoralists' smiths are generally of low status. Few iron implements are needed, and although useful, smiths are not essential to hunters and herders who can usually obtain their weapons from the resident smiths among neighbouring agricultural groups. Furthermore, pastoralists require a narrower range of iron implements, the ubiquitous spear serving as a woodworking tool and general purpose knife in addition to its role in hunting and warfare (Brown, 1980, 196-204).

Valid though these conclusions may be, it would seem, in the light of the present study, that the relative economic importance of metal artefacts is but one among many significant factors which contribute towards status differentiation. My contention, based on an albeit partial survey of the ethnographic literature related to Africa, Asia and northern Europe, is that differences in status cannot be attributed to a single cause, but instead result from an amalgam of attitudes related to the same four basic factors which underlie the setting apart of the smith from his society. To reiterate: these factors are heredity and clan-caste affiliation; mystery surrounding the smith's craft; his singular skills; and the importance (not only economic) of metal products to society.

In two situations, the predominance of one of these factors seems to result in predictable status ascription. Firstly, smiths of alien origin are almost invariably of low status (eg Mashona smiths among the Ndebelé (Zimbabwe); Bericho smiths among the Hunza, and Bari smiths among the Shiaposh (India); and smith clans among the Peul and Laobes (Senegal)). This would seem to support Clement's observation that smith status is often directly linked to the duration of metalworking activity in a given area (Clement, 1948, 35).

Secondly, patronised smiths, producing goods of high value, are universally of high status. Ashanti (Ghana) and Benin City (Nigeria) brass casters, for example, produce artefacts essential to the wealth and prestige of their royal patrons. Gola ornament makers (Liberia) are often patronised by tribal chiefs who use their services in gift exchange. Interestingly, whilst patronised ironworkers may be of high or low status, patronised brass casters invariably produce prestige goods, and are always of high social rank. Here, Brown's emphasis on the relationship between the smith's status and the importance of his products, would seem to be confirmed. However, product importance is not confined to the economic sphere. Metal artefacts play a vital role in all aspects of the social and economic system.

Outside these two situations, varied factors operate together in a largely unpredictable manner to determine the status of the smith. Akan metalworkers (Ghana) are of high status and identified with the gods because of their associations with lifegiving fire, whilst Tuareg blacksmiths (Saudi Arabia) are despised because they live by fire and are thus destined for 'hell'. In Nigeria, smiths among the Marghi belong to a submerged caste, whilst those of pre-colonial Kano City were of high status, enjoying considerable economic privileges. Both these latter groups, however, play a role in maintaining the stability of the social system. The əŋkyagu caste symbolises the relationship between the Marghi ruler and his people; the Fulani rulers of Kano were able, through the hierarchical smiths' organisation, to retain control of essential goods and services, and thus ensure the stability of their government.

I.4 SPECIALISATION AND ORGANISATION IN THE METALWORKING INDUSTRY

As already described, there are three basic but often inter-related forms of specialisation relevant to metalworking: specialisation according to metal; specialisation according to activity within the craft; and specialisation according to products. The evidence presented here (Appendix I.1, Table I.3) permits identification of these forms, and allows the exploration of their expressions and modes of co-variation within a wide range of social contexts.

I.4.1 Specialisation according to metal

Within essentially iron-based economies, copper and its alloys are, almost by definition, rare metals. Brass and bronze are generally accorded high value, and sometimes, as in Dahomey (Benin), classed with silver and gold. In the vast majority of communities, metalworkers specialise in the production and smithing of iron. Copper and other rare metals are worked among only 14% of the social groups included in this study, and within these groups, metal-based specialisation follows a consistent pattern. In some areas, one metal is worked in isolation. Bauchi Province (Nigeria), for example, is an exclusively tin smelting region, whilst in Zaïre the Bayeke smelt and cast only copper.

Generally, however, copper and rare metals are worked alongside iron, and in almost all cases the different materials are restricted to different castes or craft associations (eg Dahomey (Benin); Awka Igbo, Benin City, Igbira, Nupe and Igala (Nigeria); Bagam (Cameroon); Java (Indonesia)). Blacksmithing and goldsmithing are separate individual specialisations among the Mende (Sierra Leone), individual Gola smiths (Liberia) specialise in iron or copper alloys and the intinerant Laeshi (Rumania) smiths each specialise according to metal.

There would seem to be no metal specialisation among the Zulu smiths (South Africa), who produce bracelets in both copper and iron; among the Lango (Uganda) one of the two specialist smith groups produces utilitarian goods and small ornaments from iron and heavy bracelets from brass. In both cases the rare metals are not cast, but forged and beaten in the manner of iron. The only example of alloy casting combined with ironworking occurs in the Sudan, where certain Dinka smiths produce brass bracelets in addition to iron tools. A simple, open mould technique is used in contrast to the complex and precise lost wax process employed by such groups as the Ashanti (Ghana) and the Yoruba (Nigeria).

In the light of all the evidence, metal-based specialisation would thus seem to be closely correlated with technique. When copper and other rare metals are manipulated by ironworking techniques, specialisation on technical grounds is unnecessary. However, the sophisticated range of skills required to cast metal in closed moulds helps to keep this craft exclusive.

It is now time to turn to the relationship between metal specialisation and social status. Whereas specialist ironworkers enjoy a wide range of social positions, African smiths whose exclusive occupation is the casting of copper and its alloys are invariably of high status. These smiths produce goods of high value and prestige for influential patrons. By contrast, specialist ornament makers in Kenya who work in aluminium are of variable status, and copperworking castes in Bihar (India) are of low status. Neither group is patronised and neither group produces goods of particular economic and social significance.

In communities supporting different metal specialisations, rare metal and iron workers tend to be of similar rank. In these cases, however, both groups are patronised and both produce goods of high social value. Slight status variation is noted in Dahomey (Benin), where brassworkers hold noble positions but are considered not quite so economically important as the blacksmiths; and in Benin City (Nigeria) where the royal blacksmiths are regarded as inferior by the bronze casters.

I.4.2 Specialisation by activity

Ironworking

The specialist craft of ironworking basically encompasses collecting and/or mining; smelting; and smithing. The provision of tools and equipment necessary to the work, dealing in raw materials and marketing constitute further potentially specialised activities. A single ironworker or group of ironworkers may be restricted to one or a combination of these activity areas. Specialist individuals or groups may constitute completely separate castes or form subgroups within a single caste.

Ironworking groups without some form of activity specialisation are rare. The Adjong smith clan among the western Dinka and certain Bari smiths (both Sudan) collect and smelt their own ore; similarly, the itinerant Maguzawa (Nigeria) and Elgeyo (Kenya) both smelt and smith.

Mining and ore collection are frequently combined with smelting. In Nigeria, for example, Marghi freemen collect and smelt ore to be forged into pig iron by the specialist ŋkyagu caste.

In the majority of cases included in this study, smelting and smithing are distinct specialisations and are often caste restricted. Among the Bakitara (Uganda) mining-smelting, pig iron working and smithing are all exclusive occupations. Work is never shared, but each group helps market the products of the others. Among the Ba-Ushi (Zambia) smiths and miner-smelters belong to separate castes, whilst among the Labwor (Uganda) and the Kikuyu (Kenya) smelters and smiths form separate branches of the same craft organisation.

Among certain groups, ironworking is highly activity specialised. Mashona (Zimbabwe) miners, smelters and smiths belong to exclusive craft groups, and in Kano City (Nigeria) all aspects of the industry are restricted to different specialists. Miners, smelters, smiths, raw material dealers, middlemen and traders all participate in a complex system. Interestingly, Kano rural smiths sometimes smelt their own iron, and sometimes act as middlemen, supplying raw materials to their urban counterparts.

The magic and mystery which surround all stages of smelting and forging, generally ensure that the ironworkers produce all their own tools and peripheral equipment. Smelters build their own furnaces and often make their own charcoal; smiths seek their own anvil stones and forge their own spiritually powerful hammers. Although clayworking is always the province of another social segment, almost all smiths described here make their own tuyères, often travelling considerable distances to obtain (practically and ritually) suitable clay.

Rare metal working

The processes of copper and copper alloy working vary according to the techniques employed. Additionally cire perdue casting permits a wider possible range of specialised activities than does heat forging. However, it would seem from the evidence that in non-industrialised societies, the brass-smith, like the ironworker, generally produces his own tools and equipment. Specialist refractory makers are not recorded in pre-industrial ethnographic contexts. Copper alloy working, therefore, basically involves the potential specialist activities of mining, smelting, alloying, casting and/or smithing.

In contrast to the ironworkers, rare metal smelters are invariably separate from the smith. Sources of copper, tin, gold, etc are rare and localised. Specialist miners and smelters are always located at these ore sources and often supply customers considerable distances away. Bayeke (Zaïre) smelters and casters are of the same clan, but their roles are exclusive; copper smelters and casters are organised into separate guilds in Korhogo City (Ivory Coast).

As with ironworking, rare metal mining and smelting are sometimes combined and sometimes specialised activities. In Bauchi Province (Nigeria) tin smelting furnaces are owned by village elders who are usually specialist smelters. Miners bring their ore to these smelters, and are paid in kind. Among the Balemba (Zimbabwe), copper miners and smelters belong to separate, though inter-related clans.

References to copper mining and smelting are extremely rare, and no evidence was found concerning alloying.

I.4.3 Specialisation by product

Product specialisation relates both to the types of metal used, and to the smith who limits his product range.

The choice of metal for any item is determined by practical and social consideration. In an iron-based economy, this material is used for all tools, weapons and everyday utilitarian items. Copper and other rare metals are restricted to ornaments, and decorative and ritual items. These luxury, prestige and magico-religious artefacts may also be produced from iron.

Product specialisation in relation to the smith, is here defined as the manufacture of a single, or limited range, of metal items within the complete range of such items demanded by a given social system. Product specialisation may be manifest by individuals or defined smith groups. The evidence shows that specialisation by product may be partly or wholly determined by social or economic demand or by the skill of the smith.

The sedentary blacksmith attached to an agricultural community tends not to specialise by product. He manufactures and maintains the complete range of iron artefacts necessary within the economic and social system. This range can include tools for land clearance, agriculture and clay digging; wood- and leather-working tools; weapons for hunting, fishing and defence; household items such as vessels and cooking stands; herding equipment such as branding irons and cowbells; personal ornaments such as rings and bracelets; protective 'medicines' and ritual implements. Locally itinerant smith groups, serving a number of agricultural communities, again tend not to specialise. The Bericho smiths among the Hunza (India), for example, visit villages once or twice each year, making and repairing whatever is required. Smiths among pastoralist groups produce a much narrower range of items. However, this cannot be described as product specialisation, but rather as a reflection of the demands of a mobile economy. Pastoralists' smiths throughout Kenya, for example, produce little beside spears. Spears serve as woodworking tools and general purpose knives in addition to their more usual role in hunting and warfare, thus eliminating the necessity for a wide range of purpose made implements. Mashona smiths (Zimbabwe) similarly concentrate on spear production.

As already discussed, it may be predicted that product specialisation will be closely correlated with demand. The precise nature of this demand which underlies production and specialisation can only be determined from a detailed analysis of each individual social system; and such analyses are outside the scope of this study. However, certain patterning revealed in the evidence permits some general conclusions to be drawn.

Product specialisation seems to be directly related to the magnitude of demand (whatever its nature) and to social complexity. Magnitude of demand would seem to be at least partly responsible for the individual specialist production of axes, spears or cowbells among the Plateau Tonga (Zambia). Similarly in Sumatra (Indonesia) machetes, hoes and spears are each the responsibility of a different ironworker. Among the Basakata (Congo), again production is linked to scale of demand, but here other factors influence the allocation of individual specialities. Degree of acquired skill dictates that whilst all smiths make tools, only those who have completed their apprenticeship can manufacture the more complex weapons. Master smiths alone possess the necessary experience and magic power to produce ceremonial ornaments.

Complex social systems tend to generate complex product specialisation. The itinerant Awka (Nigeria) blacksmith, for example, specialises in producing ritual or utilitarian artefacts. At outstations, when more than one Awka smith is present, competition dictates further limitation within these categories. In Kano City (Nigeria) the blacksmiths of one ward produce door-locks, another group make swords, and a third specialise in horse equipment. Kano rural smiths make only tools, obtaining other items from their urban counterparts. In Buganda (Uganda), the Ente clan produce royal shields and ornaments for the chief's wives. In this case, both ironworking groups operate under royal patronage.

In communities supporting both specialised blacksmiths and rare metal working groups, the ironworkers tend to produce all utilitarian items, whilst the brass, copper, silver or gold smiths specialise in ornaments and ritual items. Among the Northern Hausa (Nigeria) for example, iron production centres on agricultural and metalworking tools, whilst silver is reserved for ornaments. Among the Galong (India) metalworking communities specialise in the production of iron swords, brass beyop plates or bracelets of brass and copper. In Dahomey (Benin) the brassworking caste specialises in ornaments to commemorate the King's reign, to celebrate his power or to decorate his palace. Individual Gola copper alloy workers (Liberia) specialise in figurative sculptures sometimes used by magic practitioners, and sometimes as toys by the children of the wealthy. In Benin City (Nigeria) certain ritual or ornamental items are restricted to specific lineages within the bronzeworkers' caste. Among the Yoruba (Nigeria) patron demand directly influences product specialisation. Brass casters, patronised by religious cults, produce ceremonial ornaments, whilst certain ironworkers patronised by military leaders, specialise in weapon production.

Finally, to illustrate the possible complexity of metalworking specialisation, attention may be drawn to the separate a-tong and a-ariko smiths among the Lango (Uganda). The a-tong produces weapons, tools and small ornaments in iron, and bracelets in beaten brass. The a-ariko makes only iron ariko, the heavy ritual ornaments worn by girls after initiations. Thus the a-tong specialises by activity (he does not mine or smelt), to some extent by product (he makes no ritual items), yet does not specialise according to metal. The a-ariko, on the other hand, represents all forms of specialisation considered here. Although a range of social, and perhaps historical factors may be predicted which underlie these modes of specialisation among the Lango, it is not possible to proceed beyond prediction without considering the total social system.

I.5 THE INDUSTRIAL ORGANISATION OF METALWORKING

Miners, smelters and smiths, specialising in iron, copper or other rare metals, operate within a range of complex organisational systems. Industrial activity may be resident or itinerant, part- or full-time, individual or co-operative. Organisational variables also include activity location, length and format of apprenticeship, and means of obtaining metal and other raw materials.

I.5.1 Pattern of work

Resident or itinerant work patterns, and full- or part-time activity are neither determined exclusively by the metal being manipulated, nor by the technology employed. Instead, patterns of work are directly related to the smith's position in society and are influenced by demand for his products.

The evidence shows that full-time resident smiths usually occupy a very distinctive position in their communities. They may be of high status - smiths attached to royal patrons are resident and generally full-time - or of very low status, as are the pastoralists' smiths in Kenya. The full-time smith may be supported by an individual patron (eg Benin City (Nigeria) bronzeworkers; Zulu copper and iron smiths (South Africa); and the Marghi king's personal əŋkyagu blacksmith (Nigeria)); by his society (eg Gola (Liberia) and Kano City (Nigeria) blacksmiths); or be essentially self-supporting. In the latter case, the smith's income may be derived solely from sale of products to members of his own and other tribes (eg Kigezi (Uganda)), or derived partly from his craft and partly from his fields which his family and others farm. Smiths among the Nandi (Kenya), for example, own fields cultivated by their families, and additionally exchange their products outside Nandi territory for food and other items. Dagaba full-time smiths (Ghana) obtain the greater portion of their income from land farmed by their families, and by customers in exchange for products.

There is a constant, non-seasonal demand for the products of the full-time resident smith. This demand is directly linked to the individual social and economic system. Thus the hunting and warring Masai (Kenya) support a limited number of full-time smiths to make and repair their weapons; and in contrast, the Benin, Yoruba (Nigeria), Ashanti (Ghana) and Zulu (South Africa) smiths are constantly occupied producing prestige items for their royal patrons, and serving them in other ways (maintaining public buildings, general repairs etc). Influential, wealthy tribesmen reinforce their status by employing a personal smith to make and repair all tools, weapons and household necessities on a year-round basis. Full-time resident craftwork is often closely related to exchange. Ondulu (Angola) smiths smelt their own iron, and produce hoes to trade over a wide region. Ore gathering and smelting take place during the dry season, and smithing during the rains. The specialist ironworking communities are surrounded by fields cultivated by the women and children. Kigezi smiths (Uganda) live entirely by their craft, exchanging their products in the local market or supplying private customers. Part of the smith's year is spent in preparing charcoal, part in his smithy, and part in marketing his products. Among the N Hausa (Nigeria) smithing is generally a part-time occupation secondary to farming, but on the outskirts of towns and on tribal boundaries, assured markets support full-time specialisation.

The great majority of resident metalworkers are involved in craft activities for only a part of their time, and participate, usually on a seasonal basis, in subsistence activities. Part-time resident smiths are invariably attached to agricultural communities. Ore gathering, smelting and smithing all take place in accordance with the agricultural cycle. The Angas (Nigeria), for example, begin ore gathering after the harvest is safely stored; the Ba-Ila (Zambia) and Labwor (Uganda) smelt only in the spring when there is little agricultural work to be done, and the Bongo (Sudan) both smelt and smith after the rainy season. In Indonesia smithing during the planting and harvesting of rice is believed to be dangerous to the crop. Ritual sanctions prevent the Sulawesi smith from working at these times, and free him to participate in agricultural activities.

Just as the agricultural cycle influences the smith's availability for craftwork, so it influences the demand for his products. Smiths attached to agricultural groups throughout Kenya are constantly employed at their craft immediately before the planting and weeding season and immediately before harvest when the demand for iron tools is greatest. Similarly in Burma, the Northern Chin smith works incessantly before the planting season producing hoes for cultivation. In Borneo (Indonesia), smiths are called from their fields during planting and harvesting to carry out essential repairs to agricultural implements.

Sometimes the part-time smith derives his income equally from craftwork and farming; sometimes agriculture is his primary occupation and metalworking a subsidiary activity. The high status and often affluent Kpelle smiths (Liberia) derive most of their wealth from agriculture; and among the Mossi (Ghana) and Plateau Tonga (Zambia) smiths are primarily farmers, and metalworking is virtually a casual occupation.

Contrary to commonly held beliefs, itinerant metalworkers are by no means rare in ethnographic and historical contexts. Examples of itinerant smelters and smiths, working in rare metals, or iron, and operating on a full- or part-time basis have been found in all areas surveyed. Additonally, both local and long-distant itinerants are represented in the evidence. However, information is frequently limited, and unexpanded references to "often itinerant smiths", or simply "itinerant smiths" are encountered with dismaying regularity. Neaher has stressed the potentially vital role played by the peripatetic metalworker in the spread of technique and the development of trade, and deplores the lack of attention paid by ethnographers to any other than sedentary groups (Neaher, 1976, 91). The very fact of itinerancy perhaps accounts in part for this dearth of information, for, as Thomas found when he attempted to study the Awka Igbo (Nigeria) in the early 20th century, they were all away on their travels, and dispersed throughout southern Nigeria (Thomas, 1913). Adequate data do exist, however, to confirm the operation of itinerants in many areas, and thanks to Neaher's recent study of the Awka, the organisation of at least one group of long distant peripatetic smiths may be understood (Neaher, 1976).

Although metalworking groups throughout Africa make seasonal sorties to smelt at sources of high quality ore, these movements may not accurately be described as itinerancy. However, truly itinerant smelters are attested in Nigeria, where professionals from Sokoto win and smelt ore in Koro territory under licence from the local chief. Again in Nigeria, itinerant Maguzawa metalworkers work throughout the dry season smelting ore and making hoes for the local Gbari and Hausa.

Among the Dinka (Sudan), seasonally itinerant smiths, the Adjong, follow their customers in the dry months to Shambe Lagoon, where they make and mend iron tools and produce ornaments. Kano rural smiths (Nigeria), who leave their homes in the dry season to obtain raw materials from the smelting camps, often pause along the way to produce items for sale on the journey home. The Shans of Burma do not work iron, but instead rely on the seasonally itinerant Yunnanese Shans, who set up makeshift forges and anvils in Burmese territory to produce and repair agricultural implements.

Locally itinerant smiths are found among the Gwembe Tonga (Zambia). A Tonga smith from Munyumbwe territory, for example, serves communities up to one day's journey away from his home base. In India, itinerant Hunza smiths visit each local village once or twice each year, making and mending whatever is required.

Long-distant, full-time, itinerant metalworkers are well represented in the literature, although the quality of information concerning such groups is often sadly inadequate. The Abakwariga Hausa, for example, are known to have travelled extensively, producing goods in iron and bronze for a wide variety of patrons. However, one may sympathise with Rubin's lament: "their role as craftsmen and traders throughout the Benue region prior to the rise of the Fulani is one of the great untold chapters in Nigerian history" (Rubin, 1973, 223). Whilst blacksmithing is a sedentary, high status occupation among the Gola (Liberia), market demands dictate that copper and brass workers, desirous of full-time specialisation, leave their homeland after their apprenticeship and either work by commission in the larger towns, or become attached to a wealthy patron, perhaps a non-Gola tribal chief. Smiths so patronised often move from one chiefdom to another as their services are exchanged among rulers as gifts and diplomatic favours. Like the Gola copper workers, Torguts silversmiths (Mongolia) specialise in high value, prestige ornaments. These smiths too are peripatetic, moving from tribe to tribe according to demand.

Wide-ranging itinerancy is not, however, confined to rare metal workers and the makers of high status goods. Awka Igbo brassworkers and blacksmiths alike are renowned for their skills which they ply throughout southern Nigeria, serving tribes of varied ethnic composition. Each master smith follows an arranged route, visiting one or more 'out-stations' during each six month working period. The length of his itinerancy (fig I.5.1) is limited only by the need to return to Awka in the seventh month to attend the feast of otite. Heavy fines are imposed on tribesmen who absent themselves from this feast. During each six month period, half of the Awka workforce travels, and the rest remain idle at home supported by their kin. At otite, the two groups exchange roles. This work sharing system, inaugurated during the days of the slave-trade, ensured year round protection for Awka women and children. Its perpetuation guarantees employment for a large number of skilled craftsmen.

At the 'out-stations', Awka smiths produce goods not provided by the local metalworkers. These include utilitarian implements such as hoes, machetes and fishing traps; weapons; and ritual items such as ozo staffs (from iron or brass) and bells used in religious ceremonies. Brassworkers may specialise in utilitarian trays or decorative plaques. Patron-client relationships are often established between the smith and his host, the former receiving lodging and food from the local chief as part payment for his services. Most Awka smiths achieve additional social and economic status, both at home in Awka and on their travels, through their involvement in trade. Carrying Awka products with them to the out-stations, they return home with a wide range of utilitarian and luxury items. Smiths travelling in Ijo territory, for example, bring palm products and European imports back to the Awka villages, whilst those journeying north return with maize, yams, spices and beads. Although the origins of Awka metalworking are shrouded in the mists of history, its continuation has been attributed to the superior skill of the mobile smiths, which in turn has led to a production monopoly of many items (Neaher, 1976, 86).

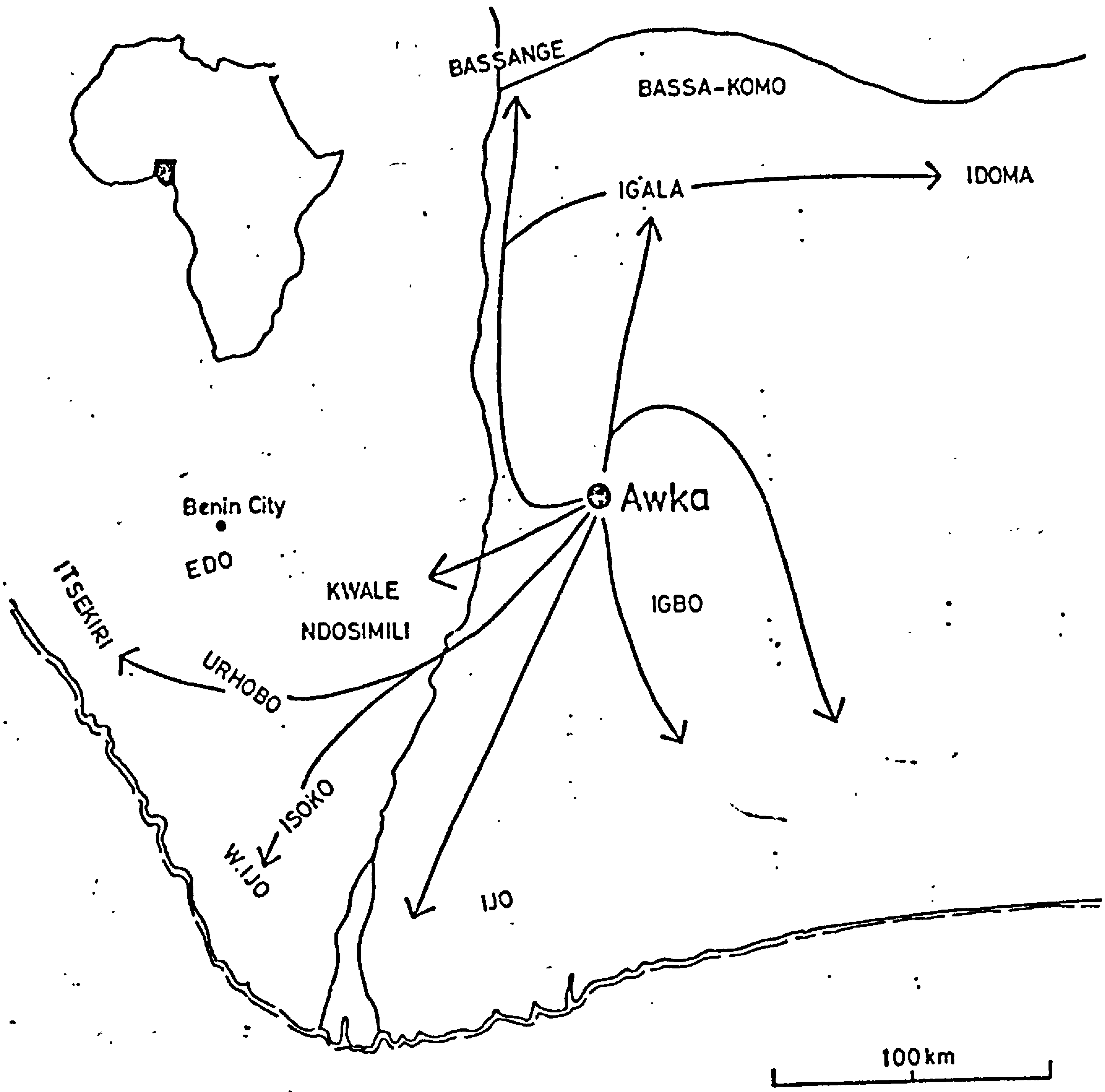


Fig I.5.1 Sketch map of areas traversed by itinerant metalworkers on their six month journeys from various Awka villages (data from Neaher, 1976).

The itinerant Bahungana metalworkers (Congo) are unique in the anthropological literature. Both smelters and smiths, the Bahungana are the acknowledged iron specialists throughout a wide region. They travel extensively, smelting ore and producing hoes, machetes, axes and arrowheads for all neighbouring tribes who have no smiths of their own. Wherever the Bahungana set up their forges, they are well received, for their products are essential to the economy of every community.

The co-existence of sedentary and itinerant metalworkers is attested in the ethnographic literature, but references are vague and lack detail. Dakakari (Zambia) males often take up smithing as a casual occupation, but most of the tribe's needs are provided for by metalworkers "from other parts". Likewise, the Malhoar caste among the brassworkers of Bihar (India) are known to be itinerant, but no records exist either of their work patterns, or of their relationship to the sedentary metalworking castes and the society they serve.

This study of work patterns has, to an extent, illustrated the relationship between a society and its resident smiths. Similarly, from the albeit rare descriptions of itinerant organisation it is possible to understand some of the forces which maintain the mobile tradition. Is it possible to see such patterns reflected in the prehistoric data?

I.5.2 Practising the craft

Those aspects of industrial organisation which are, to varying extents, influenced by technology, are now examined.

Apprenticeship

The metallurgical crafts demand a considerable degree and wide range of skill from their practitioners. Thus all copper alloy workers and virtually all blacksmiths serve long and arduous apprenticeships. As already observed, metalworking tends to be a hereditary craft, and often passes automatically from one generation to the next. In some societies however, selection within this system restricts the number of smiths. Among the Gola (Liberia) and the ɔŋkyagu caste (Marghi, Nigeria) only those showing talent and motivation are apprenticed.

Gwembe Tonga novices (Zambia) are chosen and theoretically trained by the spirit of a smithing ancestor. A novice smith, as a rule, is apprenticed to his father, but complex inheritance systems operate in some groups (eg Nuba (Sudan); Bakitara (Congo)). Apprenticeship often begins, either formally or informally, at an early age. A boy may help his master about the forge in his seventh or eighth year (eg Awka Igbo, Kano City (Nigeria)). Length of the learning process varies, but a young man is rarely initiated as a fully fledged smith until his late teens or early twenties.

Apprenticeships in both the iron and rare metal industries tend to follow a well defined pattern. The novice blacksmith first pumps the bellows and watches over heating metal, then begins to produce implements of increasing complexity. Aspiring brassworkers in Korhogo City (Ivory Coast), first fetch and carry water and file rough cast pieces. Awka copper smiths (Nigeria) learn to make plates of increasing size. Before specialising, the Gola copper ornament maker (Liberia) receives his basic training from a blacksmith. Fees and sacrifices are usually necessary throughout the learning period, and complex ritual and ceremony surrounds initiation into the craft. At initiation, the fully-fledged smith receives his tools, which may be newly forged or inherited from a previous smith.

Individual and co-operative activity

Ore-gathering, mining and smelting, irrespective of metal, are everywhere group activities. Specialist groups combine their skills to collect raw materials, build the furnace, prepare the fuel and conduct the smelting operation. Blacksmiths require the services of at least one assistant to pump the bellows and maintain the hearth temperature. Lango smiths (Uganda) work with a single apprentice assistant. Independent Kigezi smiths (Uganda) usually employ two helpers: one to operate the bellows and the other (usually the smith's son) to forge the simpler implements. Awka master smiths (Nigeria) travel in groups with their apprentices. The travellers are recognised and protected form attack by their dialect, and by the tools of their craft which they carry upon their backs. Although taboos generally prohibit women from appraoching the smithy, in some societies smiths' wives play an active role. Zala women (Ethiopia) help with the bellows, and the Ewe smith's wife (Ghana) occasionally assists at the anvil. Ironsmithing is frequently a group activity (eg əŋkyagu (Marghi, Nigeria) co-operative forges; Buganda (Uganda) clan co-operation). Dahomey blacksmiths (Benin) operate an efficient co-operative work system: a combined labour force converts the scrap collection of each worker, in turn, into tools.

Copper alloy working, and especially casting, would seem almost invariably to be a co-operative activity. Among the Yoruba (Nigeria) casting takes place in specialist group workshops, and in Benin City (Nigeria) work roles are assigned according to rank in the caste hierarchy. In Korhogo City (Ivory Coast) and Bihar (India), individual family units co-operate in the production of cast bronze artefacts.

Location of activities

The location of meatlworking acitvity is determined by practical, social and economic considerations. Although there are exceptions (some Ondulu ironworkers (Angola) carry ore several miles to smelt near their villages) ore reduction generally takes place at the raw material source, where workers live in temporary camps throughout the smelting season (eg Bari (Sudan); Kanawa (Kano City, Nigeria); Ba-Ila (Zambia)). The precise siting of the smelting furnace at the ore source is sometimes governed by religious belief. The Ba-Ushi (Zambia), for example, who associate smelting with the cult of the dead, must always build their furnaces on ancient smelting sites.

Iron and copper alloy specialists alike, who depend partly or entirely on craftwork for their livelihood and produce for trade, may generally be found on the outskirts of large population centres (eg Igbira, Igala, Nupe (Nigeria); Ente clan (Buganda, Uganda)) or at strategic rural locations such as major cross-roads (eg Kavirondo Bantu (Uganda)), or on important routes through valleys (eg Kalenjin (Kenya)). Here, location is determined by access to markets and ease of distribution.

Whatever the status of the village smith, his forge is invariably located on the edge of, or some distance from the settlement area.

Practically, this isolation guards against the obvious danger of fire, and additionally allows the smith easy access to essential commodities such as water and wood. Socially, factors such as risk of pollution, fear of the smith's magic (eg Masai and Kalenjin (Kenya)), or simply dislike of the dirt and unpleasant odours associated with the craft (eg Kavirondo Bantu (Uganda)), may influence the location of the work place. High status, integrated, agricultural smiths in Kenya always isolate their smithies, essentially to preserve the mysteries which veil their art.

Copper alloy workers require both forge facilities and a place close by where necessary equipment might be prepared. In Korhogo (Ivory Coast), casting shelters are located at the edge of the city, and wax models and moulds are formed under nearby trees. Bronze and brass workers producing prestige goods under patronage are often privileged to locate their workshops near the royal palace. In both Dahomey (Benin) and Benin City (Nigeria), sophisticated economic systems allow all necessary raw materials to be conveyed into the palace area prior to each casting episode. In Benin City, moulds and wax models are prepared in a compound adjacent to the royal residence, and casting takes place on a piece of waste ground nearby.

Metal supply

All metal, be it in ingot or scrap form, is everywhere highly valued. Smelted copper and iron often travel considerable distances; imported brass bars are valued as silver and gold in Dahomey (Benin), and one brass ring ingot serves as brideprice among the Zulu (South Africa). Scrap is carefully hoarded by smith and customer alike. Even the mobile Kenya pastoralists collect broken tools and weapons as potential raw material, and carry their collections with them wherever they go. Smiths (eg ɔŋkyagu (Marghi, Nigeria)) sometimes hoard scrap until enough has accumulated to justify making charcoal and arranging a bellows operator. To some extent raw material availability thus determines patterns of work.

The use of scrap or virgin metal is generally determined by availability. For example, in those areas of Kenya where ore is still smelted, smiths and their customers (who as a rule supply their own raw materials) can obtain ingots through trade. Outside these areas, most Kenyan ironworkers use scrap. Gola (Liberia) smiths work both smelted ore purchased from tribes in the savanna highlands and European scrap. Isoko brassworkers (Nigeria) use a combination of objects "from the ground", ingot metal and, rarely, bullet casings. Hoes from Barotseland, ingots from Plateau smelters and European scrap are equally welcome to the Gwembe Tonga (Zambia) who find metal of any kind difficult to obtain.

Sometimes, however, cultural restrictions govern the type of material to be used. Among the Yoruba (Nigeria), Ogun the god of iron is believed to be present in the raw metal, thus only virgin iron may be used for ritual and agricultural implements. The Ente clan of Buganda (Uganda) produce goods for trade from scrap metal, but all items for the Kabaka must be manufactured from smelted ore.

Metal may either be acquired by the smith himself, or provided by his customers or patrons. The blacksmith may smelt his own iron (eg Bari (Sudan); Maguzawa (Nigeria)), or obtain ingots and/or scrap through trade. Ingassana smiths (Ethiopia), for example, import iron from the Blue and White Nile regions, whils the Bemba (Zambia) buy smelted ore from the Lunda tribe to the west. Copper alloy workers likewise may obtain locally produced ingots (Bayeke (Zaïre) copper casters and smelters belong to the same clan), or acquire their metal through trade. The Basuto (Lesotho) import all their copper and brass from the Thongas (Mozambique); Korhogo City brassworkers used to cast only imported ingot material; in Bihar and central India copperworking castes have always acquired their raw materials from professional scrap dealers.

Basakata (Congo) smiths receive their entire raw material supply from their customers, who obtain ingots from the smelters or scrap through exchange. The partially itinerant Dinka (Sudan) depend on their customers for scrap iron and copper to supply their dry season forges. Clients requiring beyop plates from the specialist Galong coppersmiths (India) provide their own materials in the form of old and damaged dankis (bowls imported from Tibet). In some societies (eg Kikuyu (Kenya); Konso (Ethiopia)) a dual system operates, whereby either the smith himself or his customers may supply the raw material. Wachagga smiths (Tanzania) occasionally buy their own iron, but more often customers commissioning a tool must provide sufficient iron for two such items, the second being retained as part payment by the smith.

Client metalworkers, as a rule, receive their raw materials from their patrons (eg Dahomey (Benin); Zulu (South Africa)). In Benin City (Nigeria), the Oba supplies all metal including iron for the tongs used in the brassworking process. After casting is complete, all waste and crucible residues are returned to their donor.

Non-metal raw materials

Like metal, charcoal may be obtained by the smith himself, or supplied by his customers. In many areas, principally Kenya and Uganda, only the smith is permitted to cut wood and make charcoal, and many rituals surround this activity. Most smiths, however, prefer to prepare their own fuel, and use the slowest burning wood available, which varies from area to area. Exceptionally, Kavirondo Bantu smiths (Uganda) buy their charcoal from the neighbouring Nandi, and in pre-colonial Kano City (Nigeria) elderly women traders supplied fuel to the smiths.

In some societies, customers requiring implements must supply the smith with both metal and charcoal (eg Kikuyu (Kenya); Labwor (Uganda); Sulawesi (Indonesia)). Among the Angas (Nigeria) customers are required to prepare their own fuel, and here considerable ritual surrounds the cutting of the wood and charcoal making. Wachagga smiths (Tanzania) obtain their needs partly from their charcoal burning sons and partly from their customers.

Regarding supplies of clays and waxes necessary in the iron and bronze working crafts, very little is known. The casters of Ashanti import high-grade charcoal and wax from the Ghana hinterland, and customers requiring cast beyop plates must supply their own metal and wax to the Galong smiths (India). As to clays, Brown's (1980) study of tuyère production would appear to be unique in the literature, and although descriptions of furnace and mould making can be found, very few refer to the sources of raw materials used (see below, Part II). Other than among the Samburu, smiths throughout Kenya make their own tuyères. It is believed that a tuyère made by a woman would cause failure in smelting and forging. For the same reason, smiths generally collect their own clay. In the absence of evidence to the contrary, and mindful of the rigid technical constraints involved, it may be predicted that moulds and other refractory essentials would likewise be produced by their users. No specialist refractory makers are recorded in the pre-industrial ethnographic literature.

I.6 METALWORK TRANSACTIONS: DEMAND AND SUPPLY

Throughout this study thus far, I have attempted to explore the manner in which demand for metal artefacts relates to the makers of these artefacts and to production systems. Production, in terms of our simple linear model, takes place in consequence of demand, which in its turn is an active response to utilitarian and/or symbolic needs. These needs are embedded in and generated by individual social systems.

Distribution is likewise directly linked to demand, and like production cannot be considered as an economic activity divorced from any social setting.

> "Neither the process of production nor that of distribution is linked to specific economic activities attached to the possession of goods, but every single step in that process is geared to a number of social interests ... These interests will be very different in a small hunting or fishing community from those in a vast despotic society, but in either place the economic system will be run on non-economic motives" (Polanyi, 1944, 40).

Whilst production systems transform demand into finished products, distribution mechanisms convey these products to those who expressed the demand. The expression of demand which results in the manufacture of a particular product, and the process by which that product enters the consumption network, may both be termed transactions. Transactions can thus be conceived of as connectives in energy flows (van der Leeuw, 1981, 382).

The customer who demands a hoe to cultivate his garden will actively seek out the smith (transaction A, fig I.6.1) and express this demand. This may be described as an explicit transaction linked to periodic demand. When demand is continuous - and here it is pertinent to cite the demands of the market, the demands of inter-tribal exchange and the demands of a tax-tribute system - transactions are implicit (transaction A, fig I.6.1), and no direct contact is made between the smith and his customers prior to production.

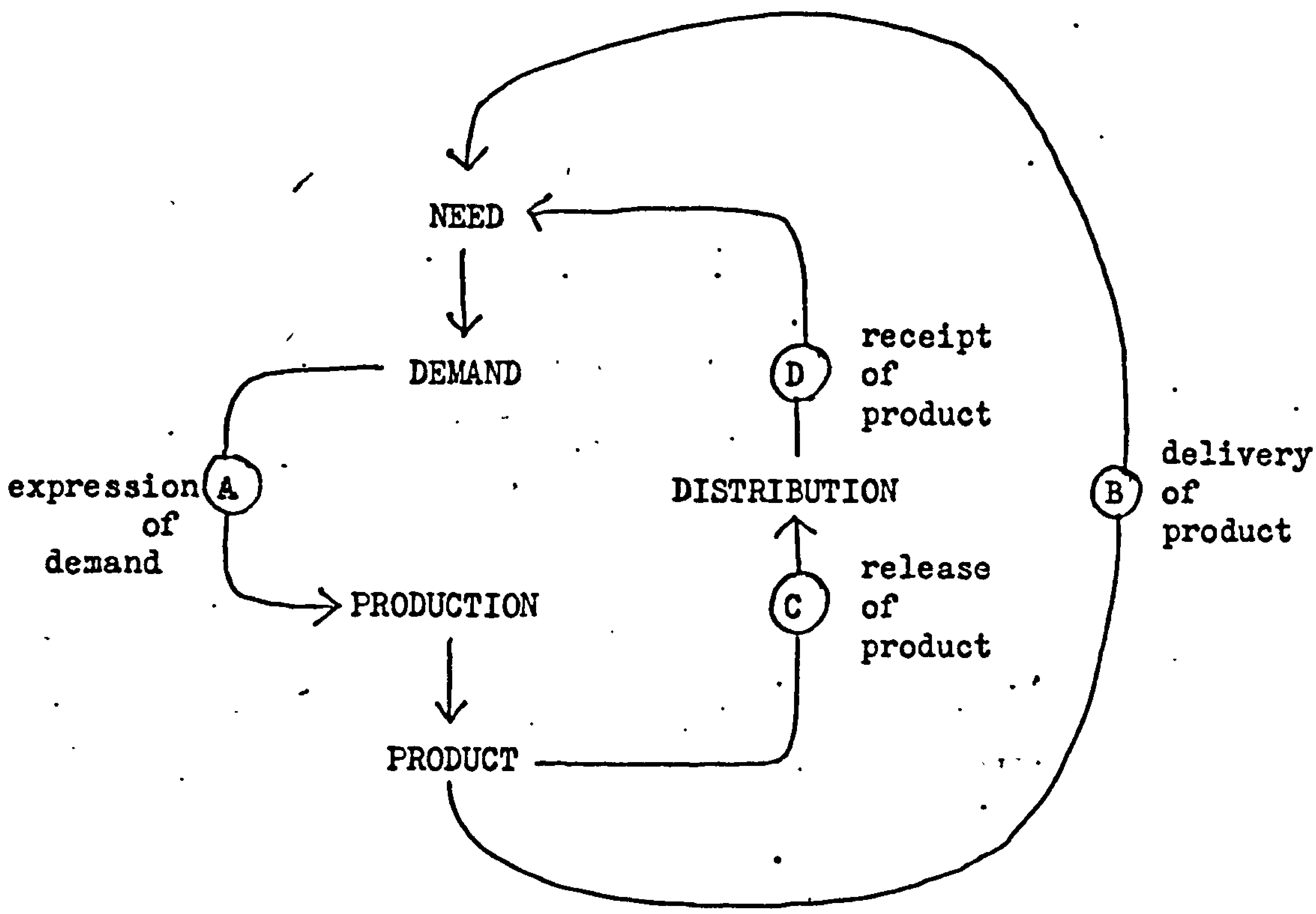


Fig I.6.1 The smith responds to an expression of demand (transaction A) by manufacturing a needed product. He may hand over this product immediately to the demanding customer (transaction B). Alternatively, he may release this product to a distribution system, for example to a middleman, (transaction C), from which the originator of the demand will eventually obtain the desired item (transaction D).

The transaction whereby the smith exchanges his products for a reward (transactions B and C, fig I.6.1) is directly related to that wherein demand is expressed (transaction A, fig I.6.1). The customer who required the hoe will again approach the smith, and receive the finished implement in exchange for other material goods, money or labour. 'Distribution' in this case entails the customer carrying his property home. Smiths producing for the market, for inter-tribal trade networks, or for a tax-tribute system, on the other hand, often make no contact with the eventual users of their products. Output may be exchanged with middlemen or at a central point of distribution. Rewards again may be in cash or kind, and here freedom from service or similar concessions in exchange for tribute may be included. When no contact is made between the smith and his customers, transaction C is followed by some form of distribution system over which the smith has no direct control (fig I.6.1). When the smith producing for trade (implicit transaction) makes direct contact with his customers - perhaps himself taking products to sell in a local market - direct distribution again follows transaction (B, fig I.6.1). The smith is rewarded in cash or kind and the customer carries home his purchase.

The majority of smiths included in this study would seem to produce a varying proportion of their output in direct response to customer commissions (explicit transactions; direct distribution). In Kenya, most smiths and their customers prefer direct transactions (Brown, 1980), and this may well be true throughout the study area. The Angas (Nigeria), and the Kavirondo Bantu (Uganda), for example, are also said to favour this form of commercial interaction. Payment for commissioned products may be in iron, money, food or other commodities, or in services such as labour in the smith's garden (eg Marakwet (Kenya); Dagaba (Ghana)).

Only those smiths with sufficient time, labour and raw materials may produce a surplus for trade (implicit transactions; direct distribution or distribution systems). Among Kenya pastoralists, surplus production is only possible when smith groups live in separate villages, and are thus freed from the obligations and restrictions of individual or community patronage. Agricultural smiths are often at liberty to make items for trade when not working on commissions (eg Kikuyu (Kenya)). Full-time Kigezi smiths (Uganda) prefer private customers, but also produce for the market.

In some groups, the socio-economic system demands that the smith produces trade items (implicit transactions; distribution systems). The Kavirondo Bantu (Uganda) and the Balemba (Zimbabwe), for example, produce iron hoes for use as currency in inter-regional exchange, and as bridewealth. Hoes manufactured by the Ondulu (Angola) are exchanged with inland tribes for cattle and palm-oil, and with coastal groups for salt. Hoes are a common medium of local exchange (up to 50 miles) in Kenya , where they function as bridewealth, gifts, bribes, and in land transactions.

The demands generated in large centres of population determine that urban smiths sell most of their products through the market system (eg Buganda (Uganda); Kano (Nigeria); Bihar (India)). Demand is continuous, transactions implicit, and distribution often involves the services of a middleman.

Generally, smith groups work in response to diverse demands, and thus participate in different forms of transaction. Awka Igbo smiths (Nigeria) produce goods on commission, make items to sell in local markets, and present gifts to their hosts at out-stations in return for food and assistance. The Northern Hausa (Nigeria) likewise make implements on request in exchange for other goods and services; contribute to inter-tribal exchange networks; and produce items for use in gift exchange. Demands are thus both periodic and continual, and transactions both explicit and implicit.

Finally, I turn to the high status client smith, whose lifestyle and production systems are determined by his patron. The relationship which exists between patron and client engenders a special system of demand and transaction. Although the patronised smith works in response to explicit and periodic requests for his products, unlike other smiths, he is not rewarded for individual commissions (eg Benin City (Nigeria), Dahomey (Benin)). Instead, his payment in food, lodging and privileges is continuous. In this system, the patron who expresses demand may reinforce his status by using the smith's products to decorate his palace, person or shrines, <u>or</u> may enter these products into a prestige exchange network. In this case either <u>direct distribution</u> (albeit at an élite level) or <u>distribution systems</u> may operate. An extreme example, illustrating the complexity of this system, concerns the Gola bronzesmith (Liberia) who produces goods for ritual use by magic practitioners, toys for the children of the wealthy, and who may himself be exchanged between rulers as a gift or diplomatic 'item'.

I.7 GENERALISATIONS FROM ETHNOGRAPHY AND IMPLICATIONS FOR PREHISTORY: SUMMARY AND DISCUSSION

Udy's investigation of the organisation of work was conducted within the framework of two operational hypotheses:

> "A. The structure of any production organisation is determined partly by the characteristics of the technological process which it is carrying on, and partly by the social setting within which it exists.
> B. The structure of any reward system is determined partly by the characteristics of the production organisation involved, and partly by the social setting, within limits imposed by features of the technological process" (Udy, 1959, 125).

To discover how the alternatives stated in these hypotheses vary one against the other, and to assess the nature of factors affecting this variation, Udy drew a world sample of 150 "production organisations" from the Human Relations Area Files (Udy, 1959, 4).

Possibly as a result of the geographically stratified nature of his sample, Udy was unable to locate adequate comparative data on pre-industrial manufacturing, and thus his study is confined in the main to subsistence activities. "Available data on the social aspects of collective manufacturing appear inadequate for purposes of comparative institutional analysis, despite the existence of much data for some culture areas, and a plethora of excellent material on the purely technical aspects of non-industrial processes" (Udy, 1959, 22).

Here, by conducting an extensive survey of the ethnographic literature without a preconceived sample strategy, I have succeeded in accumulating a considerable body of data which has enabled me to examine a particular aspect of manufacturing, namely pre-industrial metalworking. Following Udy, I have investigated the structure of production organisation in a variety of social settings and have explored the manner in which socially defined variables can influence this structure. Similarly, I have assessed the extent of technological influence on various aspects of production. However, as the ultimate aim is to understand metalworking as an element in prehistoric society, I have extended my studies beyond those of Udy, and examined the smith himself and his relationship to the social group in which he operates. It is this relationship (institutionalised in attitudes to the smith and in demand for his products) rather than technology that predominantly determines such organisational aspects as specialisation and pattern of work.

This broadly based analysis of the ethnographic data has permitted me to draw generalisations concerning the overall organisation of the metalworking industry, and to plot the "range of variation in the differing ways human groups achieve similar ends" (Herskovits, 1954, 390). It is now time to recall these generalisations and proceed to assess their broad implications for the understanding of prehistoric bronze casting.

I.7.1 The smith in his social setting

1. The smith is always set apart in his society.
2. The smith almost always enjoys a distinctive status, be it high or low.

The smith is set apart because of (usually hereditary) group affiliations; magic and mystery (and their institutionalised forms, ritual and taboo) surrounding his person and his craft; his technical skills; and the functional and symbolic significance of his products. The smith's particular status (be it high status accompanied by freedom and/or privilege, or low status accompanied by restriction and/or deprivation) results from an amalgam of attitudes towards those factors which set him apart. Although material correlates of position and status are always difficult and often impossible to recognise in the archaeological record, it is perhaps reasonable to hypothesise that prehistoric smiths, like their present-day counterparts, held distinctive positions and were ascribed a certain status.

I.7.2 Specialisation

Metalworkers may specialise by raw material and/or activity within the craft, and/or by product.

3. In an iron-based economy all tools, weapons and utilitarian artefacts are made from iron. Either iron or rare metals may be used for the production of decorative and ritual items, but in communities where different raw materials are worked, such items are rarely made from iron.

4. In communities where rare metals are cast and iron is forged, the different raw materials are generally restricted to different metalworking groups.

5. In an iron-based economy, rare metal casters are almost invariably of high status, patronised and producing goods of high economic and social value.

6. The status of ironworkers is variable.

7. Where rare metal and iron working groups are both patronised, both are of high rank.

8. Mining or ore collecting and smelting are generally combined but may be separate specialist activities.

9. Iron smelting and smithing are generally distinct specialisations and are often caste restricted.

10. Rare metal smelting and casting/beating are always distinct specialisations.

11. In complex societies, both rare metal and iron working may be highly specialised, involving the activity of many separate groups (eg miners, smelters, metal dealers, smiths, middlemen).

12. Product specialisation is determined by socio-economic demand, and by the technical skill of the smith, in varying proportions. Complex social systems (high demand) generate complex product specialisation.

13. Non-patronised sedentary and locally itinerant ironworkers do not specialise by product.

A similar complex range of specialisation might be anticipated in prehistory and all the above generalisations can serve as hypotheses to assist in the interpretation of the archaeological record. Some measure of patterning may be observed within these generalisations, and this patterning has been used to formulate additional predictive propositions.

During the bronze age, all weapons, tools and utilitarian, decorative and ritual items made of metal (with rare examples of the use of gold) had, perforce, to be cast or beaten from copper and its alloys. There was thus virtually no specialisation by metal. In this knowledge, the following hypothesis may be proposed:

14. In a bronze-dependent society, the status of the metalworker will vary (much as that of the blacksmith in ethnographic contexts), but patronised smiths producing prestige goods will always be of high rank.

Once the practically superior iron became available, a greater potential existed for complex specialisation (metal, activity or product based). It is reasonable to predict that:

15. In an iron-dependent society, there will be a wide range of metal, activity and product specialisation, and status ascription.

Whilst the status of ironworkers other than those working under élite patronage is variable and determined by social and economic parameters, rare metal casters in an iron-based economy tend (irrespective of patronage) to produce prestige goods and be of high status.

The ethnographic data permit a further general prediction concerning specialist metalworking organisation:

16. Increased product and activity specialisation, irrespective of metals used, will correlate with increased social complexity; the greater the magnitude of demand, the more specialised the smith.

I.7.3 Pattern of work

Resident or itinerant work patterns, and full- or part-time activity, relate to the smith's position in society and are largely determined by demand for his products. Both resident and itinerant metalworkers may be smelters and/or smiths, manipulate rare metals and/or iron, and work seasonally or year round. Itinerant smiths may travel locally or cover long distances.

17. There is a constant, non-seasonal demand for the products of the full-time smith (resident or itinerant).

18. Without a source of income from trade or from a patron, there can be no full-time smiths.

19. Part-time smiths (resident or itinerant) work seasonally according to the agricultural calendar, and derive varying proportions of their income from craftwork and farming.

20. Among agriculturalists, the cultivating cycle largely determines demand for the smith's products (peak demand precedes planting and harvesting).

21. Patronised smiths, and virtually all those producing exclusively for trade, do no farmwork.

22. Itinerancy is determined by demand for products and/or availability of raw materials, and social factors.

23. The organisation of itinerant routes is variable (fig I.7.1).

24. Long distant itinerants are patronised or produce for trade.

It is reasonable to suppose that similar systems of residency and itinerancy and seasonal and full-time activity may have operated in prehistory. The generalisations listed above can apply to all metalworkers, although as already seen, in an iron-based economy, smiths manipulating rare metals tend to be patronised full-time craftworkers. The following additional hypotheses may thus be proposed:

25. Where the demand for metal products is constant and non-seasonal, the smith (irrespective of metal) will be full-time and do no farmwork. He will be patronised or produce essentially for trade, and may be resident or long distant itinerant.

26. Where product demand is largely seasonal, the smith

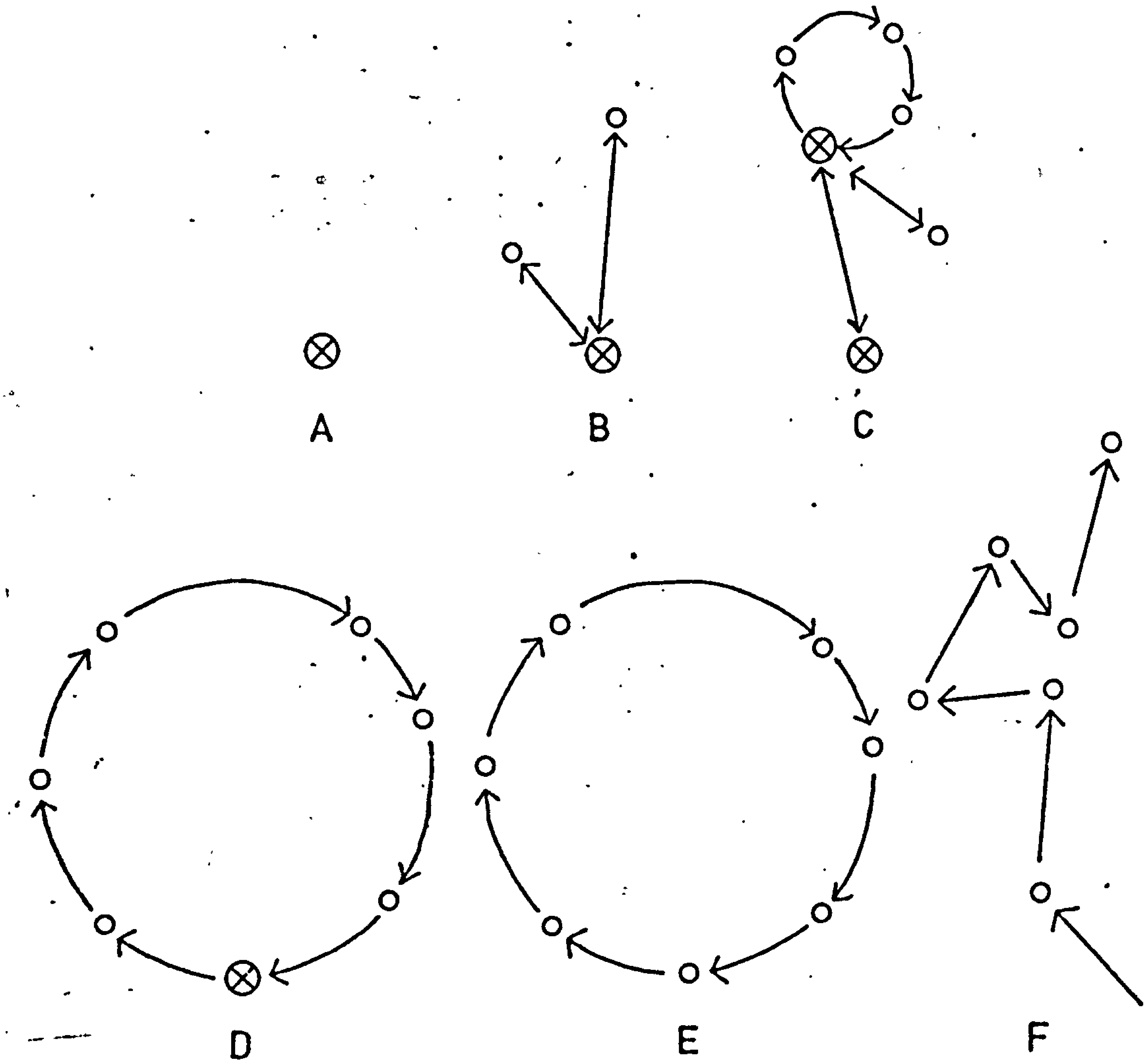


Fig I.7.1 Models of smith mobility. A: resident, stationary; B: trips to single outstations; C: temporary base established away from home; D: circuit with permanent base; E: circuit without permenent base; F: peripatetic. (O = workshop station; ⊗ = home base) (irrespective of metal) will work part-time, and participate to some degree in subsistence activities. He is unlikely to be patronised, will produce mainly to individual order, and may be resident or locally itinerant.

I.7.4 Practising the craft

Generalisations concerning those aspects of industrial organisation which are to some extent governed by technological constraints are recalled here. These generalisations, like those listed in the preceding sections, may serve as hypotheses to guide archaeological interpretation.

Apprenticeship

27. All metalworkers serve long apprenticeships, usually with fathers or kinsmen.

28. Novices proceed from simple tasks, such as pumping bellows and filing rough cast pieces, to the more complex aspects of the craft, such as casting and forging implements.

Individual and co-operative activity

29. Virtually all metalworkers are male.

30. Ore gathering, mining and smelting are everywhere group activities.

31. There are no solitary smiths. All have at least one assistant (usually an apprentice), but group size may vary.

32. Itinerant smiths (irrespective of metal) travel in groups with their apprentices, and carry their tools.

Location of activities

33. Smelting takes place at, or close to the raw material source.

34. General production location is determined by product demand. Thus the smith producing for trade will be located near a large population centre or on a well-travelled route, whilst a rural smith will be sited near the village he serves, etc.

35. Smithing and casting forges are always isolated from all living areas (including the smith's own house) for practical, and sometimes social reasons.

36. Only high status, patronised, rare metal smiths may work within settlement areas, and even here the casting place is isolated from other buildings.

Metal supply

37. Either scrap or ingot metal may be used, according to availability, although cultural restrictions may determine the choice.

38. Use of smelted iron is generally confined to the smelting areas. Rare metal ingots, on the other hand, may travel considerable distances.

39. Smiths may smelt their own metal (iron only), acquire it (as ingots or scrap) through trade, or have it supplied by their customers or patrons.

40. Scrap is carefully hoarded by both smiths and customers.

Non-metal raw materials

41. Smiths make all their own tools, a practice which is sometimes sanctioned by religious belief.

42. The smith may make his own charcoal, buy it, or obtain it from his customers.

43. For both religious and practical reasons, smiths almost invariably collect the clay, and build their own furnaces and make tuyères. There are no specialist refractory makers.

I.7.5 Transactions

Production systems transform demand into material form; distribution mechanisms convey finished products to those who expressed the demand. This expression of demand and the process by which an object enters the consumption network are defined as transactions. Transactions may be explicit, linked to periodic demand and leading to direct distribution; or implicit, linked to continuous demand and leading to a distribution network over which the smith has no control.

44. Demand for the smith's products may originate in the needs of an individual group member within a given social setting (eg tools for cultivation, ritual ornaments for initiation ceremonies); in the needs of a patron occupying a special position in society (eg prestige items for personal use or élite exchange); or in the needs of a socio-economic system as a whole (eg currency items for trade).

45. Most smiths produce a portion of their output in response to direct customer commissions (explicit transaction), and may participate in other forms of commerce. Exceptions are patronised smiths, and smiths producing exclusively for trade.

47. The output of the patronsied smith is not normally available outside élite circles, although it may be widely distributed (often inter-tribally) within these circles.

48. Rewards for non-patronised smiths, whatever their production orientation, are periodic, and may be in cash or goods (including raw materials), or in agricultural labour.

49. Patronised smiths receive continuous remuneration in subsistence and other goods, protection, and freedom from service.

It is appropriate that this summary and discussion should end with the theme of transactions. Transactions have been defined as connectives in energy flows. The initial transaction, wherein demand is expressed to the smith, serves as a spark to ignite the entire production and, ultimately, distribution systems. As has been emphasised in the first chapter of this essay, production and distribution are both direct consequences of demand: without demand there can be no production, and without production there can be no distribution or exchange. Demand thus permeates all aspects of metalworking organisation.

APPENDIX I.1

ETHNOGRAPHIC AND HISTORICAL OBSERVATIONS ON THE METALWORKING INDUSTRY: TABLES 1-10

Metals key

Fe	iron
Cu*	copper and its alloys
Ag	silver
Au	gold
Sn	tin
Zn	zinc

* Cu refers to both copper and its alloys. Compositional terminology in the ethnographic literature is often unreliable (Dark, 1973, 50) and valid distinctions between brass, bronze and copper are often impossible.

Table I.1 The Smith's Position in Society

People	Metal	Observation
SENEGAL		
Laobes (Berenger-Féraud, 1879)	Fe	Came to country with Fulani. Smiths endogamous alien caste.
Peul (Berenger-Féraud, 1879)	Fe	Smiths endogamous inferior caste. Feared, believed to be sorcerers.
MALI		
Kaarta (Cline, 1937)	Fe	Smiths high status. Often village chiefs.
CHAD		
Haddad (Lapie, 1943)	Fe	Smiths belong to separate craft caste which includes weavers, potters, doctors. Low status, believed to be aliens and infidels carrying out unorthodox practices, despite conversion to Islam.
SUDAN		
Bari (Archinard, 1884; Huntingford, 1931; Seligman et al., 1928)	Fe	Smiths neither lui (freemen) nor dupi (slaves). Belong to one of three submerged classes: fishermen, hunters, blacksmiths. Live in separate villages; tend to be endogamous although marriage outside caste not restricted. Smiths can own cattle and goats, generally restricted to lui class. Smiths mainly of Marshia clan of alien origin. Regarded as 'different' and to some extent despised, though admired for skill and industry. Frequent patron-client relationships with chiefs, smiths providing patrons with tools and weapons.
Darfur, Wadai (Cline, 1937)	Fe	Smiths and hunters socially degraded.
Dinka (Seligman et al., 1932)	Fe, Cu	Smiths can own no cattle. Can marry outside caste, but without cattle for brideprice, this is not easy.
Kuku (Seligman et al., 1932)	Fe	Smiths form distinct submerged class.
Nuba (Seligman et al., 1932)	Fe	Smiths are of Lafofa clan. Regarded as rainmakers and sickness experts.

ETHIOPIA

Afillo Mao (Cerulli, 1956)	Fe	Smiths despised.
Badditu (Cerulli, 1956)	Fe	Smiths belong to inferior caste, which includes weavers, tanners, potters and smiths. Smiths bury the dead.
Gala (Huntingford, 1931)	Fe	Craftsmen (weavers, potters, tanners, tailors, smiths) form submerged class and are held to be effeminate by the warlike Gala, and despised.
Gurage (Shack, 1964)	Fe	Smiths, tanners and woodcarvers form low status occupational caste - fuga. Weaving and potting regarded as 'respectable' semi-professions, whereas occupations of fuga caste are despised. Smiths act as ritual specialists in circumcision and other ceremonies.
Konso (Hallpike, 1968; 1972)	Fe	Smiths not a submerged class, but a separate class, not fully integrated into religious and social life of cultivators. No physical separation into craft wards or villages. Dress, speech, houses identical to rest of Konso. Have own lineage priests and can take part in some ceremonies, but can never enter councils.
Mekan (Cerulli, 1956)	Fe	Blacksmiths' caste considered impure.

GUINEA

Fouta (Durand, 1932)	Fe	Smiths despised endogamous caste (descendants of captives). Suspected of sorcery. Tribe believe that a smith betrayed Mohammed to his enemies.

LIBERIA

Various tribes (Cline, 1937)	Fe, Cu	Liberian smiths high status, treated with respect. Smith families proud, with long genealogies. Are important members of councils and secret societies. Often receive free farm labour as do chiefs and shamana.
Gola (d'Azevedo, 1973)	Fe	Smithing is ancient and sacred profession. Local smiths supported by community. Individual specialisation, not formal group or guild. Smiths have high status corresponding to office in Poro (secret

		society) and perform Poro initiation rites. Mystery and respect surrounding profession attributed to importance of iron for tools, weapons and currency, and skills required in craft.
Gola (d'Azevedo, 1973)	Cu	Specialist makers of ornaments, figurines and decorative items travel (local demand insufficient) long distances to where services have been commissioned. Often supported by wealthy patrons of ruling classes, sometimes chiefs of other tribes. Services of these specialists often exchanged among rulers as gifts or favours in diplomacy. Specialist in distant places and from other tribes have much prestige and are often very wealthy.
Kpelle (Gibbs, 1965)	Fe	Smith has high status in all communities, and is party to secret society information. Smith honoured because he makes agricultural tools and implements for ceremonies.
GHANA		
Akan (Manoukian, 1950)	Fe, Cu	Smiths deal with life-giving fire, thus set apart in special relationship with gods. In war, made bullets and cared for wounded. Organised into castes.
Ashanti (Johnson, 1979; Rattray, 1923)	Fe, Cu, Au	Metal crafts revered in Ashanti. One of praise-names for King is Otumfo (blacksmith). Crafts, including brass casting, goldsmithing and iron working highly specialised and developed for King and palace organisation. Chief craftsman often village chief. Goldsmiths' guild priviledged to wear gold ornaments otherwise restricted to King, King's wives and great chiefs.
Ewe (Manoukian, 1952b)	Fe	Virtually every village has its own smith.
BENIN		
Dahomey (Herskovits, 1938)	Fe	Weavers and smiths most honoured of Dahomean craftsmen. Smiths honoured because society depends on their products for agriculture, other manufactures and burial. Blacksmiths organised into 'forges', each operating in a separate city quarter, or separate villages.

NIGERIA

Various n.e. tribes (Neher, 1964)	Fe	Blacksmith clan prominant in all tribes, but status of clan members varies from tribe to tribe. Among the Higi, Gude, Fali and Kilba, smiths are at the bottom of the social scale. Clans usually endogamous, and smiths often grave diggers. Frequent dietary differences between smiths and ordinary tribe members. To call a non-smith 'blacksmith' is slander. Among the Chibuk, Bura and Pabir, smiths have high social status.
Southern Sudannic savanna belt and forest belt tribes (Neaher, 1976)	Fe	Savanna smiths attached to centralised Kingdoms have high status and full participation in social life, accompanied by economic advantages and political power. Ordinary savanna village smiths form a marginal, low-caste group and lack prestige. Ordinary, non-patronised forest smtihs have same high status as savanna smiths attached to central rulers.
Awka Igbo (Neaher, 1976)	Fe, Cu	Eastern zone of territory consists mainly of dispersed farms; west partially agricultural and partially villages of specialists (smiths, doctors, traders). Agulu village (in Awka township) renowned for its itinerant metalworkers, formed of 7 exogamous smithing kin groups. Smiths' guild (restircted membership) enjoys special economic and political status in Awka. At 'out-stations' smiths always welcome and highly regarded. Informal patron-client relationships are often established. When travelling, dialect and tools on back identify them as smiths, ensuring their safety.
Benin City (pre-colonial) (Dark, 1973; Roth, 1968)	Cu	Brass and bronze casters form a separate caste from royal blacksmiths and other artisans. Caste has 10 hereditary titles as part of court admission. Caste in exclusive control of Oba (King) who arranged for production of art-wrok for tributary rulers. Brass workers' status extremely high. They are rewarded for work by food, women, slaves and help in house building. Sometimes given permission to set up new settlements in bush to farm with slaves supplied by King. All who distinguished themselves in craft given patent of nobility.

Benin City (pre-colonial) (Dark, 1973)	Fe	Blacksmiths regarded as servants by brass and bronze casters.
Bida City (Nadel, 1942)	Fe	Restricted caste of smiths, enjoys official recognition and social and political priviledges. Chief blacksmith admitted to King's council, thus politically influential. Smiths exempt from tax.
Isoko (Peek, 1980)	Cu	Art of casting belongs to certain families from Isoko clans - not 'strangers'.
Kanembu (Meek, 1925)	Fe	This tribe despise all forms of industry, including metalwork.
Kano City (pre-colonial) (Jagger, 1973)	Fe	Smith caste made up of 15 ethnic groups which tend to inhabit different quarters of city. Emir appoints Sarkim Makera (chief smith) and lower officials to organise metal production throughout Emirate. Fulani rulers thus able to control and direct flow of essential goods and services, thereby ensuring stability of government. Official positions lucrative, honourable; but rewards purely economic, and no political power attached. Some more expert smiths attached to important households do general maintenance work and make all necessary agricultural implements. Rewarded with regular gifts of food, clothes and money.
Killa (Neaher, 1976)	Fe	Distinct kin group act as resident smiths to Chamba, Bata and Mbulu peoples of n.e. Nigeria.
Marghi (Vaughn, 1973)	Fe	Hereditary, endogamous social caste (əŋkyagu) includes undertakers, leather workers and blacksmiths (male) and potters (female). Occupations not clan restricted within caste. əŋkyagu do not farm; are community supported. Craftsmen not dispised, rather treated as <u>different</u> by Marghi who regard them with awe and tend to fear them. Do not live separately, and enjoy amicable social relations with Marghi, but marriage and dietary rules never broken. Caste members play important role in Marghi ceremonies. Although no political power , head of əŋkyagu often an ex-officio council

		member; acts as King's private smith and undertaker. Symbolic relationship between King and kyagu; reflected in burial rites. Both King and kyagu buried upright on iron stool surrounded by charcoal.
Northern Hausa (Smith, 1965)	Fe	Occupational ranking essential to Hausa social order. Blacksmiths of fourth (lowest) rank together with butchers, praise-singers, drummers, house-servants and hunters.
Tiv (Abraham, 1933)	Fe	Iron connotes power and prestige. Chiefs, although not metalworkers, keep a complete set of smith's tools.
Yoruba (Forde, 1951; Talbot, 1926)	Fe, Cu	Bronze and brass smiths hold high social positions. Head smith invited to meetings of council. Metalworkers (including blacksmiths) often patronised by religious cults and military leaders. In Ibadan Province, every village has its own smithy and smith.
CAMEROON		
Bagam (Malcolm, 1923; 1924)	Fe, Cu	Blacksmiths and brass casters: separate guilds restricted to small membership. All metalworkers influential tradesmen, and all trades under control of head chief. Brass caster acts as assistant to chief.
CENTRAL AFRICAN REPUBLIC		
Pangwe (Cline, 1937)	Fe	No special status and no social stigma attached to iron workers. Admired for skill and physical difficulties involved in work; for their ability to pay shaman's high fees; and for high profits they receive.
CONGO		
Fan (Viljoen, 1936)	Fe	Village smith is the priest and sacred headman of the community. Iron working is sacred craft, and only chief can know secrets.
ZAIRE		
Mandja (Cline, 1937)	Fe	Smiths only professional class of artisans in society. Wealthy and respected.

Mangebetu (Cline, 1937)	Fe	Every village has a blacksmith. Smiths highly respected and often clients of chief.
UGANDA		
Baganda (Roscoe, 1911; Trowell, 1941)	Fe	Smithing largest and most highly organised craft in Buganda. Smith clans attached to royal households. In role as royal smiths and in return for tribute have free land, pay no taxes and do no compulsory labour. Clan chief is priest.
Kavirondo Bantu (Hobley, 1922; Wagner, 1956)	Fe	Smithing generally not clan restricted. Most smiths are members of the clan in which they live. An exception is the Gemi tribe (Nilotic Kavirondo) where only members of the Uvino clan forge iron. Smiths hold no special position in community, but tend to be wealthier than potters and woodcarvers.
Labwor (Wayland, 1931)	Fe	Smiths respected, venerated and famous among surrounding tribes for spear and hoe making. Smithy and smelting house only non-stockaded Labwor structures because of respect for smith.
Lango (Driberg, 1923)	Fe, Cu	Craft guilds not distinguished by any social priviledges or disabilities.
Somali (Huntingford, 1931)	Fe	Smiths submerged class.
KENYA		
Elgeyo (Massam, 1927)	Fe	Smiths not allowed to hold stock. Other tribesmen fear that should smiths become wealthy cattle owners, they would abandon profession. They are therfore plied in food including castrated animals 'for the pot'.
Galla, Rendille (Brown, 1980)	Fe	Smiths attached to patrons for security and support. Allowed to live in larger semi-pastoral settlements, sometimes with some prestige (rare). Usually lowly social status, but respected for skill. Smiths liked by the Rendille, but inter-marriage not allowed.
Kalenjin (Brown, 1980)	Fe	Kalenjin are semi-pastoral, thus smith holds higher status than in purely pastoral groups, as tribe more dependent on his services. Smiths not told where

		to live, but non-smiths will move away, because of fear of pollution.
Kikuyu (Hobley, 1922)	Fe	Smiths form guilds without special social or economic status. No dialect peculiar to guild, and no trade symbol buried with dead smith. Smiths act as arbiters in disputes, and as they are held in fear because of magical powers, their decisions complied with.
Luyia (Brown, 1980)	Fe	All smiths belong to leading clans. Treated as peers of tribla leader. On ceremonial occasions, wear prestigious leopard skin cloaks. Sit with elders at council meetings. Highly respected for mystical powers, intelligence, skill and wisdom. Exempt from taxes in return for tribute.
Marakwet (Welbourn, 1981)	Fe	All smiths belong to same clan, which is not exclusively smiths. Smiths neither despised nor admired. Have same access to water and ownership of land and animals as rest of tribe. No restrictions on wealth accumulation. No special ceremonial duties. However, smiths set apart. Never allowed to fight, and noone can kill or harm a smith. Smith's curse greatly feared.
Masai (Hobley, 1922; Hollis, 1909; Viljoen, 1936)	Fe	Smiths form submerged serf-clans (El-Konono). Clans endogamous and despised. Smiths live in separate compounds and all contact is avoided. No hospitality given to smith, and none expected from him. A Masai oils his hands before touching anything a smith has held, to avoid contamination. Smiths have no legal rights and can be murdered without redress, but even accidental killing of a Masai by a smith has to be atoned for by death of several smiths.
Nandi (Huntingford, 1931)	Fe	Smiths submerged class. Have no exclusive caln, each smtih belonging to a Nandi clan. Regarded as inferior although not servile. Cannot openly inter-marry with Nandi or allow their cattle to inter-breed with Nandi cattle.
Sonjo (Gray, 1963)	Fe	Waturi clan exclusive smith caste; wives are tribe potters. Endogamous (strict taboos). Not allowed to own fields or

		cultivate, but can keep goats.
Suk (Beech, 1911)	Fe	Smiths only to be found among 'poor' agricultural groups. "God gave them no sheep, so he gave them cleverness instead".
Wandorobbo (Cline, 1937)	Fe	Smiths despised by this hunting tribe. Have no legal rights and can be murdered without redress.
SOMALI REPUBLIC		
Tomal (Robins, 1953)	Fe	Smiths belong to one clan. Low status.
TANZANIA		
Baholoholo (Cline, 1937)	Fe	Socially, smiths just below chiefs and hunters.
Wachagga (Cline, 1937)	Fe	Smithing confined to particular clans who tend to be located in separate parts of Kingdom. Smiths feared and honoured because of products (deadly weapons) and because of secret and supernatural nature of their craft. Inter-marriage not taboo, but feared and frowned upon.
ANGOLA		
Bayaka (Cline, 1937)	Fe	Smiths not a special clan.
Ondulu (Read, 1902)	Fe	Entire communities specialise in iron working directed towards trade. Members of blacksmith guild enjoy high social status approximating to that of Shamans. Master smith also a witch-doctor.
Ovimbundu (Childs, 1949)	Fe	Smithing one of 3 professions entered under special conditions and with special ritual. Requires sacrifices and enslavement of spirit.
ZAMBIA		
Achipawa (Gunn et al., 1960)	Fe	The only blacksmiths among the Achipawa form small family group at Karisen. Achipawas in other villages have to patronise Kambari smiths of Kumbashi, or the itinerant Hausa of the plains.

Basa (Gunn et al., 1960)	Fe	Smithing monopoly of Igbo immigrants.
Bemba (Colson et al., 1951)	Fe	Crafts unimportant to these warrior people. Simple pottery, mats and baskets made, and smiths can forge axes and spears.
Dakakari (Gunn et al., 1960)	Fe, Cu	Tribe obtain their iron and other metalwork largely from itinerant smiths. Sometimes smithing taken up by Dakakari males as casual part-time occupation.
Gwembe Tonga (Reynolds, 1968)	Fe, Cu	Smithing leading profession open to males. Smiths respected members of community and among wealthiest. Employ surplus wealth in purchasing livestock and extra wives, investing in trade goods and establishing village stores. No taboos associated with craft; smithy focal point for men to gossip and occasionally assist.
NAMIBIA		
Naman (Schapera, 1930)	Fe	Cattle herding Hottentots little respect for industrial activity. Craftsmen little better than slaves.
Ovambo (Cline, 1937)	Fe	Smiths belong to low class families, called by derogatory name. Endogamous.
ZIMBABWE		
Balemba (Sayce, 1933; Stayt, 1931)	Fe, Cu	Balemba are smith group living interspersed among tribes because of their skill as craftsmen. Held in contempt mixed with fear. Coppersmiths especially feared because of superior intelligence.
Mashona (Bullock, 1950; Kuper, 1955)	Fe	Matabele leave weapon making to separate Mashona clans. Mashona regarded with awe mixed with disdain. Among Mashona themselves, of their miners, smelters and smiths, smiths enjoy highest status.
Ndebelé (Hughes et al., 1955)	Fe	Smithing restricted to indigenous Kalanga, who before Ndebelé days, enjoyed high reputation for iron smelting and smithing.

SOUTH AFRICA		
Kaffir (Cline, 1937)	Cu	Brass working a secret craft. Brass workers highly respected and live near chief.
Zulu (Krige, 1936)	Fe, Cu	In some parts of Zululand, smithing is a secret craft and the highest ranked among professions.
SWAZILAND		
Swazi (Marwick, 1940)	Fe	Blacksmithing restricted to a few clans.
SAUDI ARABIA		
Tuareg (Robins, 1953)	Fe	Blacksmiths despised. Live by fire, and thus destined for hell.
Solubba (Robins, 1953)	Fe	'Primitive' gypsy tribe of tinkers and arms smiths, who do not keep cattle and are poor and despised. Attitude attributed to fear of aliens among indigenous people.
AFGHANISTAN		
Shiaposh (Forbes, 1964)	Fe	Bari form caste of despised smiths among the agricultural and pastoral Shiaposh.
INDIA		
C. India (Grigson, 1938)	Cu	Throughout c. India, brass workers are distinct caste called Ghasias by Hindus and Murias. Elsewhere in c. India, this name applied to most degraded of untouchable classes, with occupations such as grass-cutters and horse-tenders. Even in Bastar, where many are skilled artists, held in profound contempt.
S. India (Robins, 1953)	Fe	Among jungle tribes, iron workers all alien immigrants and form alien caste or guild.
Agami Nagas (Hutton, 1921)	Fe	Other than agriculture, weaving most important Agami industry (female). Smithing next to weaving in importance (male).
Bihar (Sinha, 1961)	Fe, Cu	All crafts superstructure on basic agricultural economy. 15 artisan castes; membership not interchangeable.

		Among copper alloy and rare metal working castes, metals descend in order of prestige. Bell metal workers (Kansari) highest, followed by brass casters using wax for moulding (Theuthari), followed by brass casters using resin instead of wax (the usually itinerant Mahoar). Goldsmiths (Dhustra) command the least prestige. All metalworking castes ritually unclean.
Galong (Dunbar, 1939)	Fe	Almost every village has its own smith. Product specialisation lead to wide-spread reputation for smiths of some communities. Village headman sometimes a smith.
Hunza (Robins, 1953)	Fe	Little caste distinction, but Bericho community of smiths regarded by Hunza people as foreigners and inferiors.
Koi (Cammiade, 1931)	Fe	No bar to intermarriage among Koi clans except with smiths. Marriage ban attributed to smiths' alien origin.
Lakhers (Robins, 1953)	Fe, Cu	Buy some of metalwork (mainly non-ferrous) from outsiders, but villages also support own blacksmiths. In return for food, they make new tools and repair the old.
Lois (Hodson, 1908)	Fe	Entire group live by smelting and smithing. Villages composed exclusively of smiths and smelters, sited near ore sources and periodically moved according to productivity of site.
Malabar (Robins, 1953)	Fe	Blacksmiths unclean caste. Pollute Brahmin at 24 feet.
U.S.S.R.		
Yakuts (Sumner, 1901)	Fe	Smiths rank equal with shamans, and are honoured and respected. Smiths give council, make predictions, cure sickness.
MONGOLIA		
Torguts (Montell, 1940)	Ag	Mongols despise most crafts and leave them to the Chinese. Silversmithing the only developed Mongol handcraft. Silversmiths itinerant professionals, often Lamas.

CHINA		
Ancient China (Robins, 1953)	Fe, Cu	Bronze was used only by wealthier classes, and then for weapons. Iron smith represented in two forma: Shên-nung (divine harvester who introduced agriculture) and Ch'e-you (inventor of arms and master of war).
BURMA		
N. Chin (Rowlands, 1971)	Fe	Smith works only for 1 village, supported by tax of grain and meat levied on villages. Holds official position. Local community dependent on smith. Smith could easily abandon occupation and return to agricultural work.
INDONESIA		
Bali (Rowlands, 1971)	Fe	Smiths form corporate group with divine tradition.
Java (Forbes, 1964)	Fe, Cu	All smiths, although among poorest classes, are respected and honoured today. Under government of princes, iron smiths used to occupy honoured positions at court, and had same title as priests. Sometimes acted in ambassadorial role. Role of princes and smith occasionally overlapped.
Sulawesi (Rowlands, 1971)	Fe	Smiths of low status, but great reverence attached to smithy, tools and products.
NEW GUINEA		
Dore (Forbes, 1964)	Fe	Smiths form separate caste.

Table I.2 Magic, Ritual and Taboo

People	Metal	Observation
SUDAN		
Bari (Seligman et al., 1932; Spire, 1905)	Fe	Smiths have magical powers and iron plays significant role in religious ceremonies, in warding off and curing sickness, and in rainmaking. Smith's wife, although of despised class, plays important part in _lui_ (freemen) mourning ceremonies. Oaths sworn on smith's hammer.
Moro (Seligman et al., 1932)	Fe	Mbori (smith clan) all said to have magical powers and can become rain-makers. Iron used by Mbori to prevent contagion of their magic. Iron (spears) play significant role in curing sickness.
Nuba (Seligman et al., 1932)	Fe	Iron powerful charm in preventing and curing sickness.
ETHIOPIA		
Zala (Cerulli, 1956)	Fe	Although smiths submerged class, forges not considered taboo. No taboos on women in smithy; they often help by working bellows.
GUINEA		
Fouta (Durand, 1932)	Fe	Iron mining highly ritualised. Pre-mining ritual involves dancing in specially made costumes, and complex chicken sacrifices. Oaths sworn on smith's anvil by laymen.
LIBERIA		
Gola (d'Azevedo, 1973)	Fe, Cu	Smith's shop and equipment surrounded by ritual sanctions. Only members of _Poro_ (secret society) may step inside. Feet must be bare, voices must be subdued and conversation kept to a minimum.
IVORY COAST		
Korhogo City (Gardi, 1969)	Cu	All tools consecrated and very difficult to buy by outsiders.

GHANA		
Akan (Manoukian, 1950)	Fe, Cu	All tools sacred. New forge consecrated before use. Dealing with life giving fire, smiths set apart in special relationship with gods.
Ashanti (Rattray, 1923)	Cu	Bellows, weights and tools of 'divine' ancestor still preserved. Anyone committing adultery with smith's wife has to pay fine, and a fee to cover purification of tools and metal stock.
TOGO		
Evhe (Cline, 1937)	Fe	Smithy normally immune to fire; if burns, portends great calamity for community. Great power invested in smith's hammer. Before smith's son can be formally initiated into profession, hammer consulted by fetish priests to see if it will accept him. Special holiday (with sacrifice) observed each year for tools. Imposter smiths punished through hammer by sickness and death.
BENIN		
Dahomey (Herskovits, 1938)	Fe	Holy days celebrate _Cu_, god of iron. Much ceremony and ritual surrounds anvil. Anvil consecrated, and setting new anvil time of great festivity.
NIGERIA		
Angas (Meek, 1925)	Fe	Ritual surrounds smelting and charcoal making. Religious leader first ceremonially cuts down special tree for smelting charcoal. Smelters may then cut their own wood.
Awka Igbo (Neaher, 1976)	Fe, Cu	Agulu smiths act as priests at home and on travels. Smiths' god is protector of smiths and families at home and when travelling. Smiths carry talisman of iron slag and clay in cloth sack, and hang it from forge roof on travels.
Benin City (Dark, 1973)	Fe, Cu	Bronze and brass smiths had own deity (_Eguehae_) their founding ancestor, Also share in worship of blacksmiths' god (_Ogun_, god of war and iron). _Ogun_ recently adopted by motor mechanics.

Gude (Neaher, 1976)	Cu	Elaborate pre-casting ritual. 'Medicine' prepared from 2 kinds of leaves, earthworm mounds and dried vine; rubbed on prepared moulds to prevent leakage, and furnace to ensure good casting. Rituals surround products. New anklets consecrated (with sacrifice) for pleasure of gods and to ensure growth of chieftaincy.
Isoko (Peek, 1980)	Cu	Casting is secret art.
Marghi (Vaughn, 1973)	Fe	Smelting rituals. Owner of furnace prepares ritual beer and chicken sacrificed. Blood runs over furnace. Workers wear traditional ram skin loin ornament during smelting. Ritual surrounds tuyères: women make all pottery, but tuyères (dzvu) made by smiths. Tuyères viewed with awe by ordinary Marghi, and often placed in fields to protect crops.
Mbawara (Meek, 1925)	Fe	Any man encountering woman gathering ore must pay heavy fine. Before forging, smiths go to sacred grove to make offerings of beer to tutelary spirit.
Tiv (Abraham, 1933)	Fe	Metaphysical association between iron, stone celts, thunderbolts and cult of dead. Tuyères used as cult emblems, with iron to placate household gods. Oaths sworn on smiths' tools.
Yoruba (Williams, 1973)	Fe, Cu	Myths stress divine origin of smith and revolutionary role of iron in food production and common good. Traditional relationship between Sango (god of thunder and lightening) and Ogun (god of war and iron). When lightening strkies village, dispossessed must seek refuge in smithy. Metals used to transfer 'medicines' to tongue. Effective curses can them be delivered.
Yoruba (Neaher, 1976)	Cu	Ijebu-Ode clan: Sacred bronzes for Ogboni earth cult always cast by elderly smiths. Casting involves invocation of spirits of dead; believed that young man, by so doing, would lose power of procreation.

CAMEROON

Bagam (Malcolm, 1923)	Fe	Ritual attached to smelting hut. Outsiders allowed in after sacrificing to furnace.

CENTRAL AFRICAN REPUBLIC

Pangwe (Cline, 1937)	Fe	Iron smelting closely alligned with fire cult, ancestor cult and the sympathetic magical powers of certain plants. Only men holding high cult office can poke smelting fire. Any sexual activity during working period will be detrimental to the success of the smelting process.

CONGO

Bahungana (de Sonsberghe, 1955)	Fe	Pre-smelting rituals include chicken sacrifice. Other rituals before removing iron from furnace.
Fan (Viljoen, 1936)	Fe	Blacksmith is priest. Has strong connections with spirit world and acts as mediator.
Kongo (Johnston, 1908)	Fe	In Kongo language, word for metalworker (<u>ngangula</u>) also means sorcerer, medicine man; and connotes craft, cunning and sagacity.
Loango (Cline, 1937)	Fe	Priest-smiths.

ZAIRE

Bayeke (de Hemptinne, 1926)	Cu	All aspects of mining and smelting and charcoal making ritualised. Chief conducts pre-mining rituals assisted by shaman and workers. Shaman conducts smelting rituals which include complex use of various infusions of barks from special trees and bushes.

UGANDA

Bakitara (Roscoe, 1923a)	Fe	All aspects of mining, smelting and smithing ritualised. Male ore (black, hard, surface ore) and female ore (red, soft, mined ore) must be mixed for successful smelt. Miners must propitiate hill spirits to obtain good ore and stop mines collapsing. Many mining taboos. Taboos surround charcoal

		burning: smelter first cuts 2 pieces of wood, one for smelting fire, other for kitchen fire. This removes taboo against contact with wife and ensures successful smelt. Smelt might fail if smelters eat potatoes, if women come near furnace, or if new father takes part in work. Many rituals and taboos surround tools of smithy. Sacrifices of sheep and fowl made at installation of new anvil.
Banyankole (Roscoe, 1923b)	Fe	Taboos connected with smelting: smelter may not have intercourse with any woman except wife, may not step over charcoal; noone may enter or leave smelter's hut whilst smelter is seated. Taboos all in force until a hoe has been forged from new iron. Ritual connected with installing anvil includes placing purifying herbs in hole where anvil will stand. Hammer making ceremonies include much ritual and goat sacrifice.
Baganda (Roscoe, 1911; Trowell, 1941)	Fe	Smithing surrounded by more taboos than any other craft. No women present; smiths cannot eat or talk with others while working. Products in some areas command higher prices than work warrants. Superstition gives value beyond utilitarian. Complex initiation ceremonies for new smith.
Kavirondo Bantu (Wagner, 1956)	Fe	Although no magic powers associated with smiths, rituals surround their art. At end of apprenticeship, new smith must dedicate his tools to ancestral spirit of clan by depositing them for one night at centre post of hut, and making goat sacrifice.
Kigezi (White, 1969)	Fe	No mysticism surrounds smithing.
KENYA		
Various tribes (Brown, 1980)	Fe	Fear of pollution expressed by dislike of or ban on marrying smiths; sexual contact with them; shaking hands; striking or being struck by them. Smiths not allowed to touch food or food-containers of non-smiths, or enter homes. Livestock kept away from

		them, and smith's products only accepted after guarding against consequences. Smithies feared and respected throughout Kenya (whatever attitude to smith) because of magical powers concentrated there.
Elgeyo (Massam, 1927)	Fe	Smith may not marry outside caste. If he did, woman's brother would die.
Highland Bantu (Brown, 1980)	Fe	Hang tuyères on trees to protect property.
Kamba of Kitui (Hobley, 1922)	Fe	Blood from sacrificial goat mixed with beer and poured over anvil during initiation ceremony for new apprentice smith.
Kikuyu (Hobley, 1922)	Fe	All smiths possess magic powers, used to inflict curses and bless tools and weapons they forge. Smith makes circumcision knives which have important connection with ritual. Taboos surround smithy. Smith's wife only woman who can enter, and then to bring food. Kikuyu too afraid of smith's magic to steal from smithy. If anything stolen, culprit probably another smith. Old clay tuyères put in fields on sticks to protect crops.
Marakwet (Welbourn, 1981)	Fe	Iron used in ritual as protection.
Masai (Hollis, 1905)	Fe	Smiths eternally impure and supernaturally dangerous. Proximity of smith's kraal brings death, sickness and misfortune to normal kraal. Products unclean. Masai take new weapons to wash in stream to clean from pollution.
Nandi (Huntingford, 1950; Hollis, 1909)	Fe	Taboo on being watched by other sex applies to both smiths and potters.
Wachuka (Cline, 1937)	Fe	Smiths have magical powers. Old tuyères used as potent charms.
TANZANIA		
Asirungu (Wyckaert, 1914)	Fe	Everyone has right to assist master smelter, including women and children, except those who have broken strict dietary and behavioural taboos. Chief chooses small group of most

		'pure' as his assistants.
Ungoni (Cline, 1937)	Fe	Pot of 'medicines' with broken tuyères buried under smelting furnace.
Wachagga (Cline, 1937)	Fe	Fear of smiths' blood very strong. Smiths must practice blood-letting for each other. Northern Wachagga forbid smiths going to war with them, for fear this will bring death. Smiths, their products and tools all have magical powers. Iron medicines made to cure sickness, to increase cows' milk yield, to encourage bees to nest. Hammer is bearer of spiritual force of smiths' profession. At initiation of new smith, great ceremony attached to presentation of hammer. Broken hammer may only be reworked into tools for smith himself. Hammers used for particularly strong curses.
ANGOLA		
Ondulu (Read, 1902)	Fe	Rigid taboos govern conduct of workers and women during smelting season. Pre-smelting rituals under direction of iron doctor. Initiation rites for new smith include sacrifice of chicken. Blood sprinkled on hammer. Hammer known as 'chief' or 'mother', regarded as provider of food (no hammer, no hoes for cultivation). Expert smith makes hammer for novice, accompanied by much ceremony and ritual.
Ovimbundu (Childs, 1949; Hambly, 1934)	Fe	Hunting, iron working, medical practice and divination all sacred professions entered under special conditions. All require sacrifice and enslavement of spirit. Complex rituals accompany initiation of new smith. Elaborate sacrifice involving chicken a goat and a puppy after hammer handle welded to head.
ZAMBIA		
Ba-Ila (Smith and Dale, 1920)	Fe	Very complex rituals associated with smelting. Success of smelt depends on purity of workers (observing taboos), ancestral spirits, special power of 'iron doctor' (master smelter), and 'medicines'.

Bakaonde (Melland, 1923)	Fe	During smelting, if father's spirit is not propitiated, the ore will turn to water rather than iron.
Ba-Ushi (Barnes, 1926)	Fe	Smelting associated with cult of dead. Furnaces always built on ancient smelting site. Shrine built near furnace, decorated like house. Pre-smelting sacrifices to ancestors.
Gwembe Tonga (Reynolds, 1968)	Fe	Smith makes periodic offerings to ancestor spirit. Sexual continence essential the night before working, and taboos on washing before going to forge.
Lambas (Doke, 1931)	Fe	Iron remains soft if smelter breaks sexual taboos. Women cannot enter smelting place. Food may be left outside.
MALAWI		
Achewa (Hodgson, 1933)	Fe	Complex ritual surrounds building of smelting furnace; involves sacrifice of chicken and use of human foetus.
ZIMBABWE		
Balemba (Stayt, 1931)	Fe	According to ancient custom, smith mixes living human flesh with the metal to make good hoes. If none is handy, uses flesh of the dead.
Mashona (Kuper, 1955)	Fe	Smelting associated with fertility. Furnaces built in shape of female torso with breasts and abdominal cicatrices.
SOUTH AFRICA		
Zulu (Krige, 1936)	Fe, Cu	Smithing 'secret' profession.
SWAZILAND		
Swazi (Marwick, 1940)	Fe	Smiths and assistants must work naked, and no woman allowed into smithy. Unmarried man cannot enter smithy; if he does, will never marry.
INDIA		
S. India (Robins, 1953)	Fe, Cu	Close connection between metalwork and agriculture. At festival of <u>Nitagris</u> (seed sowing) at full moon, blacksmiths, copper, gold and silver smiths erect

		separate forges in the temple, and make something according to their craft.
U.S.S.R.		
Yakuts (Sumner, 1901)	Fe	Ninth generation smiths have supernatural powers, and priviledged to make shaman's iron ornaments and drum.
INDONESIA		
Bali (Forbes, 1964; Rowlands, 1971)	Fe	Smith group has own temple, graveyard, associated with fire god. Magical rites surround all aspects of craft. Smiths believe they have magic power given by Brahma. Special mantras said before use of every tool.
Batak (Forbes, 1964)	Fe	Smith-priests. Craft operations preceeded by offerings. Tribesmen pour libations in smithy as if temple. Tools worshipped and given mysterious names. Tool spirits protect smith and family.
Java (Forbes, 1964)	Fe	Weapons believed to have magic power. Production of <u>kris</u> (dirk of Java) surrounded by much ritual and ceremony. Smithy decorated according to strict rules, and sacred offerings made before work begins.
Sulawesi (Rowlands, 1971)	Fe	Smith relies on entire village to help him build and consecrate smithy. Ritual sanctions prevent smith making implements during planting and harvest of rice. Such work thought to damage crop.
NEW GUINEA		
Doré (Forbes, 1964)	Fe	During initiation smiths swallow special medicines and avoid pork.

Table I.3 Organisation of Work

People	Metal	Observation
SENEGAL		
Peul (Berenger-Féraud, 1879)	Fe	Smiths often itinerant.
Laobes (Berenger-Féraud, 1979)	Fe	Smiths often itinerant. Caste also wood workers.
SUDAN		
Bongo (Schweinfurth, 1874)	Fe	Smithing and smelting take place after rains, and after harvest stored.
Dinka (Seligman et al., 1932)	Fe, Cu	Smelters of Adjong clan also smiths. Partially itinerant. During dry season whole community move to Shambe lagoon. Smiths set up forges to make and mend iron tools and cast brass bracelets.
Dyoor (Schweinfurth, 1874)	Fe	Specialist smelters. Just before seed time, move from huts to fish and smelt.
Karma (Rowlands, 1971)	Fe	Customer takes iron to smith to make dagger. Takes blade to another craftsman for hafting; to another for decorative sheath to be fitted.
Kuku (van den Plas, 1910)	Fe	Smith families wealthy. Spend much time in agriculture and stock-raising.
ETHIOPIA		
Konso (Hallpike, 1968; 1972)	Fe	Individual specialisation.
Zala (Cerulli, 1956)	Fe	Women help in working bellows.
SIERRA LEONE		
Mende (Little, 1951)	Fe, Au	Both blacksmiths and goldsmiths own no farms, and do no agricultural work.
LIBERIA		
Gola (d'Azevedo, 1973)	Cu	Specialist makers of ornaments travel long distances to patrons.
Kpelle (Gibbs, 1965)	Fe	Occupational specialisations followed on part time basis. Kpelle smiths'

		basic subsistence from agriculture.
IVORY COAST		
Korhogo City (Gardi, 1969)	Cu	Casters and smelters form separate guilds. At typical casting forge, work force consists of 4 brothers (youngest 18 years old) and 2 apprentices. Apprentices fetch and carry water and charcoal, and file rough-cast pieces.
GHANA		
Dagaba (Manoukian, 1952a)	Fe	Although smiths do not work on their farms (their families and customers help instead), earn more from farms than craft.
Ewe (Manoukian, 1952b)	Fe	Blacksmithing part time craft. Women sometimes assist at anvil.
BENIN		
Dahomey (Herskovits, 1938)	Cu	Casting co-operative activity. All guild members controlled by chief smith (oldest member of group). Monarch supplies raw materials for commissions.
Dahomey (Herskovits, 1938)	Fe	All Dahomeans, including craftsmen, cultivate plot of land. Smithing co-operative. Smith collects scrap and works for others in group while awaiting his turn at forge. When time comes, all forge members convert his scrap stock into tools. These sold, and profit used to buy more scrap. One smith chosen as leader and arbiter in this combined labour system.
NIGERIA		
Various n.e. tribes (Neher, 1964)	Cu	2 groups of brass casters. Recent entrants to profession produce poor quality work for market trade. Other group belong to blacksmiths' guild and produce fine quality 'works of art'.
Abakwariga Hausa (Neaher, 1976; Rubin, 1973)	Fe, Cu	Itinerant smiths travel far and wide, producing goods in iron and bronze for a wide variety of patrons.
Angas (Meek, 1925)	Fe	Iron ore gathering seasonal, beginning after harvest.
Awka Igbo (Neaher, 1976)	Fe, Cu	Product specialisation in Awka: most work utilitarian (hoes, machetes,

		knives etc.) in iron; full time specialists commissioned to produce elaborate status symbols (including crowns and staffs) in iron and brass, for title-taking sector of society. *Product specialisation outside Awka*: at important stations on itinerant route, where several Awka smiths present, each tends to specialise in particular class of product. Local smiths at stations do simple utilitarian and repair work. *Itinerant organisation*. Master smiths follow organised schedule of travel and residence, each accompanied by 2 or 3 apprentices. Size of circuit limited by time (only allowed 7 months travelling each year), distance, presence of competitor smiths (e.g. Hausa to N, and Abiriba Igbo along Cross River). At stations, well patronised for iron and brass products of all types. Host chief provides board and lodging.
Bauchi (Meek, 1925)	Sn	Tin smelting furnaces each owned by village elder. Miner brings ore to smelter (usually furnace owner) and is paid in kind.
Benin City (pre-colonial) (Dark, 1973; Thomas, 1918)	Fe, Cu	Brass workers and blacksmiths form separate guilds. Brass workers' guild chief *Ine* responsible to *Oba* (tribal chief). Guild organised hierarchically according to closeness of relationship with chief *Ine*. Specific lineages in brass/bronze workers' caste specialise in different products - ceremonial staffs, bell etc. *Palace casting*: commissioned by *Oba* (present throughout process). *Oba* checks tools, then tools checked by chief *Ine*. *Oba* nominally pours first. Chief *Ine* makes most important pieces, then his brother, and so on down guild hierarchy (depending on number of pieces).
Igala, Igbira, Nupe (Neaher, 1976)	Fe, Cu	Blacksmithing and bronze working guilds quite separate.
Isoko (Peek, 1980)	Fe, Cu	Distinction between metalworking groups: bronze casters (*okwero*) and blacksmiths (*odugu*).
Kano City (pre-colonial)	Fe	*Specialisation*. Many specialists at different production stages (miners,

(Jagger, 1973; Smith, 1965)		smelters, smiths, dealers, middlemen etc.). Considerable product specialisation: smiths in different areas of city or different rural villages produce limited range of objects. General organisation. Sarkim Makera (chief smith) appointed by emir. He and his officials responsible for collecting taxes, organising work commanded by emir, supervising market and consulting with other craft heads. District officials chosen from Sarkim's kin or clients, and are responsible for blacksmiths throughout emirate. City organisation. City smiths produce all military equipment required by emir. Rural smiths brought into city to help with large orders. Rural organisation. Village head smith appointed by chief. Responsible for dealing with emir's district official. Rural smiths partially itinerant, travelling round smelting camps (obtaining supplies) in dry season, making things on spot to sell in markets on way home.
Kano City (present) (Jagger, 1973)	Fe	Complex pre-colonial organisation now extinct. Iron working now restricted to small forges. Basic production unit is family group. Forge in Tamburaba ward shared by 4 smiths (2 family units) each with own anvil and own products. Co-operation limited to heavy work such as scrap cutting.
Koro (Meek, 1925)	Fe	In Koro territory, smelting done by neighbouring Jaba, or itinerant smelters from Sokoto who can win as much ore as wished in exchange for gifts to Koro chief.
Maguzawa (Meek, 1925)	Fe	During dry season itinerant Maguzawa smiths work through night smelting ore and making hoes for local Hausa and Gbari.
Marghi (Vaughn, 1973)	Fe	Collection of iron and smelting done by Marghi, not by əŋkyagu smith caste. Ore collected in valleys, stored in pots at central point. Many families participate; each has own furnace. Ore smelted at beginning of rainy season; coincides with hoe making time. After smelting blooms taken to Əŋkyagu smith who forges them into iron bars. Payment in money, food or part of iron.

		Bars retained by owner as raw material for future tools or as exchange medium. When tool required, Marghi negotiate again with smith. <u>Smiths' organisation</u>. Typical working group: 2 brothers with 1 or 2 sons of either. Elder brother is forge master. Smiths organise work 'session', accumulating orders until can justify making charcoal and arranging bellows operator.
N. Hausa (Smith, 1965)	Fe	Smithing usually part time occupation, secondary to farming. In cities and on borders of large pagan groups, assured markets lead to full time specialisation.
Yoruba (Neaher, 1976)	Fe, Cu	Product specialisation in large communities patronised by religious cults (bronze ornaments) and military leaders (iron weapons). Workshops specialised with different titles for blacksmiths and bronze workers.
CAMEROON		
Bagam (Malcolm, 1923; 1924)	Fe, Cu	Blacksmiths and brass casters form separate guilds.
CENTRAL AFRICAN REPUBLIC		
Pangwe (Cline, 1937)	Fe	Smelting furnce built and owned by 4 or 5 village non-smiths. In each work season smiths operate furnace as many times as there are owners so each can receive major portion of bloom.
CONGO		
Bahungana (de Sonsberghe, 1955)	Fe	Bahungana smelters and smiths itinerant, serving smithless tribes (Bambala, Bapindi, Bayansi, Bangongo, Bapende, Bambunda, Bakwese).
ZAIRE		
Bayeke (de Hemptinne, 1926)	Cu	Smelters and casters belong to same caste, but roles specialised. Master smelter in charge of all stages of mining and smelting. Tribal chief and shaman direct magico-religious aspects.
UGANDA		
Bakitara (Roscoe, 1923a)	Fe	3 classes of artisan: miners and smelters; pig iron workers; smiths. Classes never share work, but each sells

		products of others.
Buganda (Trowell, 1941)	Fe	Smithing highly organised; closed groups specialise in certain products. Nvubu clan make agricultural implements and weapons. Co-operative organisation. Chief smith head of clan. Arranges for pig iron to be brought from Koki for work for Kabaka. Smiths work on 3 month roster system. Royal work for 3 months; own work for 3 months.
Kavirondo Bantu (Wagner, 1956)	Fe	Iron working most specialised of crafts. Specialist smelters, specialist smiths. Some product specialisation: Logoli smiths do not forge spears, knives. These bought from Tikiri.
Kigezi (White, 1969)	Fe	Smithing full time occupation. Part of time spent in preparing charcoal, part in smithy, part in selling products. Smiths usually work independently, each with 2 assistants. 1 helps in forging simpler implements (usually smith's son), other works bellows.
Labwor (Wayland, 1931)	Fe	Smelting done by 1 branch of craft, smithing by another. Smelting (seasonal to fit with agricultural cycle) takes place at ore sources, 30 miles from territory.
Lango (Driberg, 1923)	Fe, Cu	2 classes of metalworkers: <u>a-tong</u> make tools, weapons, small ornaments (iron) and heavy <u>ogul</u> (bracelets of beaten brass); <u>a-ariko</u> make ceremonial ornament <u>ariko</u>, worn by girls. Smiths not numerous. Each has assistant to work bellows.
KENYA		
Various agriculturalists (Brown, 1980)	Fe	Work seasonal; smiths participate in subsistence activities. Work when greatest demand for tools: before planting and weeding season, and before harvest. Smelting only after safe harvesting of crops (ritual explanation).
Various pastoralists (Brown, 1980)	Fe	Smithing full time occupation: smiths totally dependent on pastoralists for food. Work throughout year in response to constant demand.

Elgeyo (Massam, 1927)	Fe	Smiths used to be itinerant.
Kikuyu (Hobley, 1922)	Fe	Formerly 1 section of smith guild smelted, another smithed (smelting ceased).
Marakwet (Welbourn, 1981)	Fe	Smiths work 4-5 days each week during wet season when greatest demand (agricultural needs). Work less often in dry season. Smiths own land and farm.
Nandi (Huntingford, 1931)	Fe	Smiths and potters have own land, but are full time specialists.
ANGOLA		
Ondulu (Childs, 1949; Read, 1902)	Fe	Entire village including women and children gather ore in dry season; men make charcoal. When sufficient materials prepared for wet season hoe making, smelting begins. After smelting, iron divided amongst families in village for wet season smithing.
ZAMBIA		
Ba-Ila (Sayce, 1933)	Fe	Smelting only in spring (fits agricultural cycle).
Ba-Ushi (Barnes, 1926)	Fe	Smelters and smtihs separate castes.
Dakakari (Gunn et al., 1960; Harris, 1938)	Fe	Smithing sometimes taken up as casual, part time occupation by Dakakari males, but most of tribe's metal needs served by travelling smiths "from other parts".
Gwembe Tonga (Reynolds, 1968)	Fe	Very few smiths; each has area monopoly; mostly sedentary. Village of Mazila and others in Simamba served by itinerant smith from Múnyumbwe area, 1 day's journey away.
Kambari (Gunn et al., 1960)	Fe	Smithing part time occupation.
Plains Hausa (Gunn et al., 1960)	Fe	Itinerants serving Achipawa.
Plateau Tonga (Colson et al., 1951)	Fe	Product specialisation: different smiths specialise in axes, spears, cow bells etc. Smithing part time occupation. Smiths primarily farmers,

		depending on herds and cultivation for livelihood. Working casually, 1 or 2 smiths can fill needs of surrounding neighbourhood.
NAMIBIA		
Naman (Schapera, 1930)	Fe, Cu	18th C. Naman smelted, but preferred not to work own iron and copper. Instead hired itinerant Herero smiths to work metals into beads. Paid daily wage of 1 ewe. Now. Smithing casual occupation. No specialist Naman smiths, no constant practitioners.
Ovambo (Cline, 1937)	Fe	Smiths itinerant.
ZIMBABWE		
Balemba (Stayt, 1931)	Cu	Copper miners and smelters, 2 inter-related clans.
Mashona (Kuper, 1955; Bullock, 1950)	Fe	Craft distinction between miners, smelters and smiths.
SOUTH AFRICA		
Zulu (Krige, 1936)	Fe, Cu	Demand for ornaments greatest at royal Kraal. King keeps 2 smiths and 6 attendants constantly employed making bracelets out of copper and iron.
SWAZILAND		
Swazi (Marwick, 1940)	Fe	Smith always busy and prosperous, but horticulture and herding still major subsistence base of smith and family. Family do most of gardening work. Smith has 1 assistant to work bellows. Works mainly at night because of intense heat.
INDIA		
Agami Nagas (Hutton, 1921)	Fe	Variable number of smiths in each village. Some live by smithing alone, some combine craft with cultivation of own fields. All smiths work individually.
Bihar (Sinha, 1961)	Cu	3 bronze/brass working castes. Malhoar caste itinerant. Brass workers depend

		on sporadic orders from clients. This makes production organisation difficult. Work on craft for only 9 months of year. Remaining months spent in agriculture, working in own fields (rare) or as hired labour (good pay, supplement craft income). Organisation based on single household unit. Some co-operation between units, e.g. sharing of tools, ovens.
Galong (Dunbar, 1938)	Cu	Some smiths specialise in bracelets, some in beyop plates.
Hunza (Robins, 1953)	Fe	Smiths tour villages once or twice a year.
U.S.S.R.		
Kazak (Forbes, 1964)	Cu	Itinerant smiths.
MONGOLIA		
Torguts (Montell, 1940)	Ag	Mongol silversmiths travelled from tribe to tribe, staying as long as needed. Itinerant professionals.
BURMA		
N. Chin (Rowlands, 1971)	Fe	Product specialisation. Each specialist group works in separate village. Work concentrated between harvest and planting; time of greatest demand for new tools and repair of old.
Shans (Robins, 1953)	Fe	Burmese Shans do not work iron. In dry season Yunnanese Shans come into Burmese territory, set up makeshift forges and anvils. Produce new tools and mend ploughs.
MALAYSIA		
Iban (Rowlands, 1971)	Fe	In Kusten district, smiths specialise in either tools or weapons. In Paiur district, every village has smith making every type of implement.
INDONESIA		
Borneo (Rowlands, 1971)	Fe	Every village has smiths who make and repair tools. Specialist smiths make swords and spears. These widely

		traded. No production, only repairs, during cultivation season. Agriculture main activity at this time. Customers pay for work in labour in smith's fields.
Java (Forbes, 1964)	Fe, Cu, Au, Ag	Iron workers (armourers), goldsmiths, silver smiths, copper smiths separate castes.
Sumatra (Rowlands, 1971)	Fe	Smiths specialise in production of machetes, spears and daggers.
PERU AND COLUMBIA		
Navajo (Forbes, 1964)	Fe, Cu, Ag	Iron, copper and silver worked by itinerant smiths.
RUMANIA		
Laeshi (Robins, 1953)	Fe, Cu	Itinerant metalworkers, specialising according to metal. Work in tribes, each member carries tools on back. Same tools (hammer, tongs, small bellows) used for all types of work.

Table I.4 Becoming a Smith

People	Metal	Observation
SUDAN		
Nuba (Seligman et al., 1932)	Fe	Learn iron working from mother's brother or other close relative. Expected to pass skills on within family.
ETHIOPIA		
Soda (Cerulli, 1956)	Fe	Iron working open to anyone willing to become apprentice for 2-3 years.
GUINEA		
Fouta (Durand, 1932)	Fe	Hereditary craft.
LIBERIA		
Gola (d'Azevedo, 1973)	Fe, Cu	Smiths recruited from patrilineages of highest rank. Must be talented and show willingness before being apprenticed. Malleable metal workers trained by blacksmiths before specialising.
IVORY COAST		
Korhogo City (Gardi, 1969)	Cu	Craft tends to be hereditary. Casters' children start to watch and receive casual instruction c. age 10. First duties: fetch water, charcoal, and file rough cast pieces.
GHANA		
Various tribes (Manoukian, 1952a)	Fe	Anyone may practice as a blacksmith, but craft tends to operate in lineages.
Ashanti (Rattray, 1923)	Cu	Art retained in certain 'divinely chosen' families. If son does not follow father, nephew compelled to. Son following father inherits all tools, weights and metal stock.
Ewe (Manoukian, 1952b)	Fe	Smithing patrilineally inherited craft with own rules and rituals.

TOGO		
Evhe (Cline, 1937)	Fe	Smiths pass vocation on to sons and grandsons or, if without offspring, to sisters' sons. Never take apprentices from outside family. Sons work for father without fee.
BENIN		
Dahomey (Herskovits, 1938)	Fe	Hereditary craft. Difficult, but not impossible, for one born outside to be accepted into guild. Can apprentice himself to a smith, but still must work for father for half of time. In practice, few venture outside their craft.
NIGERIA		
Various n.e. tribes (Neher, 1964)	Cu	Brass casters members of blacksmiths' clans. Serve long apprenticeships.
Awka Igbo (Neaher, 1976; Thomas, 1913)	Fe, Cu	Apprenticed to kinsman at age 8 or 9; not to father in case he is 'spoilt'. Accompanies master and other smiths on annual journeys, often outside Igbo territory. Travels with different master each year to increase range of skills. Masters responsible for tuition, food and housing for apprentice whilst travelling. Apprentice blacksmith first makes needles, then rings, then razors, then chains and large tools. Apprentice brass smith makes plates, increasing in size. In late teens, apprentice becomes fully fledged smith receiving his tools from master in ceremony at 'outstation'. He then returns to Awka to recruit apprentices.
Benin City (pre-colonial) (Talbot, 1926)	Cu	Boys apprenticed at early age.
Bida City (Nadel, 1942)	Fe	Craft hereditary. Sons inherit patrilineally and occasionally matrilineally. Apprenticeship begins at age 7 or 8. First subsidiary work in forge, mainly operating bellows. Gradual progress to more difficult tasks such as forging hoes and axes. By late teens, has learnt to make reaping tools and knives.
Marghi (Vaughn, 1973)	Fe	All smiths born into ɔŋkyagu caste. Skills acquired through many years' apprenticeship. Only those caste members

		with sufficient motivation and skill are apprenticed. Apprentice first operates bellows; then sharpens knives; eventually takes spells at forge, heating iron and making simple objects.
Northern Hausa (Smith, 1965)	Fe	Crafts tend to be hereditary, sons learning when young.
Verre (Neaher, 1976)	Fe	Hereditary metalworking specialisation.
Yoruba (Forde, 1951)	Fe	Hereditary lineages of smiths at Iseyin.
CONGO		
Basakata (Maes, 1930)	Fe, Cu	Metalworking hereditary craft. Complex system of inheritance, with smith's eldest sister's eldest son being first in line.
ZAIRE		
Bayeke (de Hemptinne, 1926)	Cu	Metalworkers form religious society. Numbers restricted but outsiders can be admitted, although membership usually patrilineally inherited. Only the sons of chiefs pay no initiation fee.
Mangebetu (Cline, 1937)	Fe	Craft hereditary, father to son.
UGANDA		
Bakitara (Roscoe, 1923a)	Fe	No guilds, no hereditary castes of smiths. May be drawn from any clan of serf group.
Buganda (Roscoe, 1911)	Fe	Profession usually inherited by smith's son.
Kavirondo Bantu (Wagner, 1956)	Fe	Craft not taught to those outside clan, except sisters's sons. This a purely commercial, non-magical restriction, in fear of competition. Apprenticeship begins with working bellows. Then novice gradually taught techniques of smithing and wire drawing. At end of several years apprenticeship, master supplies new smith with tools.
Kigezi (White, 1969)	Fe	In most cases, profession hereditary. Sons inherit, or sons of close relatives.

Labwor (Wayland, 1931)	Fe	Profession hereditary.
Lango (Driberg, 1923)	Fe, Cu	Craft usually descends from father to son, or other close relative. Apprentice paid (aside from an occasional pot of beer) by being initiated into craft mysteries.
KENYA		
Various tribes (Brown, 1980)	Fe	Craft always specialist and usually hereditary. Taught to sons showing most aptitude. Any outsiders must generally have smith forebears. Sons begin to spend time in smithy at age 7-8. Allowed to pump bellows. Serious training begins at age 13-14. Usual length of apprenticeship 8-10 years. Apprentice fees vary, and are usually paid in installments at each learning stage.
Elgeyo (Massam, 1927)	Fe	Craft hereditary, father to eldest son.
Kamba of Kitui (Hobley, 1922)	Fe	Outsiders can become smiths, but must first participate in preliminary ceremonies with a master smith, bringing him gifts and sacrifices.
Kikuyu (Hobley, 1922)	Fe	Initiation ceremonies for anyone wishing to enter craft guild. Birth does not confer membership. Smith's son must be initiated, just as outsider.
Marakwet (Wellbourn, 1981)	Fe	Craft hereditary. Sons learn by watching fathers. Initiation ceremonies.
Masai (Hollis, 1905)	Fe	Craft hereditary father to son, but son cannot practise until after marriage. Smith cannot leave caste by failing to practise, and outsiders cannot enter.
TANZANIA		
Wachagga (Cline, 1937)	Fe	In Malissa clan, smith's alternate sons become smiths and charcoal burners. If second son has sons, his first son must become a smith, but must pay fee of heiffer and goat, as he is not <u>directly</u> of smith descent.

ANGOLA

Bayaka (Cline, 1937)	Fe	Smiths not a separate caste, but profession is hereditary.
Ondulu (Read, 1902)	Fe	Those born into hereditary blacksmith guild achieve professional status only after long and difficult apprenticeship.
Ovimbundu (Childs, 1949; Hambly, 1934)	Fe	Smiths do not form hereditary caste and are not endogamous, although profession tends to be hereditary. Elaborate apprenticeship begins at about age 18. Apprentice not allowed to forge implements until after initiation 2 years later.

ZAMBIA

Ba-Ila (Smith and Dale, 1920)	Fe	'Iron doctor' (master smelter) hereditary position, father to son.
Dakakari, Dukawa, Kambari (Gunn et al., 1960)	Fe	Iron working hereditary male craft.
Gwembe Tonga (Reynolds, 1968)	Fe	Smiths chosen by spirit of former smith, usually direct descendant. Exceptions: descendant has offended spirit, descendant decides not to practice or later ceases practice. Theoretically trained by spirit. Practically apprenticed to experienced smith until competent. Most tribesmen learn basic smithing skills, as take place of smith's assistants when having tools made.
Lambas (Doke, 1931)	Fe	Obligatory for apprentice smith to live with master to learn mysteries of craft. Initially works bellows, tends fire, helps build smelting house. Later allowed to begin forging axes, then spears, then hoes. Apprentice provides free assistance to master, supplies own raw materials, and all his products belong to master who sells them fro his own profit.
Lozi (Forde, 1952)	Fe	Smithing usually hereditary craft.
Plateau Tonga (Colson et al., 1951)	Fe	Descent either patrilineal or matrilineal. Additionally, long-forgotten smith ancestor may decide to pass on skill to one who has no apparent hereditary claim to the craft. In practice, system allows anyone who

		cares to practice craft, and removes stigma of laziness from those not so inclined.
SOUTH AFRICA		
Kaffir (Cline, 1937)	Fe	Patrilineal inheritance.
Zulu (Krige, 1936)	Fe, Cu	In parts of Zululand, profession confined to one family.
SWAZILAND		
Swazi (Marwick, 1940)	Fe	Blacksmithing hereditary occupation. Nowadays, sons trained as smiths after leaving school.
LESOTHO		
Basuto (Ashton, 1967)	Fe	Apprenticeship and mysterious purifications necessary before initiation.
INDIA		
Bihar (Sinha, 1961)	Cu	Bronze/brass working castes restricted. No formal training of young, who learn by observation and assisting. No initiation rites at start of professional life.
Galong (Dunbar, 1938)	Fe, Cu	Smithing not a hereditary craft. No monopoly, but some communities tend to specialise.
U.S.S.R.		
Yakuts (Sumner, 1901)	Fe	Hereditary craft, transmitted father to son.
INDONESIA		
Batak (Forbes, 1964)	Fe	Son must follow father in the craft, otherwise "the tools will lay snares for him".

Table I.5 Output

People	Metal	Observation
SUDAN		
Bongo (Schweinfurth, 1874)	Fe	Products mainly designed for trade with northern tribes. Make rough spades for use as currency. Spades also bridewealth.
Kuku (Seligman et al., 1932)	Fe	Complete range of products: spears, arrowheads, hoes, axes, knives, ornaments.
LIBERIA		
Gola (d'Azevedo, 1973)	Fe, Cu	Until very recently, native tools preferred to imports. Ritual implements must always be made locally (e.g. circumcision knives). Blacksmiths used to make and repair all weapons for hunting and warfare. Present range of products. Weapons: elaborate spears, knives, swords. Ornaments: necklaces, bracelets, bells, medallions, rings, gem mountings. Figurines: ritual animal or human forms for magic practitioners; toys for rich. Decorated utensils: cups, spoons, knives, bowls. Much of this work in malleable metals, often cast in moulds.
Kpelle (Gibbs, 1965)	Fe	Smith makes own anvil, hammer and tongs. Makes machetes, hoes, knives and implements used in Poro ceremonies.
IVORY COAST		
Korhogo City (Gardi, 1969)	Cu	Casters guild produces jewellery, utensils, weapons, animal figurines, figurative sculpture and plaques.
GHANA		
Various tribes (Manoukian, 1952a)	Fe	Blacksmiths make agricultural tools and weapons: spearheads, knives, arrowheads, hoes and axes. Also needles, tongs, iron spikes and chisels.
Various tribes (Manoukian, 1952a)	Cu	Copper smiths make bracelets and other ornaments by cire perdue method. Often earn as much as blacksmiths.

Ashanti (Johnson, 1979)	Fe, Cu	Royal blacksmiths make state swords, used to swear allegiance to King and in important ceremonies. Other smiths make mourning collars, cutlasses and adzes. Others specialise in woodcarving tools.
BENIN		
Dahomey (Herskovits, 1938)	Cu	Task of brass working caste is to make ornaments for homes of rich upper classes. Designs are based on individual (customer's) inspiration. Also make pieces to commemorate monarch's reign, celebrate his power, or simply to decorate his palace. Products now for export, but these lack care and feeling.
NIGERIA		
Abakwariga Hausa (Neaher, 1976)	Fe, Cu	Clan makes entire range of weapons, tools, ornaments. Use both iron and copper alloy; latter confined to ornaments.
Awka Igbo (Neaher, 1976)	Fe, Cu	Ritual/utilitarian product specialisation; iron/copper alloy specialisation. Utilitarian products include hoes, machetes, knives, cooking stands, fishing spears and traps (iron). Ritual products mainly staffs and bells (usually copper alloy).
Baoulé (Cline, 1937)	Fe, Cu, Au, Sn	Smiths cast mainly bronze and brass. Copper and gold rarely worked; tin and iron very seldom.
Isoko (Peek, 1980)	Cu	Casters produce several types of bell, for animals and humans; also bracelets.
Kano City (pre-industrial) (Jagger, 1973)	Fe	City blacksmiths produce swords, spears, axes, arrows, horse-gear. Also chains, shackles and balls for city prison. Product specialisation within city. E.g.: smiths of 2 wards make traditional door locks; smiths of 1 ward make only swords; smiths of 1 ward specialise in horse equipment, especially stirrups. Rural smiths make agricultural tools. Client smiths make farm tools and do general maintenance.
Marghi (Vaughn, 1973)	Fe	Spears, arrow points, daggers, throwing knives; hoes, knives, sickles, axes, adzes; needles, razors, bells, chains, tobacco pipes, beads, bracelets, other jewellery; 'medicines'. Throwing knives (ceremonial), arm daggers and spears are

		prestige items only made by most skilful smiths.
N. Hausa (Smith, 1965)	Fe, Ag	Iron production centres on farming and woodworking tools. Silver confined to ornaments such as heavy bracelets and anklets. Some weapons produced but as swords of local manufacture prone to break, tempered blades imported from Morocco and Near East, and finished by local smiths.
Yoruba (Forde, 1951)	Fe, Cu	Utilitarian: hoes, axes, adzes, knives, cutlasses. Ritual: iron staffs with zoomorphic heads in honour of Osanyin, deity of medicine.
CONGO		
Basakata (Maes, 1930)	Fe, Cu	Smiths form hierarchy and are ranked according to tools allowed to produce. All smiths produce tools and are paid by individual customers. Weapons only made by fully trained smiths. Ceremonial ornaments only made by master smith who has necessary technical skill and magic.
UGANDA		
Buganda (Trowell, 1941)	Fe	<u>Ente</u> clan make spears, axes, adzes, hoes, digging spears, knives; awls, needles and bells (for dogs, cattle and babies' legs, to make them walk). Nvubu clan make royal shields; bracelets, anklets and ornaments for chief's wives.
Jie (Gulliver, 1965)	Fe	Have no smiths and purchase all iron products from neighbouring Labwor. Buy spears, knives, hoes, ornaments and bells.
Kavirondo Bantu (Wagner, 1956)	Fe	Agircultural implements: knives (used for cutting meat, slaughtering, harvesting), bill-hooks, hoes (these 2 are women's tools), axes, adzes, awls; pipes, cowbells; ritual iron rings and bracelets.
Kavirondo Bantu (Wagner, 1956)	Cu	Plain and twisted armelts, necklaces, rings, made of beaten metal and all worn by old people.
Kigezi (White, 1969)	Fe	Large range of products including drawn wire. Smiths also repair and renovate most tools.

Labwor (Wayland, 1931)	Fe	Mainly spears and hoes. Famous for these among neighbouring tribes. Wide distribution. Natives will not buy cheap equivalents from Indian stores, as these last only 5-6 months. Labwor hoes and spears last 3-4 years. Smiths also do repairs.
KENYA		
Various agriculturalists (Brown, 1980)	Fe	Greater range of products than smiths among pastoralist groups. Little specialisation; all make wide range, but most skilled in producing those tools for which highest seasonal demand. Make all own tools; also swords; knives, hoes, bill-hooks, sickles; axes, adzes, awls and other woodworking tools; branding irons, bells for people and animals; 'medicines'.
Various pastoralists (Brown, 1980)	Fe	Main product is the spear. Spears used in hunting, fighting, as general purpose knives, or as woodworking tools.
Kikuyu (Hobley, 1922)	Fe	Customers often bring own iron and charcoal and bargain with smith for manufacture of sword or spear.
Marakwet (Welbourn, 1981)	Fe	Group of unskilled smiths in s. of territory confine production to hoes. Balcksmiths can make all weapons, tools and protective ornaments. Large scale of production and distribution over wide area. Spears produced for Marakwet and nearby Pokot tribe.
Sonjo (Gray, 1963)	Fe	Arrow points, razors, knives, adze blades (formerly axes and machetes as well).
TANZANIA		
Wachagga (Johnston , 1886)	Fe	Wide range of products including weapons, tools and ornaments. Special skill shown in manufacture of delicate objects.
ZAMBIA		
Achipawa (Gunn et al., 1960)	Fe	Different hoe types produced for men and for women.
Bemba (Colson et al., 1951)	Fe	Smiths can forge axes and spears, but are 'unskilled'.

Gwembe Tonga (Reynolds, 1968)	Fe, Cu	Hunting: hunting spears, fishing spears, harpoon heads, knives. Agriculture and wood work: hoes (cultivating, cutting light firewood, clay digging), axes (various forms for various purposes), adzes. Above all iron. Either metal: pipe tongs, snuff spoons, razors. Beaten copper or brass: limb ornaments. Also repair ploughs, guns, bicycles.
MALAWI		
Yao (Colson et al., 1951)	Fe, Sn	Arrow points, knives (scrap iron). Cups, water cans for tobacco growers (tin)
NAMIBIA		
Naman (Schapera, 1930)	Fe, Cu	Arrows and spears of iron, ornaments of beaten copper.
ZIMBABWE		
Balemba (Stayt, 1931)	Fe, Cu	Mainly hoes; adzes, spears and arrow heads also produced (iron). Mainly ornaments and bracelets, originally only worn by Balemba and by Bavenda chief's wives (copper).
Mashona (Bullock, 1930; Kuper, 1955)	Fe	Hoes, axes, adzes, enormous elephant spears (utilitarian). Battle axes and fetish axes to bring out spirits in dances. Assegais produced for overlords.
SOUTH AFRICA		
Zulu (Krige, 1936)	Fe, Cu	Hoes most important products, as food supply dependent on them. Assegais and knives also produced in quantity. Ornaments in iron and brass. Brass ornaments in great demand at royal kraal.
SWAZILAND		
Swazi (Marwick, 1940)	Fe	People from wide area visit smith to commission spears, knives and crowbars.
LESOTHO		
Basuto (Ashton, 1967)	Fe, Cu	Iron: spears, knives; hoes, adzes, scrapers; needles. Copper and brass: anklets and bangles worn all over amrs and legs.

INDIA

India (Grigson, 1938)	Cu	Smiths cast ornaments, spoons, bells and hunting horns by cire perdue method.
Bihar (Sinha, 1961)	Cu	Grain measures and ornaments made in brass and bell metal. Highly specialised skilful smiths make statuettes.
Galong (Dunbar, 1938)	Fe, Cu	Some communities specialise in swords, some in beyop plates or bracelets etc. Swords are imported from Tibet and copied in northern groups to barter with the south. Value of sword dependent on number of welding lines on blade.
Hunza (Robins, 1953)	Fe	Itinerant smiths make or mend whatever is needed.

ROUMANIA

Gypsies (Robins, 1953)	Fe, Cu, Sn etc.	Smiths "mix metals" and make earrings, rings, bracelets and needles for sale. Also pick locks, duplicate keys and repair copper vessels. Same tool kit used for all work.

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Table I.6 Supply of Metal

People	Metal	Observation
SUDAN		
Bari (Seligman et al., 1932)	Fe	Some smiths collect and smelt stream ore.
Dinka (Seligman et al., 1932)	Fe	Nodules collected for smelting in west: 40-50% metallic iron. When demand high, scrap imported on grand scale. At dry season forge, customers bring metal.
Dinka (Seligman et al., 1932)	Cu	At dry season forge, customers bring scrap brass for casting bracelets.
Kerma (Rowlands, 1971)	Fe	Customer supplies raw material.
Kuku (Seligman et al., 1932)	Fe	Iron mined in mountains. Small-scale mining, shallow shafts, lateral galleries.
ETHIOPIA		
Gumuz (Cerulli, 1956)	Fe	Iron bought from Ethiopians
Ingassana (Cerulli, 1956)	Fe	Iron imported from regions of White and Blue Nile.
Konso (Hallpike, 1972)	Fe	Smiths usually buy raw materials, but will take commissions from customers providing their own.
Zala (Cerulli, 1956)	Fe	Iron imported from Walano country.
LIBERIA		
Gola (d'Azevedo, 1973)	Fe	Use both smelted ore from large tribes of savanna highlands (diminishing trade) and European imported metal.
IVORY COAST		
Korhogo City (Gardi, 1969)	Cu	Brass always preferred to copper as easier to melt. Portuguese merchants used to bring shiploads of bar and ring ingots (brass) for recasting. Now cheapest scrap used for casting: lead piping, car batteries, brass

		screws, sheet brass, water taps, copper wire. Little composition control.
GHANA		
Ashanti (Johnson, 1979)	Cu	Industry used to depend on brass imported from Europe. Today, local scrap.
BENIN		
Dahomey (Herskovits, 1938)	Cu	Brass rods imported from Europe valued as silver or gold.
Dahomey (Herskovits, 1938)	Fe	No smelting. No piece of scrap disdained. Old car parts, sewing machine wheels, discarded rails.
NIGERIA		
Bauchi (Meek, 1925)	Sn	Miner brings ore to smelter.
Benin City (pre-colonial) (Dark, 1973)	Cu	Portuguese manillas (bar ingots) and brass rods. If casting for Oba (King), Oba supplies metal, and after casting all waste and crucible residues returned to him. Oba supplies blacksmiths with iron for tongs used in brass casting.
Isoko (Peek, 1980)	Cu	Casters use chance finds, described as "objects coming from the ground"; manillas (bar ingots) and rarely bullet casings.
Kano City (pre-colonial) (Jagger, 1973)	Fe	Kano rural smiths travel round mining and smelting camps in dry season to buy supplies for selves and fellow smiths. Some rural smiths smelt their own, buying rights from local chiefs with hoes. City smiths rely on rural counterparts for supplies, and on long distance traders.
Koro (Meek, 1925)	Fe	Ore worked by itinerant smelters from Sokoto.
Marghi (Vaughn, 1973)	Fe	Ore collected and smelted by Marghi (freemen). Smithed by ŋkyagu (submerged class).
Mbarawa (Meek, 1925)	Fe	Women gather the ore.

Yoruba (Williams, 1973)	Fe	Ogun (iron god) believed present in metal. Cultural restrictions on using non-virgin iron (scrap) for ritual and agricultural implements. Iron bar ingots and copper ingots used to purchase slaves at New Calabar in early 18th C. Iron bars 9' long, 2" wide and ½" thick neatly divided into 36 equal sized African hoes.
CONGO		
Basakata (Maes, 1930)	Fe, Cu	Iron, copper and brass supplied by customer. Customer obtains these materials from smelter or through exchange.
ZAIRE		
Bayeke, Basanga (de Hemptinne, 1926)	Cu	Mines amicably exploited by several tribes. Individual ownership of shafts and galleries, but no exclusive tribal ownership of copper fields.
UGANDA		
Buganda (Trowell, 1941)	Fe	Little smelting, but for work for Kabaka (ruler), iron smelted at Koki brought to be worked by royal smiths near Kampala. Ente clan use Koki iron for royal work and scrap iron for items for sale.
Kavirondo Bantu (Wagner, 1956; Hobley, 1902)	Fe	Ore smelted in Samia and Kitosh region of territory. Clans in these areas exchange smelted iron for livestock and grain with other Bantu clans.
Labwor (Wayland, 1931)	Fe	Person requiring spear buys lump of iron from smelters. Takes it to smith with sufficient charcoal for smithing. For producing 2 spears smith charges 1 day's labour in his garden.
Lango (Driberg, 1923)	Fe	Customer must provide metal in form of iron 'currency' hoes, obtained by exchange, for production of weapons or ariko (ceremonial ornament). Smith charges production fee according to labour invested in manufacture.
KENYA		
Various tribes (Brown, 1980)	Fe	Customers often asked to supply raw materials. In smelting areas, customers can buy ingots, but scrap more

		usually seen in Kenya. In many areas, broken tools and weapons hoarded in houses as potential raw material. When pastoralists have to move, their scrap goes with them; household goods, such as stools, left behind. In areas where smith supplies raw materials, costs to customer higher. Smiths keep slag for making ornaments.
Elgeyo (Massam, 1927)	Fe	Itinerant smiths do own smelting.
Kikuyu (Brown, 1980; Hobley, 1922)	Fe	Some customers bring own iron (and charcoal) and bargain for manufacture of sword or spear. Smiths purchase iron ingots in markets from tribesmen from smelting areas.
Marakwet (Welbourn, 1981)	Fe	Smiths paid for work in scrap iron, labour in fields, and charcoal.
Sonjo (Gray, 1963)	Fe	Warriors bring imported German sword blanks for finishing and hafting. Raw iron (except wire) obtained from Masai smiths in form of broken spears.
Suk (Beech, 1911)	Fe	Introduction of iron wire removed necessity for laborious task of digging iron ore.
TANZANIA		
Wachagga (Cline, 1937; Johnston, 1886)	Fe	Smiths obtain pig iron by trade. Customer often supplies metal. Must supply enough metal for 2 of article desired; smith retains duplicate. Second tool can be replaced by goat if customer has insufficient metal. In case of weapons, 3 must be made and smith keeps 2.
ANGOLA		
Ondulu (Read, 1902)	Fe	Entire village, including women and children, gather ore from mountain sides in dry season. Smelting begins when sufficient charcoal and ore prepared for wet season hoe making.
ZAMBIA		
Achipawa (Gunn et al., 1960)	Fe	Ore transported from nearby hills and smelted in Karisen (smith village). Scrap now replaced smelted ore.

Bemba (Colson et al., 1951)	Fe	Smelting mainly done by Lunda to west of Bemba country. Ingots traded.
Gbari (Gunn et al., 1960)	Fe	Iron ore still smelted as Gbari district off railroad and main communication routes (limited access to scrap).
Gwembe Tonga (Reynolds, 1968)	Fe	Iron comes from local or Plateau smelters as ingots, or from Barotseland in form of finished hoes. Much European scrap in evidence. Metal generally scarce, thus smiths prefer customers to supply own raw materials.
Lozi (Forde, 1952)	Fe	Smelt own iron from Barotseland. Ore obtained from stream beds and swampy soil produces soft iron, but can be ground to fair degree of sharpness.
MOZAMBIQUE		
Thongas (Junod, 1927)	Fe	Regular forges in some villages using iron from wrecks. Most iron, however, imported from Transvaal. Iron for bracelets bought at Laurenço Marques from Hindu traders.
NAMIBIA		
Naman, Namaqua (Schapera, 1930)	Fe, Cu	In 18th C Naman smelted own copper and iron ores. Great Namaqua tribes obtained copper from Little Namaqua smelters to the south.
ZIMBABWE		
Balemba (Stayt, 1931)	Fe	Smelted iron handed to smith mainly for hoes. Smelter not the smith.
Balemba (Stayt, 1931)	Cu	Rich copper deposits in Messina district of Transvaal worked by some of tribe. Copper scarce. Balemba smiths present distinctively shaped ingots (studded musuku) to Bavenda chiefs, so they would have permanent supply of raw material for re-working into bracelets [and Balemba would be ensured continuing employment].
SOUTH AFRICA		
Zulu (Krige, 1936)	Cu	All brass imported through Delagoa Bay in form of ring ingots 1" thick and 6" diameter. Rings so valuable, man could buy wife with one.

LESOTHO		
Basuto (Ashton, 1967)	Fe, Cu	Tribe smelted and smithed iron. Copper and brass imported from Thonga.
INDIA		
Central India (Grigson, 1938)	Cu	Brass casters buy old brass or bronze from Hindu traders.
Agami Nagas (Hutton, 1921)	Fe	No smelting; imported iron only, in form of cheap spades.
Bihar (Sinha, 1961)	Cu	Metalworking castes have never smelted. All raw material made up of scrap acquired from caste of professional dealers. Dealers exchange for cash or finished products. Villagers sometimes sell broken metal pots to craftsmen.
Bihar (Sinha, 1961)	Fe	Customers often bring own iron.
Galong (Dunbar, 1938)	Cu	<u>Beyop</u> plates sometimes of brass, but more often from broken pieces of <u>dankis</u> - large bowls imported from Tibet, made of brittle grey alloy with high antimony content. Customer requiring <u>beyop</u> plates, takes own metal to smith who designs casting according to customer's wishes.
Galong (Dunbar, 1938)	Fe	No ore smelted, all imported metal, despite local availability of ores. Imported iron distributed in course of wider trade networks through country.
Lois (Hodson, 1908)	Fe	Iron workers smelt stream ore. 50% recovery of metal from ore.
MONGOLIA		
Torguts (Montell, 1940)	Ag	Silver dollars preferred as raw material. Hong Kong dollars preferred because of high silver content.
INDONESIA		
Borneo (Rowlands, 1971)	Fe	Interior tribes use local ore; metalwork enjoys widespread repute. Coastal tribes use low quality imported European ore.

Table I.7 Supply of Non-metals

N.B.: almost all smiths provide their own non-metal raw materials. The cases listed below are unusual, or exceptions to this rule.

People	Metal	Observation
GHANA		
Ashanti (Johnson, 1979)	Cu	Wax for modelling and high-grade charcoal used to be imported from Ghana interior.
NIGERIA		
Angas (Meek, 1925)	Fe	Customers supply their own charcoal. Religious chief first cuts down Kirya (Prosopis oblonga) or Marke (Anogeissus leiocarpus) tree for smelting charcoal. Afterwards, all those needing implements may go and cut necessary wood for charcoal.
Benin City (pre-colonial) (Dark, 1973)	Cu	Oba supplies all tools and materials, including a goat, a cock and a cow for sacrifice. Blacksmiths supply charcoal.
Kano City (pre-colonial) (Jagger, 1973)	Fe	Several elderly women (all from smelting families) trade in charcoal.
UGANDA		
Kavirondo Bantu (Wagner, 1956)	Fe	Charcoal bought from neighbouring Nandi.
Kigezi (White, 1969)	Fe	Nearly all smiths produce own charcoal, but iron working tools made only by the most expert smiths.
Labwor (Wayland, 1931)	Fe	Customer takes sufficient charcoal for smelting.
Somali (Cline, 1937)	Fe	Smith seeks his own stone anvil and hammer. The hammer must be found near the anvil as it is believed to be the anvil's child.

KENYA		
Various tribes (Brown, 1980)	Fe	Smith will travel long distances in search of good anvil stones. Only 1 tribe has specialist anvil supplier. Anvils often inherited. Samburu smiths' wives make their own tuyères. Elsewhere in Kenya, smiths collect the clay and make their own. Often travel considerable distances for clay which they carry back to their smithies in banana leaves or baskets. Lamma Island smiths cross sea to Manda for their clay.
Kikuyu (Hobley, 1922)	Fe	Some customers supply own charcoal.
Marakwet (Welbourn, 1981)	Fe	Smiths paid partly in charcoal.
TANZANIA		
Wachagga (Cline, 1937)	Fe	Alternate sons of smith become charcoal burners. Charcoal also supplied by customers.
ZAMBIA		
Lungu (Chaplin, 1961)	Fe	Charcoal site (smiths prepare) at least 1 mile from smelting area.
SWAZILAND		
Swazi (Marwick, 1940)	Fe	Smiths now use European hammers, but still prefer stone anvils and slow-burning wood tongs.
INDIA		
Agami Nagas (Hutton, 1921)	Fe	Smiths seek own anvil stones and egg-shaped hammers in mountain stream beds.
Galong (Dunbar, 1938)	Cu	Customer often supplies own wax.
INDONESIA		
Sulawesi (Rowlands, 1971)	Fe	Charcoal and labour at bellows provided by customer.

Table I.8 Location of Activities

People	Metal	Observation
SUDAN		
Bari (Seligman et al., 1932)	Fe	Some smiths live in ordinary villages and work outside; others in separate villages near ore source, which they smelt.
Dyoor (Schweinfurth, 1874)	Fe	Smelting furnaces in shaded centre of wood, away from villages, near ore source and abundant fuel.
Nuba (Seligman et al., 1932)	Fe	One smith worked in rock-shelter above main settlement area.
IOVRY COAST		
Korhogo City (Gardi, 1969)	Cu	Melting furnace on village edge. Roofed, but no walls, facing open courtyard. Wax models and moulds prepared under adjacent mango tree.
GHANA		
Ashanti (Johnson, 1979)	Fe, Cu	Craftsmen in villages within 20 miles of capital. Iron products taken to palace secretly by night; some crafts (e.g. weaving) practised in capital. In smiths' village of Fumisua, forges all located at end of village; workshops for cold chiseling in open courtyard of houses.
Ashanti (Johnson, 1979)	Au	Group of smiths live in capital, Kumasi, for security.
BENIN		
Dahomey (Herskovits, 1938)	Fe	Smith groups live in separate villages or city quarters. Forges and dwellings similar to bronze smiths'.
Dahomey (Herskovits, 1938)	Cu	Guild members live in compounds in Abomey quarter, near the King's palaces. Houses near long, low, rectangular open-sided shelters with forges.
NIGERIA		
Baoulé (Cline, 1937)	Fe, Cu	Blacksmith's and bronze caster's workshops on village outskirts, to avoid fire danger. Plain gabled roof

		on posts, no walls. 20cm high clay wall around caster's hearth, near similar wall enclosing pit of soft sand to hold mould while cooling.
Benin City (pre-colonial) (Roth, 1968; Dark 1973; Neaher, 1976)	Cu	Under direct supervision of King, all brass casters work in capital, where they live in own quarter, on road leading out from city. Utilitarian and non-ritual work in brass casters' quarter of city; special work (e.g. shrine furniture for tribal chief) on open ground near palace. Preparation area (for smelting, clay and beeswax preparation, etc.) in compound adjacent to palace.
Igala, Igbira, Nupe (Neaher, 1976)	Cu	All main towns are centres of bronze casting. As trade centres, are good locations for distribution of luxury goods.
Kano City (pre-colonial) (Jagger, 1973)	Fe	Mining camps near ore sources. Round grass huts dismantled at end of mining and smelting season. Forge usually detached from smith's compound, to reduce fire risk.
Marghi (Vaughn, 1973)	Fe	Ore collected from valleys is stored in pots in centre of village. Smelting complex near store.
Northern Hausa (Smith, 1965)	Fe	Single wards in villages occupied by single craft groups.
Tula (Fagg, 1952)	Fe	Forge not far from chief's house, but apart from living huts in smith's compound.
UGANDA		
Baganda (Trowell, 1941)	Fe	Ente clan have smithies on road outside town.
Kavirondo Bantu (Wagner, 1956)	Fe	Iron smelters never set up furnaces inside walled village, but out in bush: people do not like 'dirty' slag near their houses. Smiths' workshops under shady arbors at much frequented places (e.g. cross-roads, markets) where customers wait for orders to be filled.
Kigezi (White, 1969)	Fe	21 smiths (in 1900, 100 smiths, each with assistants) live in Mushinga village. This unparalleled situation inexplicable:

		ores are 5 miles away, and high population and large market are both recent.
Lango (Driberg, 1923)	Fe, Cu	Smithy outside village. Circular hut with no walls; to cut wind, roof reaches to within 1 ft. of ground.
KENYA		
Various tribes (Brown, 1980)	Fe	Smithies always isolated, although smith families are dispersed amongst community: to preserve mysteries of craft, guard against inadvertant breaking of taboos and against pollution by smith of land, crops and animals; and to be near supplies (trees for charcoal, and water). If smithies burn down, usually rebuilt in same place because of consecration.
Kalenjin (Brown, 1980)	Fe	Smithy built outside smith group's compound for practical reasons, but additional factors of pollution, magic and fear keep it away from non-smith villages. Smithing villages on river banks close to the few routes through valley, for maximum trade potential. Many developed into largest trading centres in area.
ANGOLA		
Ovimbundu (Childs, 1949)	Fe	Wholesale manufacture of hoes restricted to Ndulu country, because best and most accessible ore deposits are located there.
ZAMBIA		
Ba-Ila (Sayce, 1933)	Fe	Temporary shelters built for smelters near ore sources.
Ba-Ushi (Barnes, 1926)	Fe	For traditional reasons (area used by ancestor iron workers), smelting site not necessarily close to ore sources, but near village.
Gwembe Tonga (Reynolds, 1968)	Fe	Smithy on village outskirts or some distance away, on account of fire risk; often in homestead gardens. At Mazila itinerant smith worked under granary eaves at headman's homestead.
Lambas (Doke, 1931)	Fe	Small smithies often erected in villages for sharpening and repairs.

ZIMBABWE		
Balemba (Wessman, 1908)	Fe	Communal workshops, mostly near public road. Only a shelter against the sun.
SOUTH AFRICA		
Zulu (Krige, 1936)	Fe	Smithy in euphorbium tree grove c. $\frac{1}{4}$ mile from kraal.
INDIA		
Lois (Hodson, 1908)	Fe	Village of smiths and smelters near ore source; village moved when source depleted.

Table I.9 Transactions

People	Metal	Observation
SUDAN		
Bari (Seligman et al., 1932)	Fe	Commoners buy weapons and tools from smith, who thus acquires property. Smith provides chiefs with weapons and hoes, and receives feast in recompense.
Dinka (Seligman et al., 1932)	Fe	Smelters clan (Adjong) obtain pots and sheep and hippopotamous meat in exchange for iron objects, and buy wives with lumps of iron.
ETHIOPIA		
Konso (Hallpike, 1968; 1972)	Fe	All smiths sell products in markets, but also accept commissions.
LIBERIA		
Gola (d'Azevedo, 1973)	Cu	Smiths' services exchanged among rulers as gifts or favours in diplomacy.
GHANA		
Dagaba (Manoukian, 1952)	Fe	Customers pay for tools by working on smith's farm.
BENIN		
Dahomey (Herskovits, 1938)	Fe, Cu, Ag	No fixed charges for products: smith in need will sell for lower price than one who can afford to wait.
NIGERIA		
Various n.e. tribes (Neher, 1964)	Cu	Brass casters of blacksmiths' clan produce articles on request for fellow tribesmen in exchange for chicken, goat, money or favours.
Angas (Meek, 1925)	Fe	Smiths make tools ordered by customers in return for farming assistance.
Awka Igbo (Neaher, 1976)	Fe, Cu	Goods made (a) on straight commission (b) to sell in local markets (c) as gifts for hosts at outstations in return for help and food. Trade controlled by council of smiths in different villages. Also involved in exchange of non-metal goods (e.g. palm products, elephant

		tusks, European cloth and gin). Smiths probably stimulated growth of extensive trading networks in Nigeria.
Bauchi (Meek, 1925)	Sn	Half of resultant metal and clinker given to furnace owner (usually the smelter) by miner as commission and payment.
Kano City (pre-colonial) (Jagger, 1973)	Fe	Large scale professional trade in local goods. Organisation of trade has always involved many specialists: long distance traders, dealers in iron and in metal goods, middlemen and commission agents. Procurement, productions and distribution an integrated system. Emire and administrators demanded control over production. Smiths have to perform community services and pay tribute, the collection of which requires complex organisation of officials under chief smith (all officials active smiths). Size of tribute dependent on skill, output, wealth. Rural smiths present tools for use on royal farms. City smiths pay tribute of military gear, and have to maintain city gates, prison and palace.
Northern Hausa (Smith, 1965)	Fe, Ag	Three levels of trade: (a) intra-community commercial (mainly craft products and services) (b) inter-community commercial (cash crops, meat, imported goods) (c) gift exchange. Most exchange occurs in daily or weekly markets, where specialists group together in own area.
CAMEROON		
Eyap (Malcolm, 1923)	Cu	All orders submitted to head chief, who passes them on to smith.
ZAIRE		
Bayeke (de Hemptinne, 1926)	Cu	Miners divide ore from annual mining season amongst themselves, and tribal chief receives portion of ore and smelted copper.
UGANDA		
Buganda (Trowell, 1941)	Fe	During 3 month stint of royal work, smiths must produce tribute of 7 spears, 20 digging spears, 25 knives, 80

		peeling knives, 15 adzes, 7 awls, 40 small and 30 large needles.
Kavirondo Bantu (Wagner, 1956)	Fe	(a) specialists work mainly to order, smith supplying materials. (b) wholesale manufacture and trade along inter-tribal networks. Iron hoes function as bridewealth, and to some extent as currency. Prices differ according to whether customer is clansman, neighbour or stranger.
Kigezi (White, 1969)	Fe	(a) private customers (b) local markets.
KENYA		
Various tribes (Brown, 1980)	Fe	Most smiths sell within own tribe, or to neighbouring tribe if its own supplies are inadequate. Border trade direct from smithies, or at border markets. Customers and smiths prefer direct sales. No fixed prices. Pastoralists pay in meat, milk, honey; farmers yams, bananas, beans, etc. Sometimes paid in wooden boxes, baskets, feathers, beads, a mole (great delicacy) and labour in smith's fields.
Kikuyu (Hobley, 1922)	Fe	Some customers bring own materials and bargain for production of weapons and tools. In time spent on commissions, products made for casual sale.
Marakwet (Welbourn, 1981)	Fe	Some goods produced on demand to clients' specifications, others for market. Products distributed over very wide area.
Nandi (Huntingford, 1931)	Fe	Smiths and potters only craftsmen whose products leave Nandi. Exchanged for honey and small baskets with Doroba.
ANGOLA		
Ovimbundu (Childs, 1949)	Fe	Hoes made in special zone, and distributed in exchange for palm oil or cattle, or salt from coast.
ZAMBIA		
Gwembe Tonga (Reynolds, 1968)	Fe	Payment in cash or kind. Metal very acceptable, as scarce.

ZIMBABWE		
Balemba (Stayt, 1931)	Fe	Hoes made mainly as currency to trade with neighbouring tribes.
Balemba (Stayt, 1931)	Cu	Smith pays tribute in copper vessels and ornaments to chief, in lieu of service.
Mashona (Kuper, 1955)	Fe	Smiths paid overlords tribute of iron tools. Hoes, axes, knives etc. carried by middlemen pedlars from tribe to tribe.
INDIA		
Bihar (Sinha, 1961)	Fe, Cu	Products sold mainly at weekly markets; smiths also hawk around nearby villages. Buyers may place orders and bring iron or brass. Blacksmith usually has fixed number of clients in own and neighbouring villages. Maintains and repairs tools for fixed annual sum.
Hunza (Robins, 1953)	Fe	Each household pays annual tax to Bericho community of smiths.

Table I. .10 Change

People	Metal	Observation
SUDAN		
Dinka (Seligman et al., 1932)	Fe	Smiths used to smelt own iron. In 1910, demand far exceeded supply and scrap iron imported on grand scale.
ETHIOPIA		
Konso (Hallpike, 1968; 1972)	Fe	Before 1897, smiths owned little or no land. Taboos on eating and drinking with, and marrying into smith clan. Now many craftsmen have land, and eat and drink with cultivators, although marriage to all craftsmen is still disgraceful. Cultivators may take up crafts, but still prejudice against smithing. Smiths sometimes take up weaving when too old for heavy work. Nevertheless, craftsman/cultivator status distinction is still conferred by birth.
LIBERIA		
Kpelle (Gibbs, 1965)	Fe	Iron used to be smelted from ore; now scrap used (e.g. car springs).
IVORY COAST		
Korhogo City (Gardi, 1969)	Cu	Probably used to be impossible for outsider to buy tools, which were all consecrated. Now everyone seems to have his price.
GHANA		
Ashanti (Johnson, 1979)	Fe	Many smiths have moved into area on outskirts of Kumasi, where work as fitters. Toolmakers obtain pieces of lorry spring to forge into hoes and adzes.
Ashanti (Johnson, 1979)	Cu, Au	Brasscasters get very mixed (and often low grade) scrap. Used to depend on European brass, now local scrap. Gold weights and other traditional brassware now made for tourist trade.
Ewe (Manoukian, 1952b)	Fe	Knives, hoes and spears used to be made; craft now confined to mending and reshaping tools, and servicing bicycles.

BENIN

Dahomey (Herskovits, 1938)	Fe	Smiths do not smelt: say not done for 1000 years, since white man came to Africa. Traditional hereditary determinants of guild membership weakening.
Dahomey (Herskovits, 1938)	Cu	Popularity of Dahomean brasswork in north Africa commercially exploited by Nigeria. Export pieces lack care and feeling, while much attention lavished on own pieces which are highly prized by chiefs. In Kingdom, brassworkers controlled by King. Now no controls on time worked, articles produced, distribution or prices.

NIGERIA

Various n. tribes (Meek, 1925)	Fe	Imported bar-iron displacing locally smelted ironstone. Reduction in supply of European iron in First War keenly felt where it was relied on, as own smelting was neglected.
Various n.e. tribes (Neaher, 1964)	Cu	Commercial jewellery rapidly replacing cast brass anklets.
Afikpo Ibo (Ottenberg, 1965)	Fe	Traditionally men of certain lineages were blacksmiths, but function now taken over by tribes to north.
Afikpo Ibo (Ottenberg, 1965)	Sn, Zn	Tin smithing came with European contact. A few men make lamps and childrens' book boxes from kerosene tins and galvanised sheet zinc.
Awka Igbo (Neaher, 1976)	Fe, Cu	Obligatory fine for non-attendance at otite discontinued 30 years ago. Advance payment means smiths can spend part of 'home leave' on road again, compensating for fewer smiths as result of education (potential smiths entering other professions e.g. civil service). After Biafran War, smiths tended to stay in homeland: Awka now a "virtual beehive of workshops". Women disdain marrying a smith: status declined. Some smiths do mechanical repairs, but most still supply usual tools to locals. Bellows now automatic (bicycle wheels).
Awka Igbo (Neaher, 1976)	Fe	With advent of colonial trade, smiths abandoned locally smelted ores for imported scrap, considered to be harder and more durable.

Awka Igbo (Neaher, 1976)	Cu	Need for local industry diminished when European imports available. Elders complain of tedium, expense and difficulty of lost wax process.
Benin City (Neaher, 1976)	Cu	Brass working school at royal court (possibly formed in 14C) still exists, but now serves tourist trade.
Kano City (Jagger, 1973)	Fe	Under British rule, system of forced levies and compulsory labour abolished, and production of weapons outlawed. Maintenance of public buildings undertaken by Public Works Dept. Of 15 smith groups in 1900, 11 remain: lack of sons to continue craft; old forges demolished to make way for new buildings. Craft titles and prestige lapsed; chief smith title purely nominal. 1911-1930: gradual replacement of local ore by scrap, following arrival of railway.
Yoruba (Forde, 1951)	Cu	Cire perdue brass and bronze casting declining in importance. Brass figures now very crude.
Yoruba (Williams, 1973)	Fe	Cultural restrictions on using previously heated iron have meant that European iron has been resisted for use in tools and weapons.
UGANDA		
Baganda (Trowell, 1941)	Fe	Blacksmiths not as ready to accept industrial change as are other craftsmen (e.g. potters), because more conservative and self-complacent. Would not repair bicycles unless ordered by Kabaka. Head of smith clan (Ente) is chief smith. Today a priest, and does not work in smithy, although used to when a boy. Communication taboos are relaxing: passers-by stop at workshop to chat.
Kavirondo Bantu (Wagner, 1956)	Fe	Imported iron goods cheap, forcing down prices of local products, despite their greater durability. With less demand for native products, number of smiths and the respect they commanded fell. In south, now sharpen and repair knives and hoes. Used to smelt own iron; now only European sheet metal used.

Kigezi (White, 1969)	Fe	Imported hoes, pangas and sickles resulted in decreased demand for local products, drop in smiths' income and hence also status. An emigrated smith is not replaced. Some smiths have ceased production and taken up farming. Other professions can be entered because no restrictive mysticism.
KENYA		
Elgeyo (Massam, 1927)	Fe	Under impact of imported metal, smithing trade dying out and no longer hereditary.
Kamba of Kitui (Hobley, 1922)	Fe	Originally all smiths belonged to one clan; members of other clans now admitted to guild.
Marakwet (Welbourn, 1981)	Fe	Smiths say they used to be rich pastoralists. With imported metal and consequent drop in demand for their products, took up farming. No longer paid only in animals, but in charcoal, scrap and labour. Smithing now only in rainy season, rather than all year round.
Nandi (1: Hollis, 1909; 2: Huntingford, 1931; 3: Huntingford, 1950)	Fe	1. Smith of recent Masai origin feared and loathed; lifeway restricted. 2. Smiths not so restricted in marriage as formerly. 3. Smiths assimilated and treated with respect.
Sonjo (Gray, 1963)	Fe	As result of imported iron, now many fewer smiths. Demand for wives' pottery has remained high, leading to disparity between sexes in clan. Many men have left to work among Masai.
ZAMBIA		
Achipawa (Gunn et al, 1960)	Fe	30 years ago ore obtained from nearby hills; now European scrap used.
Gwembe Tonga (Reynolds, 1968)	Fe, Cu	Bellows nozzle formerly horn or wood; now iron pipe. Hammer formerly stone, with bark or hide handle, or unhafted iron; now European hammer. Anvil formerly heavy stone or iron hammer in wood block; now old railway line.
MALAWI		
Yao (Colson et al., 1951)	Fe	Smiths no longer smelt, but use scrap, particularly car springs.

NAMIBIA		
Naman & Namaqua (Schapera, 1930)	Fe	18C: smelted own ores and hired itinerant Herero smiths to make tools and ornaments. 19C: very little ore working, and most tools and ornaments obtained by barter. 20C: smelting disappeared. Iron wire obtained from Europeans and made into ornaments. European metal objects obtained with ease.
ZIMBABWE		
Balemba (Stayt, 1931)	Fe, Cu	Iron and bronze working, once very important, now extinct. Products superceded by European imports. Because of rarity, all old iron and copper objects are regarded as sacred, thought to possess some of former owners' personality.
Ndebelé (Hughes et al., 1955)	Fe	No longer any smelting: smiths use scrap.
SOUTH AFRICA		
Zulu (Krige, 1936)	Fe	Now practically no iron work, as iron can be imported from Europeans.
SWAZILAND		
Swazi (Marwick, 1940)	Fe	Most taboos disappeared. Thus, no women allowed in smithy (visited smith's 12 year old daughter was working on bellows); smith must work naked (visited smith wore shorts).
LESOTHO		
Basuto (Ashton, 1967)	Fe	By mid 19C, had come to depend on Zulus for main supply of weapons and hoes. Following recent introduction of European guns, ploughs, hoes, etc., metalworking practically extinct. A few smiths use hoop iron to meet diminishing demand for spears and battle axes.
INDIA		
Bihar (Sinha, 1961)	Cu	In one village, by 1958 3 of 20 original casting families in one generation survivied. Of these, only 1 still practiced. Brass less fashionable, not patronised as before. Many Bengi immigrants prefer imported gold and

		silver goods. But main reason for decline of craft is that jungles near villages exhausted, and wood for fuel would have to be bought.
Koi (Cammiade, 1931)	Fe	Smiths rapidly forgetting how to smelt.
The Meitheis (Hodson, 1908)	Fe	Iron used to be smelted and made into tools and weapons, but craft now extinct.

PART II

TECHNOLOGY AND APPROACHES TO ANALYSIS

> "The alchemists earned for the crucible, which can be defined as a pot for melting metals and chemical compounds, the impressive title of 'the cradle of experimental chemistry': but the crucible is far older than alchemy. Its origin is lost somewhere in the mists of prehistory, when man first threw away his stone axe and bone chisel and took to metal tools and arms. To do this he had first to discover how to make a pot in which he could melt metals to pour into a mould, and start the crucible on its long journey to Battersea"
>
> (Bennett, 1956, 16)

II.1 BRONZE CASTING AND THE ARCHAEOLOGICAL RECORD

Rowlands defined the categories of archaeological evidence which should ideally be available for interpretation of the bronze casting industry:

"1. The sources of raw materials and evidence of exploitation
2. The workshop areas with associated evidence of production having taken place
3. The evidence of specialist skills
4. The objects produced
5. The distribution of objects produced" (Rowlands, 1976, 116).

Data relevant to the first two of these categories were found to be virtually absent in middle bronze age contexts, and Rowlands was thus compelled to confine his study of this period to the artefacts themselves and their distribution. Until quite recently, the later bronze and early iron age periods were similarly poor in production data, and in consequence, as already observed, attention has been directed almost exclusively towards metalwork typology.

Although evidence for sources of raw materials and the mining and smelting of ores is still very scarce, careful excavations conducted during the last decade or so have yielded a considerable body of stratified production debris, principally refractory materials. It is upon these materials, never before studied in a systematic way, that I shall focus in this investigation of the later prehistoric bronze casting industry.

II.1.1 The mechanics of bronze casting

The complexities of the bronze casting process have been described in detail elsewhere (eg Coghlan, 1951, 47-73; Evans, CJ, 1976; Hodges, 1976, 69-73; McIntyre, 1953; Tylecote, 1962, 107-141). A brief summary of the essential stages will suffice here.

The metal to be cast - be it scrap, newly smelted ore, or a combination - is melted in a refractory crucible. Alloying and mixing of raw material types is achieved at this time. As bronze of utilitarian quality (12% or less of tin) remains solid until c 1000°C, melting must take place in an enclosed fire, probably assisted by forced draught. This draught may be provided by bellows and tuyères (blow-pipes). During the melting process any impurities will rise to the surface and be skimmed off as dross. The skimmed molten metal is poled (stirred), probably with a green stick, to eliminate excess oxides which would cause the casting to be brittle (Hodges, 1976, 70).

Moulds formed from suitable refractory materials may be dressed with materials such as clay dust, animal fat, wood ash or soot, to ensure clean separation of the cast artefact and prevent welding taking place if metal is used as the moulding material (see for example Coghlan, 1951, 55; 1968; Mohen, 1978). The prepared moulds are pre-heated to protect them from extremes of thermal shock, and to avoid 'piping' (casting flaws) caused by too rapid cooling of the metal as it contacts the mould face. Moulds may be set, pouring gates uppermost, in a casting trench, to receive the molten bronze (Leahy, 1977, 11).

When the moulds are ready, and the metal melted, skimmed and poled, the crucible is lifted from the fire and its contents discharged. After cooling, the cast objects are extracted from their moulds, and any excess metal (casting flashes, runners, headers) removed. The objects may then be subjected to a range of post-casting techniques executed with a variety of finishing tools. Like the casting process, these techniques have been admirably described elsewhere (eg Maryon, 1938a; 1938b ; Lowery et al, 1971).

II.1.2 Archaeological evidence for production: the potential of refractories

As bronze artefacts are produced by specialists in response to demand and are afterwards moved via direct distribution or distribution systems, it is unlikely that weapons, tools and ornaments will be found at the production site. The precise context of manufacture of virtually every bronze artefact, thus far recovered, is unknown. Furthermore, bronze has intrinsic value as a raw material, and enormous numbers of broken or redundant implements must have been remelted and recast. It has been suggested that the practice of recycling bronzes, both in the late bronze age and afterwards (when even undamaged implements would have had no value other than as raw material) may well be the most significant factor in distorting recovery rates of finished objects (Needham, 1981, 40; fig II.1.1). Although distribution patterns may be described, it is difficult from the evidence of extant bronzes alone, to relate these to rates of production, centres of manufacture and metalworking organisation.

Hoards of scrap implements, apparently destined for the melting pot, may be more informative. Studies of late bronze age hoards have generally focussed on the typology and chronology of the implements involved, and little attempt has been made to consider large caches of metal in the light of contemporary industrial organisation (eg Coombs, 1975; papers in Burgess and Coombs, 1979; Savory, 1976). Recently, the emphasis has shifted from typology to the reasons for hoard deposition, and new theories have been proposed (Bradley, 1982; Burgess, 1979; Kristiansen, 1981; Muckelroy, 1980). Barrett and Bradley have suggested that the accumulation and deposition of bronze may take place at various points within the production-distribution system. Scrap may be hoarded by individual smiths prior to recasting; finished or part-finished implements may be stored for future exchange; long distance exchange systems, outside the control of the smith, may result in the accumulation of large quantities of scrap and ingot metal (Barrett and Bradley, 1980a, 260). Quantified analyses of hoard weights and compositions urged by Barrett and Bradley, and detailed assessments of depositional contexts and associations, are presently in progress (Robin Taylor, University of Reading; Roger Thomas, University of Cambridge). It is hoped that the results of this work will help to clarify why, and at what stages, large quantities of metal objects were buried in the ground during the late bronze age.

Most relevant to the study of production are those hoards containing part-finished implements, scrap material obviously intended for recycling, ingot metal, casting waste and/or bronze moulds. These have been interpreted either as the original property of a smith (eg Childe, 1930, 45) or as the stock-in-trade of a middleman or merchant

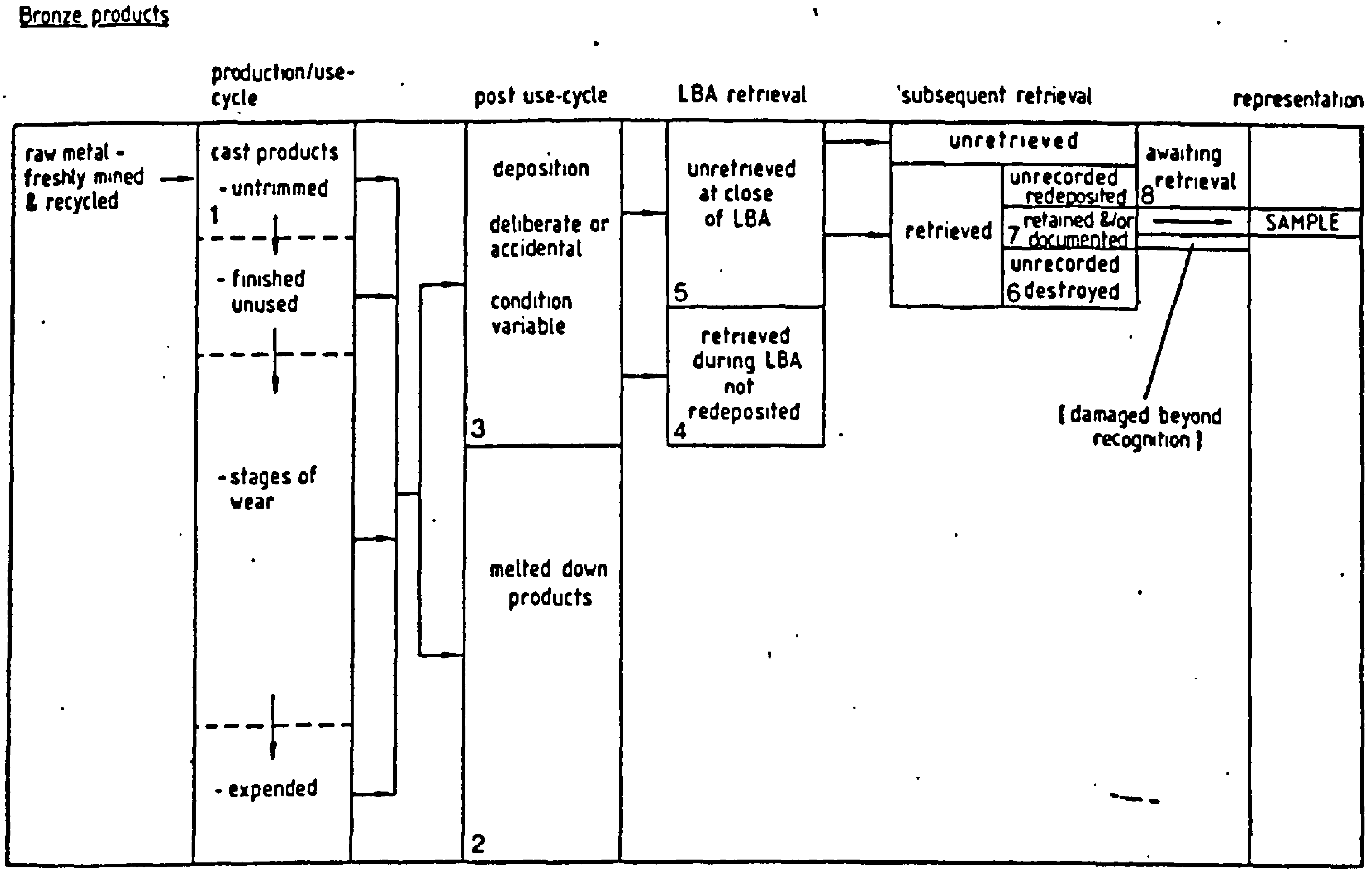


Fig II.1.1 Diagrammatic representation of factors affecting the deposition, survival and retrieval of bronze artefacts (after Needham, 1981) operating within a complex exchange system (eg Rowlands, 1976, 167). The implications of individual bronze hoards for the organisation of metalworking will vary according to which of these interpretations is accepted. Whilst many hoards may indeed represent merchants' stocks, it is here proposed that those hoards containing moulds and/or casting debris belonged to a bronze founder or founder group. It would make little economic sense for a smith to dispose of his own raw material (a bronze mould at the end of its useful life may be regarded as a metal ingot) in other than finished form.

Of all artefacts of bronze which occur in the archaeological record, bronze moulds provide the best evidence for production organisation. Analyses of their composition can yield a measure of technological information (eg Brown and Blin-Stoyle, 1959; Green, 1973); the objects cast may be identified, and the presence of bronze moulds *in situ* denotes the presence of a smith. However, because of their intrinsic value, bronze moulds will be carefully curated prior to recasting, and will not be discarded. The only likely circumstance in which a metal mould will be found, is when damage, excessive wear or changes in the smith's casting needs result in one or both valves being consigned to a hoard of scrap which is buried and never recovered. Such caches may be accumulated in the smith's workshop, his house or at an appropriate point on an itinerant circuit. Bronze moulds do not identify production loci so much as the smith's choice of site for hoarding.

Moulds of stone, on the other hand, when broken or of no further use have limited value as potential raw material and will therefore be discarded. No smith is likely to clutter his workshop or burden his pack with worn out equipment. As stone moulds are portable and reusable, they may be broken in transit, but more often discard will take place at the casting site where breakage or redundancy occurs. Wherever found, moulds of stone, like those of bronze, indicate the activity of a smith, and the objects cast can usually be identified. However, stone moulds are potentially more informative than their bronze counterparts. Firstly, they are likely to be found on production sites, and secondly, petrological analysis may define the source of raw materials from which they are carved. This latter can have important implications for the movement of bronze founders (Part IV, below).

Refractories of clay have no value outside their useful life in the casting process other than as possible tempering material for future production (Ch II.2, below). With the exception of re-usable crucibles and tuyères, which are portable and thus susceptible to breakage in transit, the bulk of clay refractories will invariably be discarded where they are used. Crucibles and tuyères with settlement associations, and all clay moulds and furnaces, thus denote not only the presence of a smith, but also his production site.

Furnaces of clay are constructed *in situ* and are abandoned or demolished when of no further use. Clay moulds are complex and fragile and will therefore (and this is confirmed in the ethnographic record: Table II.2.1) be modelled at or in close proximity to the casting site. *Cire perdue* mould is obviously not reusable. Similarly, a clay bivalve mould is likely to be broken during removal from the casting. Thus both will be discarded where they are made and used. Crucibles and tuyères found on or near settlement sites are likely to have been employed in bronzeworking at those sites; crucibles and tuyères without settlement associations may, like errant stone moulds, indicate the peregrinations of a travelling smith.

Whereas metal analyses can determine the composition of artefacts of bronze, and petrology can often characterise the source of stone used for mould production, the study of ceramic refractories can yield a wider range of technological and organisational information. Raw material preparation methods, and manufacturing techniques may be inferred from physical examination of the artefacts concerned. Mineralogical composition can be determined for each artefact type represented at a casting site, and assessed in the light of available resources and technological constraints governing production (Ch II.2). Relationships may be defined between refractory fabrics, implements cast, and individual casting episodes. Different refractory assemblages may be compared to investigate spatial and chronological variation in technology and raw material exploitation patterns.

II.1.3 The casting process and industrial organisation

> "The outcome of this art is dependent upon and subject to many operations which, if they are not all carried out with great care and diligence and well observed throughout, convert the whole thing into nothing, and the result becomes like its name - cast away" (Biringuccio, 211: Smith and Gnudi, 1959).

Unlike those aspects of industrial organisation examined in earlier chapters (pattern of work, raw material supply etc), the preparation of essential refractory equipment (moulds, crucibles, furnaces, tuyères) and the casting process itself are rigidly controlled by technological constraints. The smith must operate within these constraints, otherwise his work will fail.

The mechanics of the casting process remain invariable, irrespective of time or place. A modern founder, producing bronze statuettes for the tourist industry, must follow the same basic work routine as did his prehistoric ancestors. However, some flexibility is possible - within a technologically defined range - in the manufacture of casting equipment. Provided each item of equipment is functionally efficient, variations in form and/or material selection and preparation are allowable. Modes of formal and /or material variation will reflect:

1. The smith's physical environment and his skill in exploiting this environment
2. Social factors corresponding to those governing other aspects of industrial organisation.

Therefore, to understand production evidence, it follows that the technological constraints governing the manufacture of casting equipment must first be examined, and then the modes of variation within these constraints assessed and described. Here again, evidence from other places and other periods serves as a guide to the range of variation which might be anticipated in archaeological contexts.

II.2 TECHNOLOGICAL CONSTRAINTS, REFRACTORY FORMULAE AND METHODS OF PRODUCTION

In technology, the term 'refractory' refers both to the resistance of a material to the action of heat irrespective of accompanying conditions, and to the behaviour of the material under conditions of use. Refractoriness cannot be expressed in terms of temperature alone.

Materials intended for the production of such items as furnaces, moulds and crucibles should ideally conform to all of the following specifications (from Percy, 1861; Searle, 1924):

1. be able to withstand the temperatures and sudden changes in temperature to which they are likely to be exposed in use
2. be resistant to pressure, vibration and accidental blows
3. be resistant to slag attack when the charge comes into direct contact with the refractory material
4. be resistant to the effect of flames, fuel and gases exuded therefrom
5. expand or contract uniformly within conveniently narrow limits.

Additionally, when compounded materials are used in refractory production, the amalgam must be sufficiently plastic to allow the desired shapes to be formed. Few, if any refractory compositions conform to all these specifications, and the user must decide which he should stress and which forego to suit his particular purposes (Searle, 1924, 2).

In modern industrial literature, refractory products are generally classified according to their refractoriness - chimicomineralogical composition and method of manufacture (Kingery et al, 1976, 540). Some aspects of refractoriness can be measured by a series of physical tests which determine porosity, softening point, rate of vitrification and changes in volume (see for example Ennos and Scott, 1924, 51-53; Hill, 1974; Mellor, 1918, 300; Searle, 1924, 643-62). Factors such as corrosion, abrasion and durability can only be ascertained by observing refractory products in use. So much depends on the conditions to which they are exposed. The composition of a given refractory item can be determined by chemical and physical methods including wet chemical, petrological and particle size analysis. Techniques of manufacture vary according to the materials involved, and can be assessed through physical observation and experimentation. The testing and analysis of refractory products will be discussed in Ch II.3.

II.2.1 Crucibles

> "They increase the work if they are not good, and often cause great extra expense as well as necessitating repetition of the work. If they are good, they save everything" (Biringuccio, 391: Smith and Gnudi, 1959).

Good crucibles have been described as among the most difficult of clay artefacts to manufacture, owing to the severe conditions to which they are subjected. Although simply made, crucibles demand an exceptionally high degree of skill in the selection and preparation of suitable raw materials (Searle, 1924, 467). The technological requirements for crucible production are timeless and universal, and may be summarised as follows (from Percy, 1861, 217; Searle, 1924, 467; Singer and Singer, 1963, 1277):

1. sufficient heat resistance to withstand any temperature to which the vessels are likely to be exposed without fusing or softening
2. resistance to thermal shock including that sustained during rapid cooling from furnace to pouring temperature
3. sufficient density to prevent loss of contents by absorption
4. resistance to the corrosive attack of the charge
5. resistance to corrosion by ashes and fuel gases
6. sufficient strength not to crumble or break whilst being moved or carried full of molten metal.

In recent times, refractory materials have been the subject of extensive research, and the characteristics and efficiency of varied combinations of binders and fillers have been assessed. No attempt will be made here to describe all the recipes which have proved successful in crucible production. It is, however, useful at this stage to outline some general principles relative to the selection and preparation of raw materials to meet the above requirements.

Recent and contemporary writers are in agreement that crucibles should be formed from a mixture of clay and other substances. Percy advocates the addition of one third part by volume of variable sized particles of grog (derived from cleaned, used crucibles or glass pots) to a well-weathered and -ground fireclay (Percy, 1861, 217). Searle stresses that clays selected for crucible manufacture must possess strong binding properties in order to unite as great a proportion as possible of non-plastic ingredients. These he lists as: grog, to provide resistance to heat and thermal shock; felspar, to increase density at the moderate temperatures of copper alloy working, and thus prevent metal wastage by absorption; free silica or quartz, to provide mechanical strength and decrease sensitivity to sudden temperature changes (Searle, 1924, 478). Carbonaceous materials (for example, coke dust, blacklead, plumbago or graphite) are described in modern industrial literature as first having been introduced into crucibles some three hundred years ago, although extensive use did not commence until the early 19th century. These materials were found to improve thermal conductivity and increase resistance to cracking, and are now the chief constituents of crucible manufacture (Dixon, 1964, 474; Bennett, 1956, 18).

Classical, medieval and modern texts indicate that despite differences in form and manufacturing techniques, and minor variations in materials selected, the basic principles of crucible production have changed but little through the ages. All writers stress the careful selection and preparation of binding clays and fillers. Pliny stipulates the use of tasconium, a white, earth-like potter's clay, for the manufacture of metal-melting pots, this, he claims, being the only substance "which can endure the combined efforts of the blast, the heat of the fire and the glowing charge of the crucible" (Pliny, 33, 69: Rackham, 1969). Early medieval writers, whilst emphasising the procurement of suitable quality clays, also describe the addition of fillers to increase refractory properties.

> "Take fragments of old vases, in which cooper or brass has been before fused, and break them small upon a stone. Then take the earth of which pots are made, of which kinds there are two, one white, another grey; of these the white is useful for colouring gold, but the other for composing these vases; and when you have ground it together very finely you mix this crude earth with the other ... so that two parts may be crude and three burnt, and placing them together in a large vase, pour warm water over them, and beat strongly with mallets and the hands until it has become quite tenacious" (Theophilus 3.15: Hendrie, 1847).

Small 'vases' are formed by hand from this mixture and dried beside the fire prior to use.

> "It is first necessary to have the clay of good nature, that is resistant to the force of the fire by its own natural virtue ... This should be well freed from small stones and beaten well with an iron, and then thoroughly mixed by hand. With this should be mixed some young ram's horn ashes ... If this clay should not be strong enough by itself, it is mixed with another lean clay, with crushed peperino, flintstone, or some other stone that in your judgement seems to be arid and resistant" (Biringuccio, 391: Smith and Gnudi, 1959).

The crucibles, both large and small, are formed on a hand-turned wheel, and most are provided with a triangular mouth for easy pouring. They are well dried and fired as pottery.

> "... assayers themselves make scorifiers and triangular crucibles out of fatty [plastic] clay ... With this clay they mix the dust of old broken crucibles, or of burnt and worn bricks; then they knead and pestle the clay thus mixed with dust and dry it. As to these crucibles, the older they are, the dryer and better they are" (Agricola, 7: Hoover and Hoover, 1950).

The vessels are moulded in circular, bottomless brass moulds, and presumably finished by hand.

During the later medieval period, cast iron melting pots lined with clay appear to have replaced clay and grog crucibles in the production of church bells and cannons (Elphick, 1970; Ffoulkes, 1937). After the time of Agricola, the texts are silent on the making of crucibles for small-scale bronzework. Refractory vessels used in the glassworking industry, however, are subject to similar constraints to those employed for the melting of metal, and these have been described in some detail. During the 16th and 17th centuries, glass factories were built throughout Britain in areas where cheap fuel and/or superior glass sands were available (Charleston, 1961; Godfrey, 1975; Kenyon, 1967).

However, 'pot' production was often a serious problem. High quality fire-clays were either not locally available, or not known and trusted by the glassworkers. In consequence, clays were often imported at great expense over considerable distances (Marson, 1918, 36; Godfrey, 1975, 143; Kenyon, 1967, 41; Winbolt, 1933, 53).

Recipes for glass pots vary from area to area in the number of different clays used, and in the type and proportion of filler. Proportions depend in the main on the plastic qualities of the binding clay. Phillips (1941) simply advocates 40% plastic fire-clay with 60% burnt, ground and screened fire-clay as filler, whilst Marson (1918, 61) suggests the following complex formula:

Base: fine ground strong fire-clay - 5 parts by volume (pbv)

Binder: fine ground mild fire-clay (very plastic) - 4 pbv

Grog: ground burnt fire-clay - 2 pbv

ground potsherds (old cleaned glass pots) - ½ pbv.

All American glass pots used to be made from imported German clays, but when supplies were interrupted by the first world war a substitute had to be sought. After much experimenting, it was found that a blend of three American clays not only satisfactorily replaced the expensive German material, but in fact produced a better result (Grafton, 1920, 653). Similarly in the early glassworking industry at Jamestown, Virginia, melting pots were for some time imported from Britain until suitable local materials were accepted (Harrington, 1952, 37).

In recent times, three principle types of crucible have been used in fine copper and rare metal working. London crucibles are especially resistant to corrosion and thermal shock. The normal composition is three parts fire-clay to one of grog, although some makers substitute a Devonshire ball-clay for part or all of the fire-clay, and use a higher proportion of grog (Searle, 1924, 467; Percy, 1861, 222). Cornish crucibles are prefired to a high temperature to minimise thermal shock, are open textured and thus often discarded after a single use to prevent contamination by the residues of previous melts. They are made from one part Teignmouth clay, one part Poole clay (both ball-clays) and two parts refractory sand from St Agnes Beacon (Searle, 1924, 469; Singer and Singer, 1963, 1277). For small, less refractory crucibles, 1/8 part of St Austell china clay in sometimes included (Percy, 1861, 227). Hessian crucibles are most often used in gold and silver working, and can serve for up to three melts. Four to five parts of sand is bound with two parts of siliceous clay (Searle, 1924, 468; Singer and Singer, 1963, 1277).

Unfortunately, descriptions of crucible production and use are rare in the ethnographic record. Detailed accounts of mould making are often followed by simple allusion to 'clay cups' or 'clay crucibles' for copper and brass melting (eg Grigson, 1938; Rattray, 1923; Talbot, 1926, 923-28). The limited information that is available, however, reveals a range of solutions to the same technological problem. The Bayeke (Congo) use as a crucible the base of a broken 'porcelain' vase. This is very carefully lined with wood ash before being charged with broken copper and placed among the charcoal near the top of the furnace. After 20 to 30 minutes when the metal has become molten, the crucible is removed without the aid of tongs, the master founder protecting his hands with tow or wet rags (de Hemptinne, 1926). The Bambara (Sudan) smith first mixes a quantity of finely ground charcoal with damp red clay. He next adds a certain proportion of chopped straw and works the whole with his hands until it is well combined. From this paste he forms a round based crucible, 6 to 7mm thick, which he fires - presumably after pre-drying - for five minutes in the forge hearth. It is immediately filled with copper for melting and returned to the fire (Zeltner, 1915). Available fire-clays in the Kyotot and Osaka districts of Japan are derived from the granite and are not particularly refractory. Late 19th century Japanese brass casters overcame this problem by first forming a thin, inner crucible from porcelain, then enclosing this in an outer vessel of granitic clay. This ingenious method involved minimal expenditure on porcelain clay (an extremely costly commodity) and prevented loss of metal through the use of poor quality refractories (Gowland, 1899, 22).

II.2.2 Moulds

> "Good earths are neither unctuous nor lean, neither wholly tender or rough, and with a grain that is fine without pebbles or shells, when applied to a work they easily dry out without fractures, and when dry, hold their own shape well. Above all they must resist the fire well" (Biringuccio, 1540, On the requisite quality of clay for making moulds for casting in bronze: Smith and Gnudi, 1959).

> "The founders ought to take particular care of the baking ... as well as the internal cleanliness of the pieces, that is why it is extremely important to choose the best materials and to take care that the loam of the moulds should be good, well broken and puddled correctly with hair and batter so that the gun mould and core are good ... well baked and re-baked and well placed so that the trunnions are put so correctly that the piece is neatly balanced" (Gaya, 1678, Traité des armes et des machines de guerre: Ffoulkes, 1911).

Although bronze casting moulds are not exposed to long periods of intense heat, and are not subject to slag attack or corrosion from furnace gases, they must nonetheless be capable of withstanding thermal shock sustained when molten metal is introduced. They, like crucibles, must thus be formed from highly refractory materials. Additionally, moulds must be permeable to allow the escape of gases which would otherwise spoil the casting; yet the casting surface itself must be sufficiently dense to produce a true image and act as a barrier against metal penetration. Mould making thus demands an exceptionally high degree of skill, both in the selection and preparation of raw materials, and in the forming of the casting matrix.

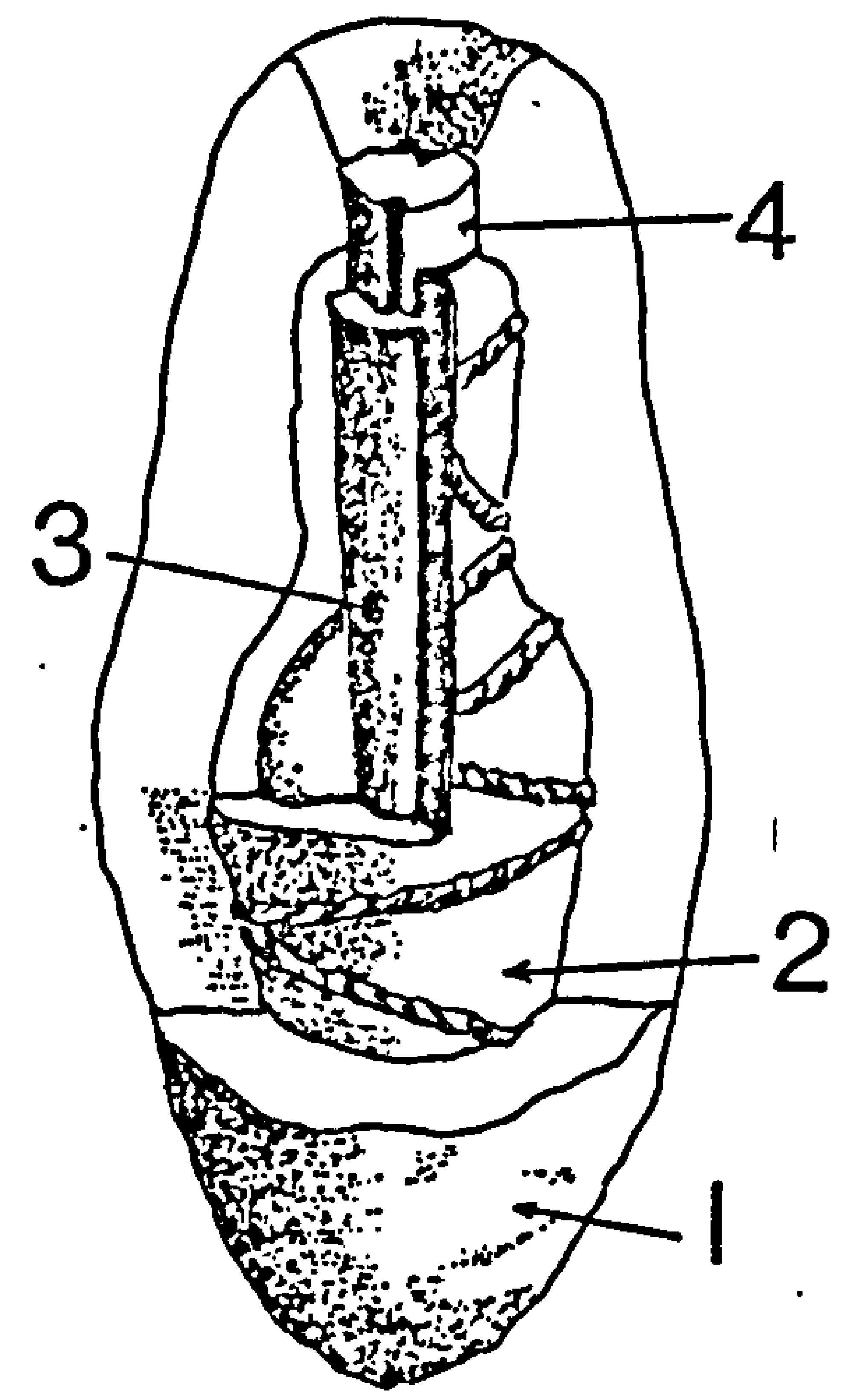
Just as we find no equivalent for the bronze age smith, so we may search in vain for parallels for his non-ceramic mould technology. The skilfully produced moulds in stone and bronze, well known in archaeological contexts, have nowhere been replicated since man became functionally dependent upon iron. The manufacture and use of these moulds can only be understood through examination of the archaeological artefacts themselves. Other than the recognition that the same technological constraints govern all mould making, no direct guidance to stone and bronze mould production may be found in historical, ethnographic or modern texts.

Since the beginning of ironworking, with rare and irrelevant exceptions (eg the modern electronics industry), all copper alloy artefacts have been cast in ceramic moulds, and much has been written on the subject of moulding clays and sands for both industrial and artistic application. Furthermore, of all refractory items, with the possible exception of iron smelting furnaces, moulds have received the most detailed scrutiny from ethnographers interested in metalworking technology. There thus exists a wealth of documentary information to assist in the interpretation of late bronze age two-piece clay moulds, and the debris of iron age cire perdue casting.

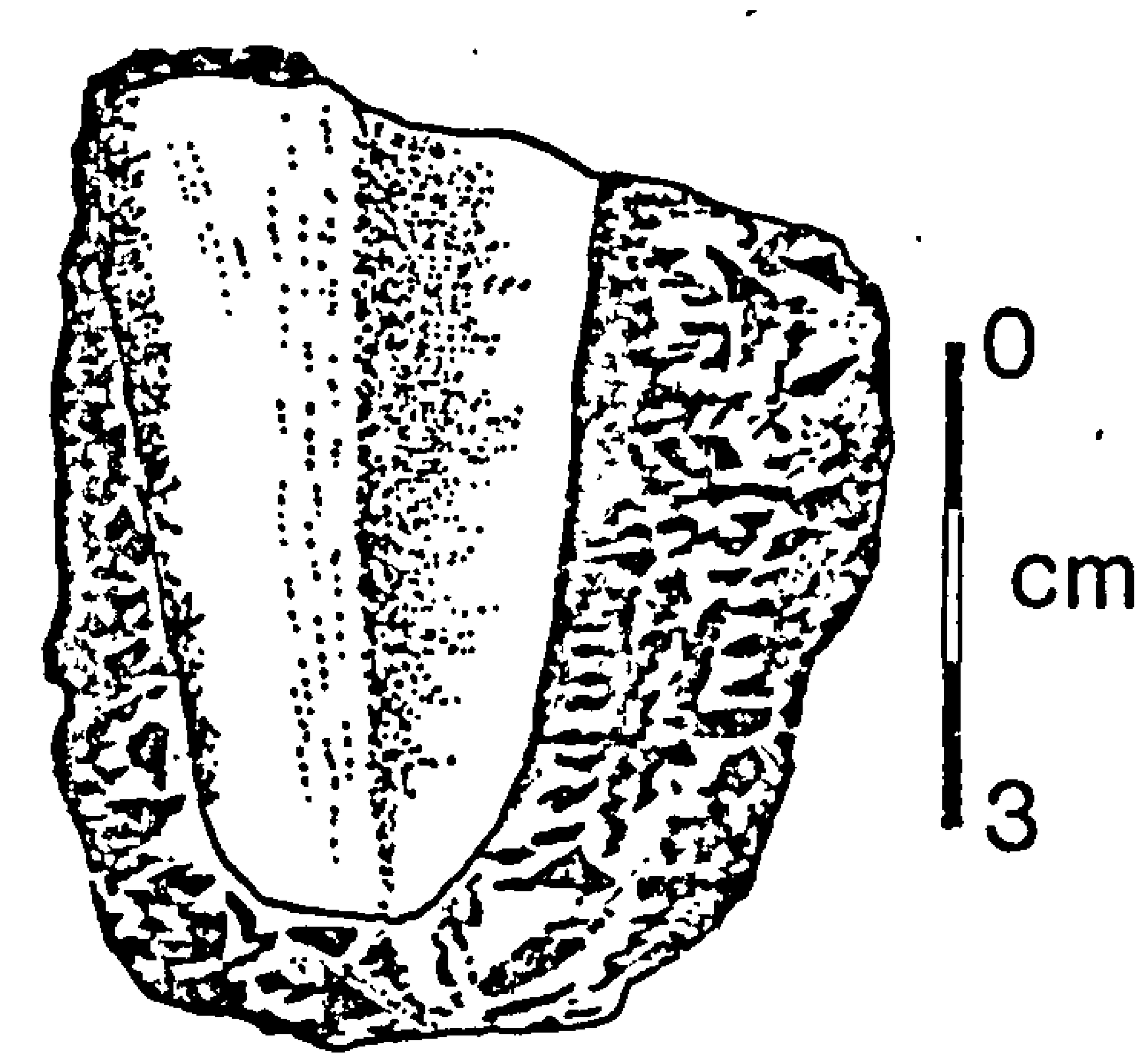
The essential components of a simple two piece-mould are the inner valves and the outer wrap. When a hollow casting is desired, a core, located by chaplets or trunnions, is a necessary third component (fig II.2.1). Cire perdue casting may be seen as a sophisticated development of the bivalve mould system. Here, if a large item is to be cast, a core of appropriate shape is prepared from tempered clay and allowed to dry. The exact form to be cast is modelled in wax over this core (as a general rule, cores are not used in the production of small artefacts; instead, the model is shaped entirely from wax). Next an inner mould of fine and an outer mould of porous clay are added in layers and dried. At the same time a gate or aperture is formed to allow the wax to be extruded and the molten metal introduced (fig II.2.2).

The efficiency of ceramic moulding materials for both bivalve and cire perdue casting depends on refractoriness, permeability and the bonding strength of the clays (Adams, 1926). In modern mould manufacture sand, or a mixture of sands, frequently serves as the filler, and a ratio of 25% clay to 75% sand is generally recommended (Trainer, 1926, 357). Rounded sand grains give the most satisfactory results (Boswell, 1918, 6; Thomas, 1926, 362; Old, 1972, 2). Although most foundries producing large numbers of castings now use artificially bonded and sometimes synthetic sands, naturally bonded sand is still preferred for moulds made by hand (Blunden, 1975, 294; Boswell, 1918, 6; Old, 1972, 1).

Cores for large scale cire perdue work and for hollow casting in two piece moulds must be highly permeable to allow the escape of gases, and sufficiently friable when fired to allow for easy removal. This may be achieved by mixing sand with a very small proportion of binder, or combining organic materials such as sawdust with a plastic fire-clay. An extremely fine clay compound, sometimes in liquid form, is prepared for the first investment (inner mould layer) in cire perdue, and for the inner matrices of bivalve moulds. Modern sculptors often use a material called dental investment for this stage of the work (Jackson, 1973a, 25). Outer mould, applied when the inner is dry, consists of rougher materials, which in contrast to the core mixture, must be neither fragile nor

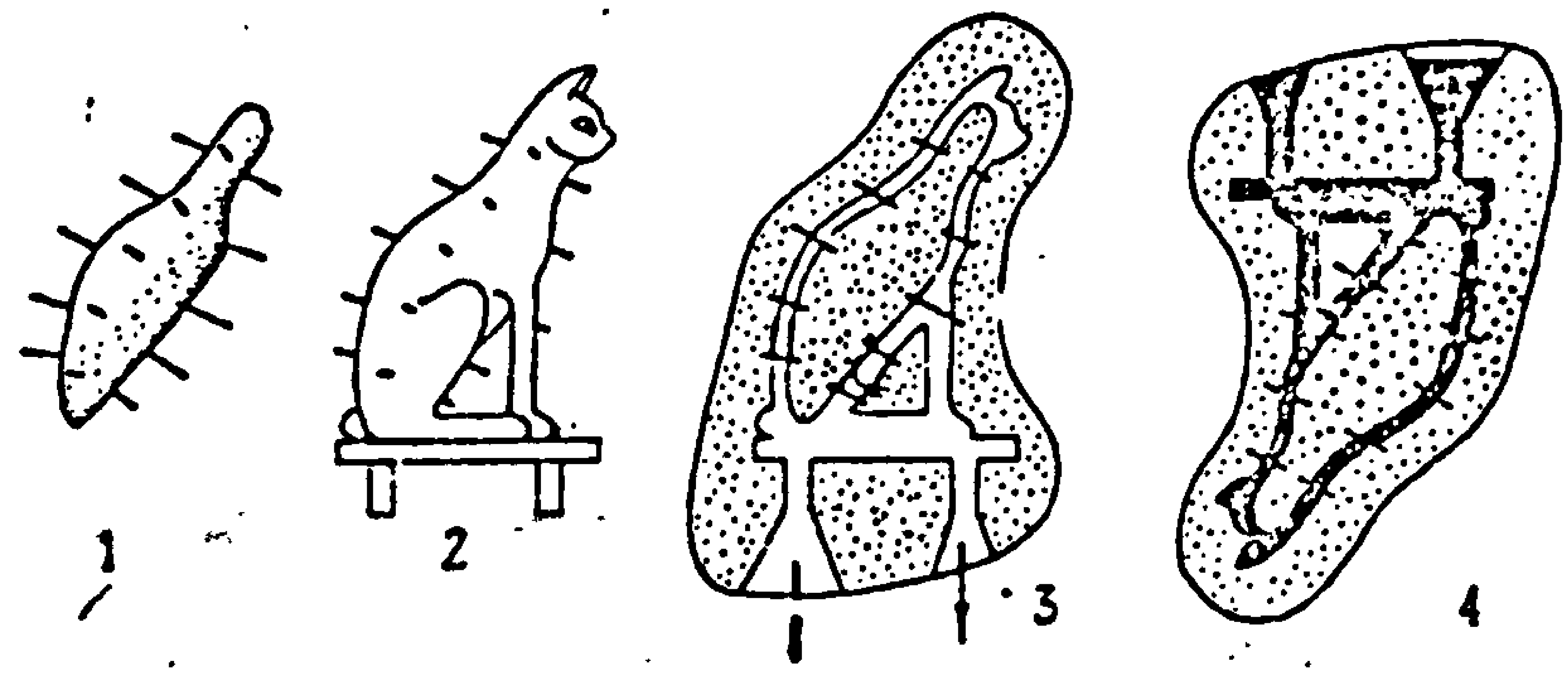


Schematic representation of the various parts of a spearhead casting mould. (1) Outer casing of coarse clay, pressed round the inner mould to support the core and to prevent the escape of metal from the joints; (2) Inner mould of fine clay in two halves, bound together by a fibrous thong; (3) Spearhead of bronze, as it would appear on breaking open the mould; (4) Clay core, when removed, leaves a socket for the spear shaft (after Sheppard 1930). A core was found at Fimber, and seems to be made from the same clay as the inner mould halves.



The tip of a spearhead mould from Fimber, showing the igneous tempered outer wrap adhering to the finely prepared inner sheath (after Sheppard 1930).

Fig II.2.1 Bivalve casting, illustrated by remains from Fimber (see Ch III.3).



LOST WAX CASTING. CLAY CORE WITH PROTRUDING CHAPLETS (1). OVER THIS IS MODELLED THE WAX FIGURE (2). THIS IS INVESTED WITH CLAY AND THEN HEATED TO REMOVE THE WAX (3) AND FIRED. BRONZE IS CAST INTO THE SPACE OCCUPIED ORIGINALLY BY THE WAX (4). HEADERS AND CHAPLETS ARE LATER REMOVED.

Fig II.2.2 Cire perdue casting (after Hodges, 1976).

collapsible when fired. Ground used mould has been recommended as an additive for outer, investment clays (Jackson, 1973b, 23).

In preindustrial societies, the technological constraints governing ceramic mould manufacture were acknowledged, and met in a variety of ways. Early medieval writers, principally describing the bell and gunfounding industries, stress the selection of binding clays, and discuss the merits of various fillers. Kritoboulos provides the following account of the gunfounding which preceded the 1453 siege of Constantinople by Mohammed II.

> "They take a quantity of very fat clay, the purest and the lightest possible, which they make plastic by kneading it for several days. The mass is knit together and prevented from breaking by the admixture of linen, hemp and other shreds, and the whole worked up and well mixed in such a manner as to make one tough and compact mass. Then they make a long cylinder '*en forme de flute*', very long to be the mandrel or core of the shape" (Ffoulkes, 1937, 13).

To ensure mould permeability, Biringuccio (Smith and Gnudi, 1959) advocates the addition of two thirds by volume of wool clippings to a carefully chosen and tested plastic clay. If no wool clippings are available, he suggests the clay might be mixed with various earths, wash ashes, coarse sand, crushed brick, wool cardings or hairs from the tanneries. The latter two are not recommended for thin bronze, on account of their excessive length.

Instructions set out by Theophilus for the founding of bells, do not specify the nature of clays and fillers to be employed. However the careful preparation of materials and the urgent necessity to ensure that the whole work is dry before proceeding to the next stage, are stressed throughout (Theophilus 3.85: Hendrie, 1847). The dire consequences of attempting to introduce molten bronze into a damp mould have been recorded. In May, 1716 preparations were being made for the casting of large guns from the melted down trophies from Marlborough's campaigns:

> "... about eleven o'clock at night the metal being ready was let go ... the burning metal no sooner sank down to the bottom of the mould, but with a noise and force equal to that of gunpowder it came pouring up again blowing like the mouth of a volcano or a little Vesuvius. There was in the place about 20 men as well as workmen and spectators, seventeen of whom were so burnt that nothing more horrible could be thought of, neither can words describe their misery. About nine of the seventeen are already dead, the other eight are still living, but in such a condition that the surgeons say they have very small hopes of above two of them" (Ffoulkes, 1937, 55).

From selected descriptions of mould making in ethnographic and historical contexts (Table II.2.1), it is clear that copper alloy casters everywhere take particular care in the selection and preparation of their raw materials, and that moulds of all sizes are thoroughly dried at each stage of production. Variations in materials chosen, methods of manufacture and casting technology, once again illustrate the range of means by which individual bronze casters may achieve the same result.

II.2.3 Furnaces and tuyères

> "Although all masters have the same objective, each one proceeds to make his kind of furnace according to his own ideas so that it can be said that there are almost as many shapes of such furnaces as there are masters" (Biringuccio, 7.1: Smith and Gnudi, 1959).

Any furnace intended for the melting of metals must be so designed that the melting temperature of the metal concerned may be reached with ease. To achieve the minimum melting temperature of a serviceable copper

TABLE II.2.1 MOULD MATERIALS AND PREPARATION IN ETHNOGRAPHIC AND HISTORICAL CONTEXTS

People	Materials	Preparation methods
SUDAN		
Bambara (Zeltner, 1915)	Ingot mould: sun dried brick	Semi-cylindrical hollow cut in brick, whilst metal melts. Brick warmed before fire. A little karité tree butter added, which melts and impregnates the brick.
GHANA		
Ashanti (Rattray, 1923; Roth, 1968)	Core (used in hollow casting but not for gold weights): "special clay" Model: beeswax Inner mould layers: fine clay slip, sometimes mixed with up to 2/3 by volume powdered charcoal Outer mould layers: coarser clay mixed with palm-nut fibre or silk threads	1. Core formed and exact replica of item required modelled in beeswax over core 2. Model coated with several layers of fine clay slip (sometimes with added charcoal) and allowed to dry 3. The whole now covered with outer mould mixture, and allowed to dry 4. Mould heated to allow wax to run out 5. Smith takes small crucible (materials not stipulated) containing pieces of brass rod, and inverts over mould. The two components are luted together with clay, and the whole is thoroughly dried.
BENIN		
Dahomey (Herskovits, 1938)	Core: sand bound with small amounts of clay Model: beeswax Mould and pouring gate: "heavy clay"	No details provided.
NIGERIA		
Baoulé (Cline, 1937)	Model: "wax" Inner mould: pulverised clay and wood ashes Outer mould: clay mixed with palm fibre	Inner material applied to wax model with chicken feather, and thoroughly dried between successive coats. Complete mould sun dried for ten days.

TABLE II.2.1 (continued)

Bauchi (Meek, 1925)	Ingot mould: clay with ashes	Ashes rubbed into still damp surface.
Benin City (Dark, 1973)	Inner mould: very fine clay slip Outer mould: clay with a "certain amount" of carbon and grog	No details provided.
Gude (Neher, 1964)	Model: "wax" Mould: carefully pounded and mixed red termite mound clay, and donkey dung	Mould dried, heated, and wax allowed to escape through cracks in mould which are subsequently plastered.
Nupe (Meek, 1925)	Ingot mould: stone	No details provided.
Isoko (Peek, 1980)	Mould: sand clay, ekpe, or mud clay, ovie	No details provided (oral historical account).
CAMEROON		
Bagem (Malcolm, 1923)	Core: clay containing a certain proportion of kaolin, mixed with grass Outer mould: clay mixed with grass	Integral crucible added to dried mould. Often removed from fire during metal melting for more clay to be applied.
CONGO		
Various tribes (Dark, 1973)	Core: soft, spongy wood	Core burnt out in pre-heating stage.
Bayeke (de Hemptinne, 1926)	Ingot mould: termite mound clay, coated with wood ash	Mould prepared while copper is melting. Dried in fire.
Garanganze (Cline, 1937)	Ingot mould: natural sand beside furnace	Formed in shape of Maltese cross, with smith's fingers, whilst copper is melting.

TABLE II.2.1 (continued)

INDIA		
C India (Grigson, 1938)	Core (mati-kutan): white ant-hill clay mixed with plain water Model (main-kutan): "wax" Inner mould layers: white ant-hill clay and plain water Outer mould layers: ant-hill clay with water in which certain leaves and grasses have been cooked	1. Core sun dried then covered with wax 2. Inner mould material applied in layers, leaving aperture to drain wax 3. Mould dried then heated to remove wax 4. Outer mould layers applied and thoroughly dried before use.
Bihar (Sinha, 1961)	Core: red, sticky clay with fine sand, powdered chaff, bits of flax and fine bits of cloth Model: "wax" Inner mould layers: levigated red, sticky clay without filler Outer mould layer 1: red clay with cow dung Outer mould layer 2: red clay with flax	All layers carefully dried before additional material applied.
THAILAND		
Various areas (Newman, 1977)	Mould: clay with chopped bamboo, charcoal, grog and water	Powdered charcoal used as mould dressing.
JAPAN		
Late 19th century Osaka and Kyoto (Gowland, 1899)	Core: long weathered clay with rice husks and ground firebricks Core face: clay with fine sand Model: vegetable wax or beeswax or conifer resin Inner mould layers: fine clay, sometimes mixed with powdered porcelain Outer mould layers: coarse clay with rice husks	Clay weathered for months or even years. Proportions of temper vary according to size of objects cast. Cores built on bamboo strip. Porcelain added to inner mould to prevent fusion. Mould dried between layers in warm part of foundry, and finally baked in carefully regulated charcoal fire, prior to use.

TABLE II.2.1 (concluded)

ENGLAND		
18th century gunfounders (Jackson and de Beer, 1973)	Core: well blended homogeneous clay, with horse dung and sometimes wood shavings. Equal proportions of clay and temper Inner mould layers: finely pulverised refractory clay, silica sand and water Outer mould layers: clay with wool clippings (following Biringuccio recipe)	Mould clay worked with choppers to ensure perfect blending. Inner mould layers carefully applied to fill all details on model. Biringuccio's instructions followed for forming and drying between layers.
19th century bellfounders (Walters, 1912)	Core: foundation of clay bricks, covered with fine, soft clay mixed with calves' hair Inner mould layers: "finest clay" Outer mould layers: coarser clay with hair and hay	Each layer dried and greased before next addition.

alloy (approximately 1000°C) some form of closed structure is necessary. Although natural draught may be exploited, this is unreliable, and provision for forced air assistance is generally required.

Biringuccio stresses the need for careful furnace design, and in addition, states three principle 'precautions' which should be observed when bronze melting facilities are constructed:

> "The first is that you make the furnace of bricks or stones that resist the fire, if not the entire furnace, at least that part exposed to the fire ... The second precaution is that if the furnace is new, it must be thoroughly baked with charcoal and wood before you put in the bronze, especially the bottom ... The third is that you take care when the bottom is baked to repair any crack that might have formed in it ..." (Biringuccio, 7.1: Smith and Gnudi, 1959).

These instructions were later reiterated by Agricola, who provides a lengthy description of raw material preparation, furnace construction, prefiring and repairing (Agricola, 9: Hoover and Hoover, 1950; fig II.2.2). Although both authorities were referring to the building of durable furnaces, similar rules apply to temporary structures. Whatever the number of melts intended, all furnaces must be strong enough to resist high temperatures. Refractory strength is achieved through the raw materials chosen and through careful drying before use.

Beyond these basic constraints, however, the care taken in design and construction will vary according to the desired life-span of the furnace. The furnace intended for a single melting episode need not be so painstakingly constructed as that designed for repeated use. As all modern foundry furnaces fall into the latter category, and most are constructed from high temperature compounds which would not have been available in prehistory, the economic literature is of little direct value here. Turning to the ethnographic record for descriptions of the construction of single and multiple use facilities, one is confronted with further problems. The processes involved in iron and copper smelting are often related in detail, and the <u>shape</u> of furnaces is described in many accounts, but little note is generally taken of the <u>methods</u>, and particularly <u>materials</u> used in furnace building.

A—SCREEN. B—POLES. C—SHOVEL. D—TWO-WHEELED CART. E—HAND-SIEVE. F—NARROW BOARDS. G—BOX. H—COVERED PIT.

Fig II.2.2 Seiving the clay in preparation for furnace building. According to Agricola, the dried and seived clay was mixed with powdered charcoal during the medieval period. After Agricola, book IX (Hoover and Hoover, 1950)

Angas smiths (Nigeria) use a "large pot" with an air hole in the top as a smelting furnace, and protect themselves from the heat behind a "mud screen" (Meek, 1925). The Lambas (Zambia) prefer a semi-subterranean smelting facility surrounded by a "mud wall" pierced to accomodate six tuyères (Doke, 1931). The Baoulé (Nigeria) caster's hearth consists of a "clay wall" about 20cm high with an aperture for a single tuyère. Nearby, a second "clay wall" surrounds the casting pit filled with soft sand (Cline, 1937). Bowl hearths used by Balemba copper workers (Zimbabwe) are lined with "clay and ashes" (Stayt, 1931, 65). The Dyoor (Sudan) build their cone-shaped furnaces of "common clay". This furnace cannot exceed four feet in height, owing, it is stated, to the great difficulty of preventing the mass of clay from cracking whilst drying (Schweinfurth, 1874, 206). In a more extensive account, Wyckaert emphasises the great care taken by the Asirungu (Tanzania) in the building of their cylindrical smelting furnaces. A three metre high, two metre diameter framework of green wood is constructed, its complexity depending of the quality of the clay mortar. The smiths form the frame, and their womenfolk dress it with clay. Inside the base of the cylinder, a small cone-shaped bowl is hollowed out to receive the "medicines". This is lined with clay "of the highest quality" prepared by the smiths' wives "with the minutest care" (Wyckaert, 1914).

Brown's detailed work in Kenya contains more specific descriptions, and these serve both to reiterate the technological constraints governing the building of furnaces as set out by the medieval authors, and to illustrate the manner in which various metalworking peoples utilise their environment to meet these constraints. The Highland Bantu of western Kenya prepare both furnaces and tuyères from the same type of clay. This is ground in a quern and mixed with water to a soft, dough-like consistency. Sand is added to increase refractory strength and the paste is used to line a simple bowl-shaped depression. The Marachi (W Kenya) smelt in a more complex bowl furnace. Here, equal proportions of termite mound clay and clay from nearby hillsides are punded together on a dung-covered hut floor. Water is added and the paste used to line the furnace bowl and build a surrounding wall with provision for tuyères. The structure is left for one day to dry in the heat of the sun. Furnaces of the hill-dwelling Pokot (NW Kenya) are formed entirely above ground around a framework of wattle.

For the construction observed, material from termite cones situated on dry sandy soil and on alluvial clay was thoroughly mixed with water by trampling with the bare feet. When the right consistency was reached, the mixture was plastered on to the inside of the wattle walls. The outside was covered with alluvial clay. Tuyères were plastered in place, and the whole structure smoothed by hand before being left to dry. The entire building operation took five hours, and required the help of at least six men (Brown, 1980, 58-83).

Tuyères are essentially blow-pipes designed to introduce forced draught into a melting or smelting furnace, thereby raising the internal temperature. Almost without exception, tuyères are used in conjunction with some type of bellows aparatus. Materials and methods used in the manufacture of bellows have been investigated in some detail by various ethnographers. However, despite the intrinsic interest of the subject, bellows making will not be considered here. No remains have been identified in British prehistoric contexts of the durable pot or drum bellows used in ancient Egypt (Forbes, 1964, 113) and by many east African groups (Cline, 1937, 106-08; Huntingford, 1961). It must therefore be assumed, for the present, that this item of smith's equipment was made (like the skin bellows in use in most African societies today) from perishable materials. Interest will thus be confined to the refractory component, the tuyère.

As tuyères serve to connect bellows to furnace, their production is subject to similar technolgical restraints to those controlling furnace construction. Tuyères used in bronze casting may be made from any material or compound which will retain its shape without fusing or cracking for the duration of at least one melt. Agricola (Hoover and Hoover, 1950) refers to tuyères of bronze, and Theophilus (Hendrie, 1847) to blow-pipes of iron, but for guidance to the interpretation of prehistoric clay tuyères, the ethnographic record must once again be quarried.

As already seen (Table I.2), in many areas of Africa, considerable magic and taboos surround the production, use and ultimate deposition of this piece of refractory equipment. Whilst pottery making is generally the province of women, the smiths almost invariably produce their own tuyères. Sometimes the mixture is the same as that used for the furnace itself, but frequently a special compound prepared from available raw materials is employed. The selection of this compound is determined partly by technology and partly by social and/or ritual factors.

In Bauchi province (Nigeria) smiths uses a "special kind of clay" mixed with goat hair to mould tuyères (Meek, 1925). The Lungu (Zambia) first form small balls from pounded ant-hill clay, and keep these moist under the cover of branches. Meanwhile the roots of the nTombolyo tree are mashed to a paste in a small mortar. At production time, the clay balls are dipped in ashes, kneaded, then flattened and pierced with a stick to form the requisite shape. The newly made tuyères are then coated with the prepared root paste and turned on to a bed of millet chaff to dry in the sun for three days (Chaplin, 1961, 53).

Only expert smelters among the Ba-Ushi (Zambia) may make tuyères. Long poles, lubricated with white wood ash, are generally covered in layers of well beaten clay. Between layers the growing form is smeared with a certain red tuber crushed in hot water. This is said to strengthen and impart a glaze to the finished product. When complete, the Ba-Ushi tuyères, like those of the Lungu, are rolled in millet chaff before being sun dried (Barnes, 1926).

The Basakata and other Congo tribes use potting clay as a base for tuyère paste. This clay, which is used without additives for pottery making, is heavily tempered with banana and palm fibres to provide refractory strength and "suppleness". Tuyères moulded from this mixture may be sun dried, hardened before the furnace, or fired prior to use (Maes, 1930).

In Kenya, smiths are often prohibited by taboo from using potting clay for tuyère making. Many iron smelters collect their own selected clay for this purpose from the region of the ore deposits. Generally the dry clay is cleaned from extraneous stone, grit and vegetable matter, then ground in a quern before mixing with temper and water. Tempering materials vary from area to area and from tribe to tribe. The Samburu add donkey dung to tuyère clay, the Rendille white ash, and the Samia, Marachi and Wanga all prefer ground discarded tuyères. All Kenyan blow-pipes are modelled by hand, usually around a smooth stick. The completed objects are dried in sun or shade and are often fired (Brown, 1980, 32-34).

II.2.4 Summary and discussion

The technological constraints governing the production of each item of refractory equipment used in the bronze casting process may be conveniently summarised in tabular form (Table II.2.2). Constraints operate at two levels: the invariable, general (column A); and the variable, particular (column B).

Firstly, those constant requirements which must be met to ensure the success of any and every casting operation are defined (column A). All refractories used in bronzeworking must, for example, be capable of withstanding the temperature required to melt bronze. Crucibles and moulds must be thermal shock resistant. Whatever material is selected for mould production, allowance must be made for the escape of gases produced as the metal contacts the mould face. This may be achieved through body permeability, and/or the provision of venting systems.

Secondly, constraints may be defined which vary according to the particular casting régime under consideration (column B, Table II.2.2). The shape of the mould matrix, for example, will be determined by the shape of the object to be cast. A crucible used in the casting of a single item of jewellery will be smaller than one made for sword production. The care taken in furnace construction will vary according to the desired lifespan of that furnace.

The selection of material combinations to meet these constraints will inevitably be limited by the range of raw materials to be found within reasonable proximity of the smith's workshop. It would not have been possible, for example, for prehistoric British metalworkers to quarry termite chimneys for furnace making, nor would banana and palm fibres have been available as tempering materials. Variation (Table II.2.2, column C) in materials chosen, methods of preparation and artefact style (where such is not wholly determined by technology) are

TABLE II.2.2 TECHNOLOGICAL CONSTRAINTS ON THE PRODUCTION OF REFRACTORY EQUIPMENT

Refractory item	A: Universal technological requirements	B: Variable technological requirements	C: Allowable variation within technological constraints
All	1. High temperature and thermal shock resistance 2. Resistance to pressure, vibration and accidental blows 3. Resistance to slag attack 4. Resistance to flame, fuel and gases in furnace 5. Limited and uniform expansion or contraction	Durability related to desired lifespan.	1. Form 2. Material selection and preparation 3. Forming techniques
Crucible	1. Resistant to high temperatures over long periods 2. Thermal shock resistant (hot to cold) in removal from furnace 3. Dense to prevent absorption of metal 4. Resistant to corrosion from contents 5. Strength to be moved when full of molten metal 6. Resistant to gases, fuel and flames 7. Shaped for easy holding and pouring contents without spillage	Size related to size of casting.	Always ceramic, but types and proportions of sands and clays may vary. Form and forming techniques may vary.
Mould	1. Thermal shock resistant (cold to hot) on entry of metal 2. Permeable to allow gases to escape 3. Inner surface dense to form true image and act as barrier against metal penetration 4. Provision for entry of metal and exit of air and gases and (in cire perdue) wax	1. Core (friable) and locating device for hollow casting 2. Shape determined by item to be cast	Can be made of ceramic, metal or stone. Outer surface shape can vary.
Furnace	1. Fire resistant 2. Provision for draught 3. Strength to remain standing	1. Design related to required temperature 2. Durability of construction related to desired lifespan	Always ceramic (not necessarily pre-fired). Outer shape may vary widely.
Tuyère	1. Fire resistant 2. Shaped to receive bellows nozzle		May be ceramic (not necessarily pre-fired), lithic, metallic, organic. Shape may vary widely.

ultimately governed by cultural criteria.

Arnold has examined pottery making in Ticul, Guatamala with particular reference to the selection of raw materials for vessel production and for architectural purposes (Arnold, 1970; 1971). Using the framework of cognitive anthropology, he aimed to demonstrate that "one portion of the cognitive system used by Maya potters ... is manifested in a body of physical or artefactual data. The particular [emic] cognitive system ... is the series of community defined categories which potters know and use in selecting and utilising raw materials for making pottery. The physical [etic] data are derived from X-ray diffraction studies of the raw materials" (Arnold, 1971, 22). Arnold's etic data defined the unique ecological framework (the set of discrete raw material resources not found in other areas) within which the potters must work. His emic data were the ethnomineralogical systems of the Ticul potters, that is, the potters' understanding of the raw material combinations exploited and their stated reasons for selecting these combinations. "The potter ... does not recognise mineralogical differences, but he does recognise the physical properties which result from these mineralogical differences. Thus the physical properties of the materials constitute the building blocks of the potter's cognitive system" (Arnold, 1970, 2).

Although Arnold's informants provided technological reasons for raw material selection, it is clear from Part I of this study that other, cultural factors are equally significant. The smith who, for example, adds a certain crushed rock to his mould clay to prevent it cracking, may well be selecting this particular rock type because his smith ancestors had always used it. A certain clay may be 'preferred' for crucible making, not only because of its mechanical efficiency, but also perhaps because other clays are restricted by taboo to the potters, located within the territory of another tribe, or considered 'inferior' by tradition. Any ethnomineralogical system should thus be seen as a blend of technological constraints and cultural determinants operating within a restricted ecological zone.

Unfortunately, it is not possible to emulate Arnold and ask British prehistoric smiths their reasons for selecting this clay, or that particular tempering material. However, given knowledge of the rigid technological constraints governing refractory production, it is hoped that by investigating the environmental resources where production took place, and by examining the composition of the artefacts themselves (etic data), some progress may be made towards an understanding of the ethnomineralogical systems (emic data) in operation in the late bronze and iron ages.

II.3 APPROACHES TO REFRACTORY ANALYSIS

II.3.1 Refractory recognition; previous analyses; analytical techniques - selection and methods

Although iron age crucibles have long been recognised by their distinctive grey, sandy fabric and frequent traces of slagging, it is only during the last decade or so that fragments of clay mould and crucibles have been identified in bronze age contexts. In his "Metallurgy in Archaeology", Tylecote was able to list only one site in southern Britain which had produced late bronze age mould (Tylecote, 1962, 119). In 1972 the remarkable Pit 209 at Gussage All Saints, Dorset, yielded the first clay mould of iron age date known in Britain, and three years later, the first bronze age crucibles and large mould assemblage were recovered from the 'open settlement' at Dainton, Devon. These two sites provided a body of comparative material, and since their publication (Foster, 1980; Howard, 1980a; 1980b; 1980c; 1980d; Spratling, 1979; Needham, 1980a; Silvester, 1980; Wainwright, 1979) prehistoric refractories have been recognised at an increasing number of locations. There are, for example, now 22 excavated bronze age sites with evidence of casting activity (see Ch III.16).

The three important criteria for the recognition of refractory artefacts are form (identifiable matrices in the case of clay moulds), fabric and traces of metal. To allow the proper investigation of these elements, clay objects suspected of metalworking associations should never be washed during post-excavation processing. It is likely that a large number of refractory fragments lie unrecognised in museum basements, scrubbed of all features which would have permitted their identification. Although it is often difficult to identify anomalous crucible and mould sherds on the basis of fabric alone, the range of pastes prepared for prehistoric refractory production are becoming increasingly familiar, and excavators are now more aware of the type of material to look for. Such detailed descriptions of colour, texture and general visual appearance of refractory fabrics as those included in the various site studies presented below (Part III), should contribute towards further recognition.

During recent years, considerable attention has been focussed on the scientific analysis of ancient pottery fabrics to investigate sources of raw materials and methods of manufacture. Until the present study, however, this type of research has extended hardly at all to other branches of the ceramic industry, and refractory bodies found in archaeological contexts have received but a cursory glance. Published examinations of prehistoric crucibles have, almost without exception, been undertaken by metallurgists interested only in residual slag. The fabrics themselves, as already noted, have been generally ingored.

In Sweden, Dr Hulthén has analysed crucible and mould fabrics from the Migration Period site of Helgö. Her results and associated experimental work have shown that local clay and a local quartz sand were probably combined for refractory making at the site. Both crucibles and moulds are tempered with up to 60% of fine-grained quartz which seems to have been artificially crushed. Moulds additionally contain pulverised charcoal (Lamm, 1973, 4). Crucibles have been fired to a temperature exceeding 1000^{o}C and liquid-state sintering is often visible in thin section (Hulthén, pers comm). Crucibles used for medieval glassworking at several British sites have been chemically analysed by Dr S C Waterton of Stourbridge, and the constituent elements compared with those present in local clays. The results established that crucibles, or at least the clay to make them, were imported from elsewhere to the glass-houses. Crucibles produced much higher silica figures than any of the local clays and contained a different suite of trace elements (Wood, 1965, 71). A single thin section analysis of a glassworking crucible from the post-medieval site of Bagot's Park has appeared in print. Here, a high precentage of rounded quartz sand (to 0•3mm) seems to have been added to a refractory clay, identified as a Cannock coalfield fire-clay (Crossley, 1967, 74). In the 1950s, Hodges examined clay moulds from various Irish bronze age sites and attempted to replicate the fabrics. He took a local weathered clay, levigated it and added a small quantity of fine sand. Particle size analysis of the archaeological material showed a greater proportion of fine grains in inner sheaths than in outer wraps, suggesting to Hodges that raw clays had, in fact, been levigated (Hodges, 1954, 63). From visual inspection of crucibles from the Glastonbury Lake Village, Clement Reid identified the fire-clay seams and gannister beds of the Bristol coalfields as the probably raw material source (Bulleid and Gray, 1917, 301). His identification was not, however, tested by scientific analysis.

The results of the rare investigations that were available at the start of the present study are interesting, and suggest that techniques of ceramic analysis should profitably be applied to refractory materials. A formidable range of analytical techniques is currently available (for reviews, see Peacock, 1970 and Kingery, 1981). Many of these techniques are extremely time consuming, very expensive (precluding their application to large bodies of material within the confines of a research degree), and require sophisticated equipment with limited availability. Furthermore, many are suitable only for certain types of ware, and most provide information limited to one aspect of the artefacts under study.

Petrological examination in thin section was chosen as the technique most appropriate to this broad-based study of refractory materials. Of all available analytical methods, petrology can yield the widest range of data. In addition to providing a ready assessment of the mineralogical composition of a given artefact, thereby allowing the possibility of source determination, thin sectioning (alone among ceramic analytical techniques) can at the same time reveal details of technology. The use of unmodified raw clays, the addition and preparation of temper, paste preparation techniques, forming techniques, firing conditions and temperature range can all, in ideal circumstances, be ascertained under the petrological microscope. The need to investigate prehistoric refractory technology and to locate the sources of raw materials exploited for refractory production dictated the choice of thin section analysis.

It quickly became apparent at the outset of this study that thin section preparation techniques normally used in pottery studies were unsuitable for sandy, friable, refractory fabrics. New preparation methods had thus to be devised.

Cutting the section

The smallest viable amount of material was removed from each of the artefacts examined. All mould, crucible, tuyère and furnace sections were cut with a fine hacksaw blade without lubricant. This technique provided maximum control and insured against disintegration of the friable sherds. Core samples were removed from implement sockets with a fine penknife blade and a dental pick. Every care was taken throughout the study not to impair the archaeological or display value of artefacts examined.

Pre-mounting treatment

Most hard-fired pottery samples, it seems, require no pre-sectioning treatment, and may be fixed directly to a glass slide with Lakeside 70 or similar mounting medium. Friable samples require impregnation prior to mounting, and a popular medium has been microcrystalline wax (Sofranoff, 1975). Although fairly efficient in some cases, this substance was found to be generally unsuitable for refractory sherds. A few samples were impregnated with Lakeside 70 under vacuum conditions, and a few with the same medium without a vacuum system. The efficiency of this highly viscous substance was also unpredictable. The impregnating method found to be consistently successful was that favoured by geologists for consolidating sand and friable sandstone samples (see for example Lister, 1978; Wells, 1962). The ceramic fragments are placed in small tinfoil trays containing Araldite resin AY 18, and hardener HZ 18, mixed with an equal volume of acetone to reduce viscosity. The trays are then placed in a vacuum impregnating oven (Gallenkamp OVL-570 was used here), and the chamber evacuated. Pressure is slowly returned to normal after four hours. The samples are then cured in the oven at 50°C for one hour, at 75°C for one hour, and at 100°C for a further hour. Cured samples are allowed to cool naturally in the oven, after which they are ready for grinding and mounting.

Mounting and grinding

After impregnation, all samples were ground to a flat, smooth face and mounted on a glass slide with Rapid Araldite. The mounted sections were cold-cured for twelve hours then ground by conventional methods to 0·03-0·05mm. Finished sections were thoroughly cleaned and covered with glass slips mounted with Canada Balsam or "Eukitt" resin.

Examination of sections

All thin sections were examined under a Leitz SM-Lux polarising microscope. Constituent minerals were identified and studied in the light of relevant geological literature. These studies helped formulate the raw material sampling strategies described below (II.3.2). Textural analysis was performed on a representative sample of sections from each site, sample size being determined by the range of artefacts present and fabric variations observed within each artefact category. Textural analysis and the statistical techniques employed are discussed below (II.3.3).

*　　　　*　　　　*

At the outset of the study, it was hoped that thin sectioning would be supplemented by heavy mineral analysis where appropriate. This technique has been successfully used to characterise sandy pottery from various areas (eg Gale, 1979; Peacock, 1967; Williams, 1975; Williams, Jenkins and Livens, 1974). However, in practice, insufficient refractory material was generally available for heavy mineral separation. The technique (for methods used, see Griffiths, 1967; Peacock, 1967) was confined to a limited number of sherds from Danebury and Gussage All Saints.

II.3.2 Ceramic ecology

Ceramic ecology was originally defined as "the attempt to relate the raw materials and technologies that the local potter has available, to the functions in his culture of the products he fashions" (Matson, 1966, 203). In subsequent developments of this theme, other workers have emphasised the effects of climatic and agricultural limitations, and availability of raw materials on the growth of full-time pottery manufacture (Arnold, 1975; Foster, 1967; Peacock, 1982; Reina and Hill, 1978; Rice, 1977; Spriggs and Miller, 1977). Arnold's especial interest in the raw material aspects of ceramic resource ecology prompted him to conduct an extensive survey of potters, principally in Latin America, to ascertain the location of their clays, tempers and pigments (Arnold, 1976; 1980; 1981). From the results of this survey Arnold was able to identify three thresholds of energy and distance to ceramic resources. Following Browman (1976) he defines these as the preferred, maximum and marginal territories of exploitation. More than one third of the potters studied obtain their clays less than 1km from the production site (preferred territory); 76% from less than 4km away, and almost all (96%) from within a 7km radius (maximum territory). The preferred territory of temper exploitation is also 1km, but 97% of Arnold's sample quarry their temper less than 8km away, suggesting an 8km radius as the maximum territory for this commodity (Arnold, 1980, 149; 1981, 36, fig 2.1). Distance thresholds to slip, glaze and paint resources are more difficult to determine. As 32% of Arnold's sample obtain these materials within 8km of the production site, this radius seems to constitute the preferred territory, but distances range from 1 to 880km (Arnold, 1981, fig 2.2). The constituents of glazes, slips and paints (secondary resources) are required in much smaller quantities than (primary resources) clays and tempers, thus their availability in proximity to the production site is not so crucial (Arnold, 1976, 95).

Unfortunately, no data whatsoever are available concerning the distances bronze casters are prepared to travel for their ceramic raw materials. Although Arnold's preferred and maximum territories may serve to guide resource sampling strategies, it is not possible here, considering the different constraints on refractory production, to postulate a parallel exploitation system. The approach taken here, which may perhaps be termed 'refractory resource ecology', is therefore essentially exploratory in nature. Survey and analysis of ceramic resources has been undertaken in the area of most of the major sites studied with three major aims in view:

1. to assess the suitability and abundance of local resources for refractory production

2. to examine the skill of the bronzeworkers in manipulating local ceramic resources to conform to the intrinsic technological constraints
3. to investigate the relationship between suitable refractory resources and the location of metalworking activity.

Additionally, the combination of this ceramic ecological survey with petrological analyses of archaeological materials has enabled me, in many cases, to describe the technology of refractory production. Techniques of paste preparation, the properties and treatment of non-plastics added to the clay body, and the elimination of unwanted non-plastics from an impure clay have all been recognised and documented. This broadly-based archaeolgical-ecological approach has greatly facilitated meaningful inter-site and inter-regional comparisons.

A primary aim of archaeological fabric characterisation has always been to locate the source of production of the ceramics concerned (Shepard, 1942; 1976). Although some characterisation studies have yielded remarkably successful results (eg Peacock, 1968; 1969; Williams, 1975), the 'pottery fabric' appendices which now temper most national and regional journals are usually inconclusive, often ending with a plea for "further work" (eg Finch, 1971; Howard, 1980b; Williams, 1978).

The relationship between minerals observed in thin section and actual geological deposits is often extremely difficult to define. Clay is formed as a result of the disruption and decomposition of existing rocks, and subsequent hydration of the resultant rock flour. Clays found overlying or in close proximity to the the parent rock are known as 'residual', whilst those which have been carried away by glacial or other natural action and deposited elsewhere are called 'transported' clays. These latter type are by far the commonest over the greater portion of the British Isles, and herein lies the reason for the inconclusive nature of many ceramic studies. Transported clays are known geologically as 'drift', and there is a singular lack of detailed drift information in the geological literature. For most areas of Britain, the Memoirs of the Geological Survey contain but scant reference to the often considerable deposits of drift which overly the meticulously described bedrock formations. It is only those areas where glacial deposits form distinctive topographical features (such as the boulder clay cliffs of Holderness, North Humberside, and the ball-clay deposits on the Isle of Purbeck, Dorset) which have attracted interest in clay lithology.

So how, therefore, can the petrologist relate the mineral assemblage he sees in thin sections of ancient ceramics to those present in natural clay formations? How can he decide whether those minerals do in fact occur naturally in the clays rather than represent crushed rock fragments added as temper? The only presently available answer lies in systematically sampling sources of clay local to the study area, and clay and perhaps rock sources within geological zones suggested by the mineral suites observed in archaeological thin sections (Howard, 1982). Although the major concern of the ceramic petrologist is with the mineralogical matching of clays collected in the field with those used for ceramic production, he too must give some consideration to the working properties of the raw materials. Many clays can, for example, be eliminated from a given study on the basis of their physical unsuitability (ascertained by means of a few simple tests) for manufacture of ceramic goods.

Raw material sampling and processing

The methodology I devised for clay sampling and analysis is based to some extent on techniques developed by craftsmen and industrialists (Binns and McMahon, 1967; Cardew, 1969; Hill, 1974; Lawrence, 1972; Mellor, 1918; Norton, 1949; Searle and Grimshaw, 1960). The procedures described for sample collection, preparation and recording require a minimum expenditure of time, and have been designed to allow a quick and easy physical assessment of the materials of interest. Sampling strategies, which necessarily vary according to the geology and topography surrounding each site, and according to the results of artefact analysis, will be described within each case study.

1. Recording

All stages of collection and processing were clearly and concisely recorded. The format illustrated in figs II.3.1a-c was found to be the most suitable for the recording of basic data, and at the same time sufficiently flexible for the inclusion of additional experimental tests and results.

2. Collecting

A minimum of 150gm (uncontaminated by surface soil and organic debris) is necessary for testing purposes, although more was usually collected to allow for additional experiment (Pls 1-2). Samples were bagged, and the bags indelibly labelled with an identification number, sampling date and six figure grid reference at the time of collection. Notes on depth, and general and geological context were recorded in a sampling notebook for later transference to the record card (fig II.3.2).

3. Preparation

About 100gm of each clay sample was dried then lightly crushed. Any obvious stones and organic matter were removed at this stage. Water was added until a plastic, workable condition was reached. The clay was then thoroughly wedged to ensure the homogeneous distribution of inclusions throughout the groundmass, and to exclude air pockets which may distort results. Clays were then formed into briquettes approximately 12cm long by 2cm wide and 1cm thick. The surplus was formed into small blocks for weight shrinkage tests. Each briquette and associated block was marked with an identification number, and briquettes were marked with a 100mm line (fig II.3.3). The weight of each small block was recorded.

4. Drying

Briquettes and blocks were allowed to dry at room temperature (15-18°C) for at least seven days, then finally dried at 100°C for one hour to ensure the removal of all water of plasticity. Any distortion or cracking during drying was recorded. Line lengths were measured and percentage linear shrinkage calculated. Small blocks were weighed and percentage weight loss, plastic to dry, recorded. The blocks were then stored as reference samples of the raw clay. The dry briquettes were weighed, and the data added to the record forms. Dry colours were recorded using Munsell soil colour charts.

5. Firing

All unmodified clay samples were fired to 850°C in a Carbolite muffle furnace by raising the temperature by 100°C every 30 minutes. Although an unlikely prehistoric procedure, this firing regime is appropriate in basic test conditions to minimise the risk of cracking and deformation. Fired briquettes were allowed to cool in the kiln, after which any cracking or distortion resulting from firing was recorded. Line lengths were measured and percentage linear shrinkage, dry to fired and plastic to fired, was calculated. Briquettes were weighed and percentage weight loss, dry to fired, and plastic to fired, was calculated. Fired surface colours were recorded, and a section cut through each briquette enabled core colour and thickness to be determined (fig II.3.4).

6. Thin section analysis

Thin sections were prepared from each fired clay sample. Any pre-sectioning treatment, such as impregnation of the sample slice, was noted. The sections were examined microscopically, and the results described on the recording forms (figs II.3.1a-b).

7. Further tests and sampling

The procedures described above were applied to all raw clays collected in each sampling area. The results permitted an assessment of the basic suitability of available raw materials for ceramic manufacture. When raw material thin sections were compared with those prepared from archaeological refractories, it was possible to suggest which, if any, local clays were used for crucible and mould production in prehistory, When a likely refractory clay was identified, this was subjected to further testing at higher temperature. If examination of archaeological refractories suggested the modification of a particular clay by the addition of rock temper, attempts were made to locate the rock type used. Potential sources of refractory sand were also sampled, and rock and sand samples were described on the recording forms (fig II.3.1c; Pl 1b).

CLAY SAMPLING RECORD

IDENTIFICATION	Sample no. YK 2 (c)	Date 18·12·80	NGR TA 233 723		Identity no.
	Site name THORNWICK BAY	Site type BEACH CLIFF	Depth ≤20m. FROM CLIFF TOP	Sample context RED CLAY IN BOULDER CLAY CLIFF FACE	

WEIGHT SHRINKAGE	Block Weight	Plastic 22·6g	Dry 18·8g	Brick Weight	Dry 121·2g	Fired 121·2g
	Percent Shrinkage	Plastic-dry 16·8	Dry-fired 0	Plastic-fired 16·8		

LINEAR SHRINKAGE	Line Length	Plastic 100	Dry 91	Fired 90
	Percent Shrinkage	Plastic-dry 9·0	Dry-fired 1·1	Plastic-fired 10·0

COLOUR	Dry 10YR 5/4	Fired exterior 2·5YR 5/8	Fired core –	CORE DEPTH –

DISTORTIONS	Drying	Warp SLIGHT	Crack –	Firing	Warp –	Crack –	Bloat –

OTHER TESTS	Test	Results
	—	—

THIN SECTION

Pre-sectioning treatment: —

Description: Ferruginous clay, contains both brown and white mica. Medium scatter of angular → sub-rounded quartz 0·01mm → 0·6mm. Occasional grains quartzite and metaquartzite. Single fragment of lava. Plagioclase felspar (to 0·1mm) present but very rare.

DOCUMENTATION Lamplugh, 1891.

STORE	Clay	Brick	Sectn

NOTES Geol: Boulder Clay; Hessle layer at junction with Purple layer

Fig II.3.1a Example of form used for recording clay samples (NB: the forms reproduced in this fig are reduced versions of the originals).

CLAY SAMPLING RECORD

IDENTIFICATION	Sample no. BR 3 (C)	Date 26·2·82	NGR SJ 292 143		Identity no.	
	Site name BREIDDIN QUARRY		Site type QUARRY FACE	Depth 1m.	Sample context CLAY INTERBEDDED WITH SAND. RARE POCKETS.	
WEIGHT SHRINKAGE	Block Weight	Plastic 25·9g.	Dry 21·7g	Brick Weight	Dry 79·9	Fired 74·0
	Percent Shrinkage	Plastic-dry 16·2		Dry-fired 7·4	Plastic-fired 22·4	
LINEAR SHRINKAGE	Line Length	Plastic 100		Dry 93	Fired 92	
	Percent Shrinkage	Plastic-dry 7·0		Dry-fired 1·1	Plastic-fired 8·0	
COLOUR	Dry 2·5Y 7/4	Fired exterior 5YR 6/8		Fired core =	CORE DEPTH —	
DISTORTIONS	Drying	Warp slight	Crack —	Firing	Warp slight	Crack slight / Bloat —
OTHER TESTS	Test	Results				
THIN SECTION	Pre-sectioning treatment: Impregnated with Araldite AY18 + H218					
	Description: Quartz sparse in matrix. Dolerite fragments to 3mm; fine-grained with all ferromagnesian minerals altered to brown. No other inclusions.					
DOCUMENTATION						
STORE				Clay	Brick	Sectn
NOTES	Geol: DOLERITE					

Fig II.3.1b Example of form used for recording clay samples.

CLAY SAMPLING RECORD

IDENTIFICATION	Sample no. YK 7 (R)	Date 18·12·80	NGR TA 225692 – 230692		Identity no.	
	Site name FLAMBOROUGH, SOUTH LANDING		Site type BEACH	Depth SURFACE	Sample context ROCKS ERODED OUT OF BOULDER CLAY	
WEIGHT SHRINKAGE	Block Weight	Plastic	Dry	Brick Weight	Plastic	Dry
	Percent Shrinkage	Plastic-dry	Dry-fired	Plastic-fired		
LINEAR SHRINKAGE	Line Length	Plastic	Dry	Fired		
	Percent Shrinkage	Plastic-dry	Dry-fired	Plastic-fired		
COLOUR	Dry	Fired exterior	Fired core	CORE DEPTH		
DISTORTIONS	Drying	Warp	Crack	Firing	Warp	Crack / Bloat
OTHER TESTS	Test	Results				
THIN SECTION	Pre-sectioning treatment —					
	Description Granite (? Eskdale), fine-grained basalt (black in hand specimen), dolerite – 3 variants. Sample bag included 4 fragments of Whin Sill dolerite.					
DOCUMENTATION						
STORE		Clay	Brick	Sectn		
NOTES Geol: Boulder Clay; erratics from all layers.						

Fig II.3.1c Example of form used for recording rock samples.

Sample no.: HA 6

Date: 20·2·80

NGR: SU362253

Depth: 10 cm below modern turf level.

Site name: Braishfield: New Inn.

Site type: Road cutting

Sample context: Sparse pockets of clay; some organic content (mainly ? moss)

Fig II.3.2 Typical entry in a sampling notebook.

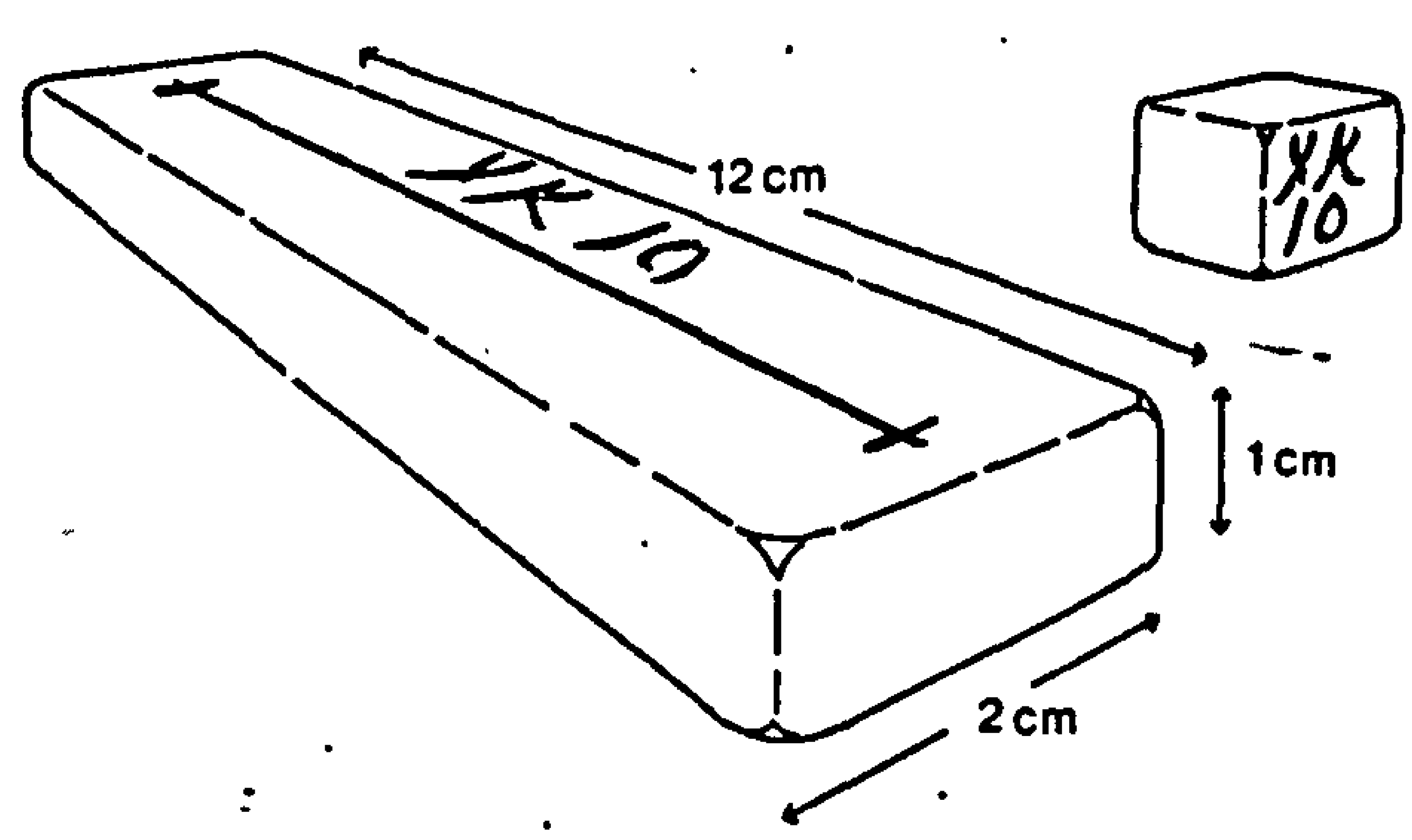


Fig II.3.3 A clay briquette marked with a 10cm line and field sampling number, together with its associated block. Preparation of the block both simplifies the weighing process and creates a convenient sample of the raw clay for retention.

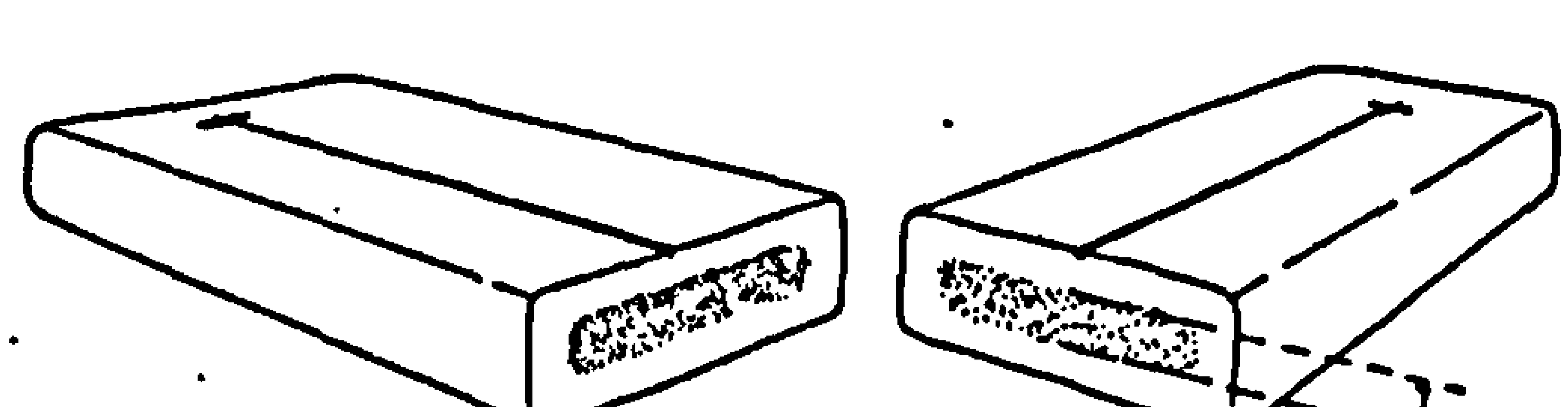


Fig II.3.4 A fired briquette, cut after weighing and measuring to allow core depth and colour to be determined.

II.3.3 Textural analysis and statistical techniques

Factors which influence the efficiency of a refractory fabric have been listed as: refractoriness, plasticity and composition of the bond clay; refractoriness of grain - determined mainly by mineral character; grain size - the average size of sand grains; grain uniformity - the range and distribution of grain sizes; grain shape - degree of rounding and sphericity of sand grains (Hansen, 1926, 373). Additionally, the significance of proportion of grains to bonding substance has been stressed (Trainer, 1926, 327). The identification of clay minerals present in archaeological ceramics is extremely difficult, and unless a precisely matched clay can be located the refractoriness and plasticity of the bonding material must remain a matter of speculation. However, the mineral character of the grain may be determined by microscopic examination (II.3.1, above). Furthermore, textural characteristics can readily be measured under the petrological microscope with the aid of a micrometer eyepiece .

Grain size, sorting, sphericity and roundness have long been of interest to sedimentary geologists studying fragmental deposits. A series of standardised grade scales has been proposed for dimensional classification and labelling of particles, but that devised by Wentworth in 1922 is most often employed (Hatch and Rastall, 1971, 61; Nockolds et al., 1978, 224-6; Selley, 1976, 11-12). The Wentworth scale ranges from 'cobbles' (>64mm diameter) to 'clay' (<0•0039mm diameter). A slight variation on this scale is that proposed by Krumbein (1941) which retains the Wentworth grades but converts the boundaries into 'Phi' values by a logarithmic transformation:

$$\phi = -\log_2 \text{diameter}.$$

In addition to this conversion, the Phi scale provides convenient numeric labels for the Wentworth grade fractions (see Table II.3.1). A common practice, followed here, is to plot grain size curves on probability paper: samples with normal Gaussian grain size distributions plot out on a straight line. Mean size, standard deviation, kurtosis and skewness are derived from the resultant graph, or calculated mathematically.(Selley, 1976, 18-20).

Table II.3.1 Particle size grades

Particle diameter (mm.)	Ø value	Wentworth grade		Rock name
		Cobbles		
64	-6			Conglomerate
		Pebbles		
4	-2			
		Granules		
2	-1	---------------------		
		Very coarse		
1	0			
		Coarse		
·5	1			
		Medium	Sand	Sandstone
·25	2			
		Fine		
·125	3			
		Very fine		
·0625	4	---------------------		
		Coarse		
·03125	5		Silt	Siltstone
		Medium		
·01563	6			

The use of a standardised scale in textural analysis of archaeological ceramics was first proposed by Shepard (1976, 118), and has since become commonplace in Britain. Following Peacock (1971), Wentworth grain size statistics are frequently used to classify fabrics lacking diagnostic minerals, with the ultimate aim of locating manufacturing centres (e.g. Hodder, 1974; Streeten, 1982). As Williams (1979, 75) has observed, however, this goal often remains elusive. Elsewhere, the occasional use of quantified particle size analysis in ceramic studies seems more related to an interest in tempering materials in their own right (e.g. Weaver, 1963; Stjernquist, 1972, 56-8). Mineral inclusions visible in thin section may be natural to the raw clay, added by the potter, or a combination of these two. Textural analysis can help to determine the origin of included materials and aid evaluation of preparation techniques. "... the significance of texture bears a direct relation to the kind of temper used and to technique. Uniformity in one kind of temper will reflect technique, whereas in another it may be predetermined by the material itself. When these relationships are disregarded, texture classification is an unevaluated procedure" (Shepard, 1976, 117).

In the present study, the primary aims of textural analysis were to investigate the technology of production of metallurgical ceramics (the nature of tempering materials, paste preparation and forming techniques), and to assess the refractory qualities of the fabrics concerned. Refractoriness was determined through comparison with similar modern materials and experiments and analyses thereon. The textural statistics of crucibles, moulds, tuyères and furnaces were compared, allowing conclusions to be drawn concerning the manufacture of different refractory items at a single site, and at different sites through time.

Despite recent attempts to disaggregate prehistoric pottery (Hamilton, 1977), it seems likely that thin sectioning, and grain by grain measurement under the microscope will remain standard procedure for textural analysis of archaeological ceramics. Not only is disaggregation very difficult, but any remotely successful method can easily damage the very particles of interest. It is, however, important to recognise an inherent bias in the measurement of thin sectioned grains. A section is most unlikley to cut every grain through its longest axis (Selley, 1976, 13). The size and distribution parameters of particle inclusions measured in thin section, and those which would be recorded if the same material could be measured in a series of graded sieves, do not thus precisely coincide. Thin sectioning will tend to underestimate true grain size. This problem was recognised by Shepard (1976 , 120), but because the bias is uniform from one sherd to another, was considered to be of minor concern. Meaningful relative statistics can be derived, and Shepard's interest concerned differences within and between fabric groups.

Here, however, in addition to comparing archaeological fabrics with each other, I was also concerned with the relationship between prehistoric pastes and modern refractory sands, the absolute characeteristics of which have been determined by sieving. A similar problem arises in geology when thin section grain counts of cemented and indurated rocks inevitably provide somewhat different data from weight percentages obtained by sieving friable rocks of identical particle size characteristics. To resolve this problem, Friedman (1958; 1962) proposed conversion equations derived empirically from repeated measurements of test specimens. In the present study, statistics have been converted according to Friedman's formulae.

A random sample of grains in each thin section analysed was measured at 100x magnification, and the distribution of grains over the range of Ø classes recorded as cumulative percentages. Following Pye (1943), Peacock (1971, 257) measured 50 grains per section. Working with sandstones, Friedman (1958, 413-15) concluded that between 100 and 300 grains constituted an adequate sample. However, as Friedman points out, "fewer counts /can/ lead to satisfactory results, depending on the population parameter to be estimated and the objective of the study" (1958, 415). The importance of these two factors is missed in a recent study which claims to confirm the invariable adequacy of a standard 50 grains for characterising archaeological ceramic fabrics (Wandibba, 1982). In the present analyses of refractory artefacts, the number of grains measured was determined in the main by the observed extent of size variation within each thin section. Where little variation is observed, a small sample will suffice, whereas when size distribution is very spread, more grains need to be measured before the resultant curve becomes stable. Too small a sample does not result in bias (pace Wandibba, 1982) but, instead, unacceptably low precision. Here, sample sizes ranged from 20 to 222, averaging 84 per slide[1]. At the same time as the inclusions were measured, the ratios of quartz to other tempering materials and of total grains to matrix were calculated. These data were then transferred to punched cards, and stored (with artefact identifications) in an SPSS computer file. Mean and standard deviation of grain sizes were calculated from the cumulative percentage scores on the Ø grades (Folk and Ward, 1957), and these statistics were corrected for thin section bias (Friedman, 1962). Inter-ceramic comparisons were conducted with the Ø scores subjected to principal components analyses. The various programs (Nie et al, 1975; Nie and Hull, 1979) appear in figs II.3.5-7.

1. 20, 183 inclusions were measured in a total of 240 slides.

```
VARIABLE LIST  SITE, SLIDE, GRAINS, MATRIX, PHIM05, PHI0, PHI05, PHI10, PHI15,
               PHI20, PHI25, PHI30, PHI35, PHI40, PHI45, PHI50, PHI55, DATE,
               OBJECT
INPUT FORMAT   FREEFIELD
COMPUTE        P1=PHIM05
COMPUTE        P2=PHI0-PHIM05
COMPUTE        P3=PHI05-PHI0
COMPUTE        P4=PHI10-PHI05
COMPUTE        P5=PHI15-PHI10
COMPUTE        P6=PHI20-PHI15
COMPUTE        P7=PHI25-PHI20
COMPUTE        P8=PHI30-PHI25
COMPUTE        P9=PHI35-PHI30
COMPUTE        P10=PHI40-PHI35
COMPUTE        P11=PHI45-PHI40
COMPUTE        P12=PHI50-PHI45
COMPUTE        P13=PHI55-PHI50
COMMENT
                                CALCULATE MEAN GRAIN SIZE
COMMENT
COMPUTE        X=(P1*150+P2*121+P3*86+P4*61+P5*43+P6*30.5+P7*22+P8*16+P9*11.5+
               P10*8+P11*5.5+P12*3.5+P13*1.5)/100
COMMENT
                                APPLY FRIEDMAN CORRECTION
COMMENT
COMPUTE        M=(.9027*X + .3315)/100
COMMENT
                                CALCULATE GRAIN SIZE S. D.
COMMENT
COMPUTE        SD=(P1*(150-M)**2+P2*(121-M)**2+P3*(86-M)**2+P4*(61-M)**2+
               P5*(43-M)**2+P6*(30.5-M)**2+P7*(22-M)**2+P8*(16-M)**2+P9*(11.5-M)
               **2+P10*(8-M)**2+P11*(5.5-M)**2+P12*(3.5-M)**2+P13*(1.5-M)**2)/
               100
COMMENT
                                APPLY FRIEDMAN CORRECTION
COMMENT
COMPUTE        STD=(.7177*SD + .1356)/100
COMPUTE        P1TOP4 = P1+P2+P3+P4
VAR LABELS     GRAINS NO. OF GRAINS MEASURED/MATRIX PERCENT GRAINS:MATRIX/
               PHIM05 PHI -1 TO -.5/PHI0 PHI -.5 TO 0/PHI05 PHI 0 TO .5/
               PHI10 PHI .5 TO 1/PHI15 PHI 1 TO 1.5/PHI20 PHI 1.5 TO 2/
               PHI25 PHI 2 TO 2.5/PHI30 PHI 2.5 TO 3/PHI35 PHI 3 TO 3.5/
               PHI40 PHI 3.5 TO 4/PHI45 PHI 4 TO 4.5/PHI50 PHI 4.5 TO 5/
               PHI55 PHI 5 TO 5.5/
               P1     PHI -1 TO -.5/P2   PHI -.5 TO 0/P3    PHI 0 TO .5/
               P4    PHI .5 TO 1/P5    PHI 1 TO 1.5/P6    PHI 1.5 TO 2/
               P7    PHI 2 TO 2.5/P8    PHI 2.5 TO 3/P9    PHI 3 TO 3.5/
               P10   PHI 3.5 TO 4/P11   PHI 4 TO 4.5/P12   PHI 4.5 TO 5/
               P13   PHI 5 TO 5.5
VALUE LABELS   SITE  (1)ULEYBURY (2)THETFORD  (3)S CADBURY     (4)DANEBURY
               (5)GUSSAGE  (6)FIMBER  (7)BREIDDIN
               (8) BEESTON  (9) BECKFORD   (10)MUCKING
               (11)MEARE  (12)M CASTLE  (13)WEELSBY AV  (14)GLASTONBURY
               (15)GR GRAVES    (16)M M WARREN  (17)SALMONSBURY
               (18)WALES RATH  (19)A C CROSS  (20)C CASTLE
               /
               DATE (1) BA  (2) IA
               /
               OBJECT  (1)MOULD (2)CRUCIBLE (3)TUYERE (4)FURNACE (5)SPRU :(UP
               (6)CORE  (7)IN MOULD  (8)OU MOULD  (9)UNKNOWN
MISSING VALUES ALL (999.)
PRINT FORMATS  SLIDE(A)/M, STD (4)
READ INPUT DATA
```

Fig II.3.5 SPSS program for data entry and transformation

```
REPORT          FORMAT=LIST/
                VARS=         SLIDE(5), MATRIX(3) ' % ' 'GR:' 'MAT',
                GRAINS(6) 'NO. OF' 'GRAINS',
                P1 TO P13(4), M(5) 'MEAN' 'GRAIN' 'SIZE' 'MM.', STD(4) 'STD'
                'DEV'/
                BREAK=SITE(10) (LABEL) (PAGE)/
                SUMMARY=VALIDN 'N SLIDES' (GRAINS) SUM 'N GRAINS' (GRAINS)/
                BREAK=DATE(2) (LABEL)/
                BREAK=OBJECT(8) (LABEL)/
```

Fig II.3.6 SPSS "Report" program

```
FACTOR          VARIABLES=P1TOP4, P5 TO P13/
                TYPE=PA1/
                MINEIGEN=.5/
                FACSCORE=.25/
                ROTATE=NOROTATE/
OPTIONS         2
STATISTICS      1, 2, 4, 5
```

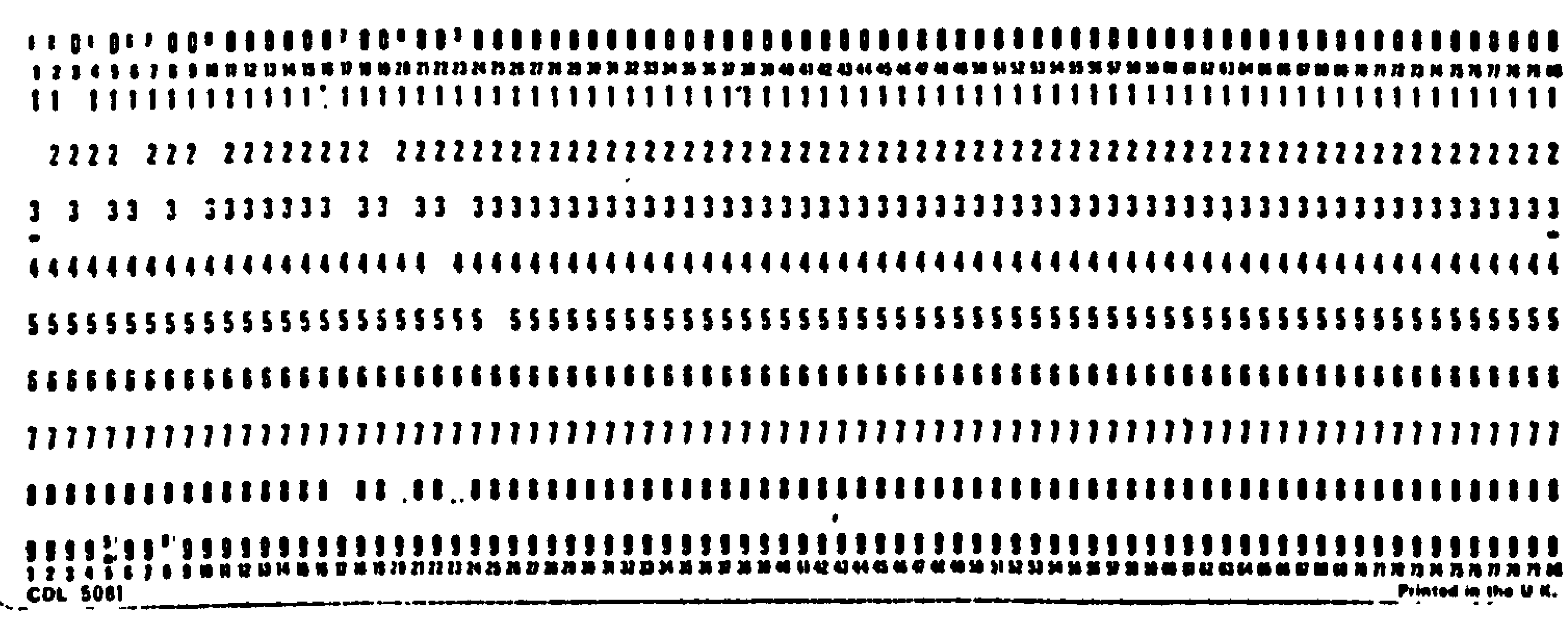


Fig II.3.7 SPSS principal components program

PART III

THE ARCHAEOLOGICAL EVIDENCE FOR BRONZE CASTING IN PREHISTORIC BRITAIN: SELECTED SITE STUDIES

III.1 INTRODUCTION

The declared aim of this study is to achieve a better understanding of craft technology and the organisation of production in later prehistoric Britain. The archaeological material considered in furtherance of this aim consists of refractory artefacts, particularly those from settlement sites (where such artefacts are made of clay, or, more rarely, stone). Stone and bronze moulds which occur without context, or in hoards, are also considered. An exhaustive search through the archaeological literature was conducted in order to identify prehistoric settlements where bronze working evidence has been recognised. Sites thus isolated are listed below with summarised descriptions of the production debris (Ch III.16).

From the 93 loci at which bronze artefacts are known to have been cast, fourteen were selected for detailed and original study. The results of these investigations (III.2-15) constitute the bulk of this Part, and a major element in the entire work. The choice of sites (Table III.1.1 and fig III.1.1) was governed to some extent by museum policy and the attitudes of excavators to petrological analysis. The comparative rarity of prehistoric refractory artefacts often results, understandably, in an embargo on any form of investigation entailing the 'destruction' of material. Within these limitations, the selection of sites representing each period was largely based upon the results obtained as analyses progressed. The material and technological diversity observed in earlier refractory assemblages suggested that as large a sample as possible of bronze age sites should be examined. Initial analyses of iron age refractories, on the other hand, indicated a considerable degree of homogeneity in crucible and mould recipes of this period. Sites representing different settlement forms (Champion, 1979, 355-79) from a wide geographical area were selected to test this homogeneity. Interest in change in technology and organisation over time determined the inclusion in the iron age sample of all those rare sites of that date which have produced casting mould.

Fabric studies of refractory artefacts from individual sites were undertaken with the following basic aims in view:

1. to investigate the technology of production of the different artefact types, noting particularly clay preparation methods and refractory properties
2. to determine mineralogical composition, noting variations within and between the various artefact categories
3. to identify, as far as possible, the sources of raw materials involved
4. to investigate, where applicable, the relationship between mould fabrics and implements cast.

Whenever possible, all refractories from a site were examined in hand specimen with a 10x lens. Observable variations in paste preparation (inclusion density and distribution, quality of clay working), fabric composition (identity of visible inclusions), and firing technology (atmosphere, approximate temperature range) were recorded and described at this stage. All fired colours are described according to the Munsell soil colour charts (Munsell, 1975). Samples for petrological and textural analysis were selected on the basis of this initial fabric inspection and on the results of typological determinations (crucibles, furnaces, moulds, implements cast etc). Thin sectioning methods and inclusion size/density analyses have been fully described above (II.3.1 and 3).

Following the laboratory work, programmes of raw material sampling and analysis were carried out for the majority of sites. Each sampling programme was designed to assess the working properties of clays available within the maximum ceramic exploitation territories as defined above (II.3.2); and to identify the sources of raw materials exploited for refractory production at each site, as revealed through petrological analysis. All sampled raw materials were processed according to the methods set out in II.3.2 above, and specimens are listed and discussed within the appropriate site chapters.

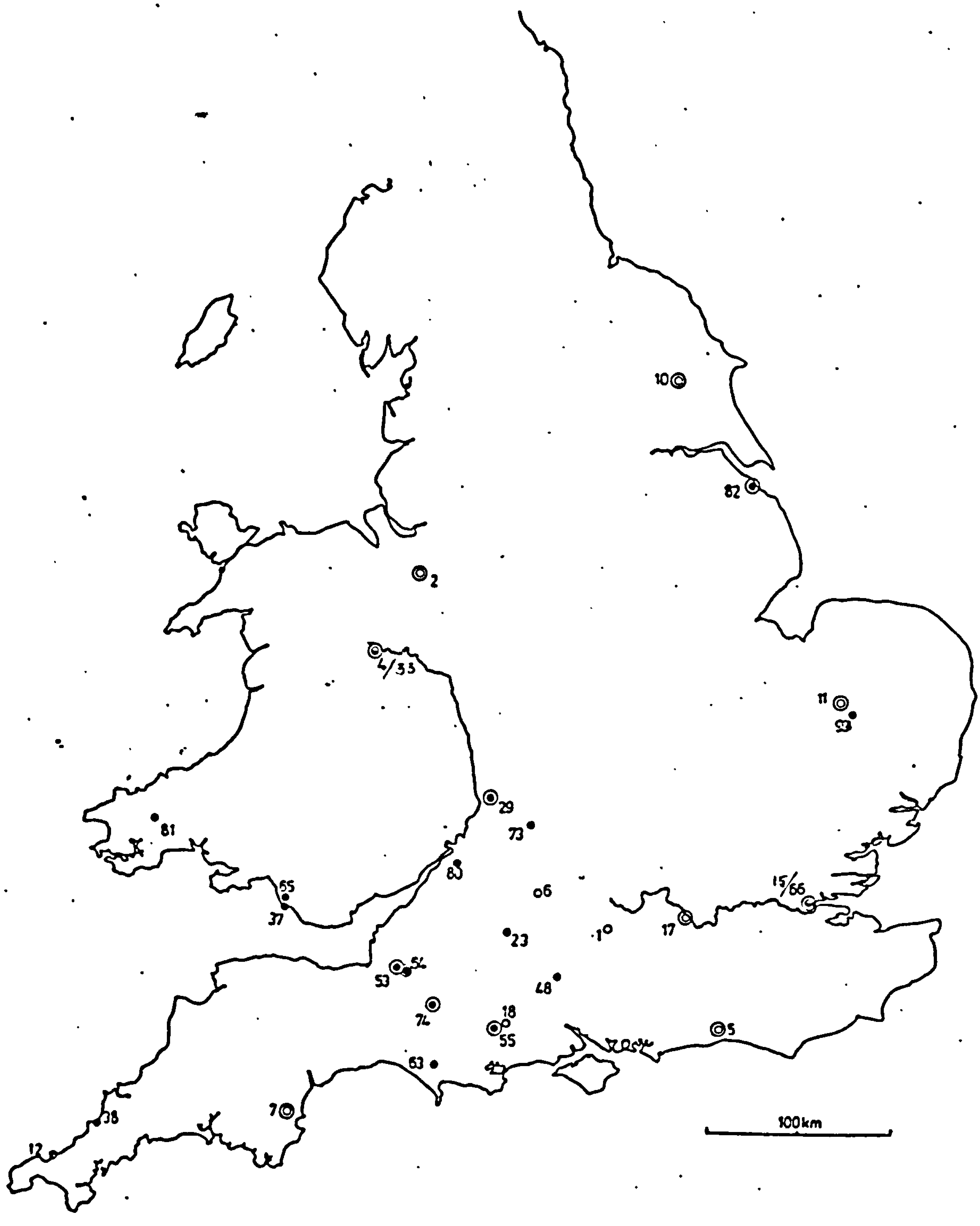
In practice, it was sometimes not possible to conduct the full analytical programme outlined here. In some cases museum policy disallowed thin sectioning of diagnostic pieces. Much of the recently excavated material was subject to post-excavation processing and typological reconstruction.prior to its release for fabric analysis. Time prohibited the collection of raw materials relevant to all sites studied. Any variations in the programme which may directly affect the overall interpretation of a site are noted below within the individual studies.

In addition to material from those sites examined in detail, refractories from a further fourteen sites (four of bronze age and ten of iron age date) were analysed, as well as a core from an uncontexted socketed axe (Table III.1.1 and fig III.1.1). These analyses aimed to provide a fuller assessment of technological variation during each economic period. The results are included where appropriate in the production site corpus (III.16).

TABLE III.1.1 SITES OF ANALYSED REFRACTORY MATERIALS

'major' sites (Chs III.2-15)		'minor' sites (Ch III.16)	
11	Grime's Graves	1	Aldermaston
10	Fimber	6	Burderop Down
7	Dainton	12	Gwithian
2	Beeston Castle	18	South Lodge
5	Bramber	23	All Cannings Cross
17	Runnymede Bridge	37	Candlestone Castle
15/66	Mucking	38	Carloggas, St Mawgan
4/33	The Breiddin	48	Danebury
29	Beckford	63	Maiden Castle
64	Meare	65	Merthyr Mawr Warren
53	Glastonbury	73	Salmonsbury
55	Gussage All Saints	80	Uley Bury
74	South Cadbury	81	Walesland Rath
82	Weelsby Avenue, Grimsby	93	Thetford

numbers are those of the production site catalogue (Ch III.16), and identify sites on the map, fig III.1.1



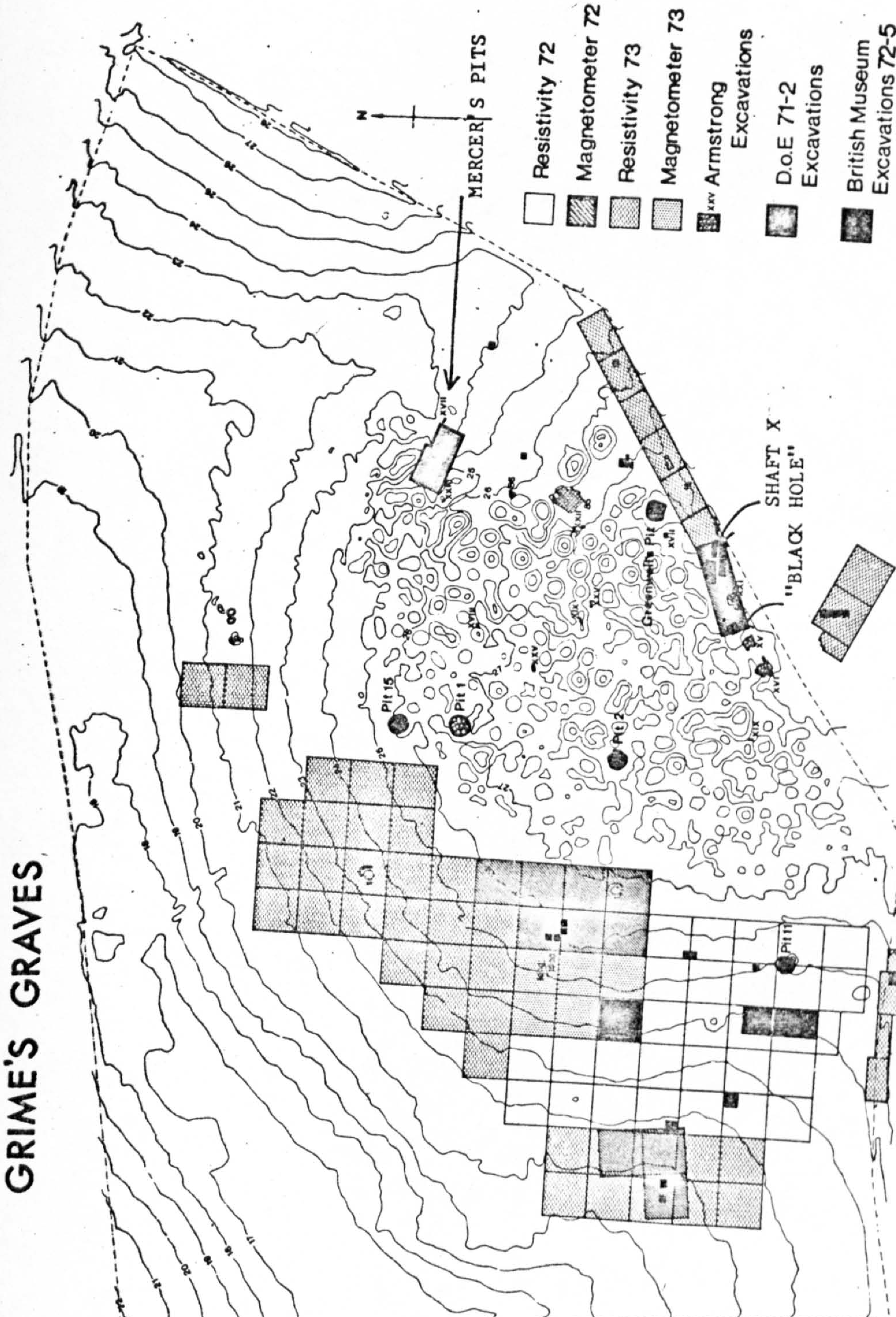
<u>Fig III.1.1</u> Location of sites from which refractory material has been examined in this study. Circled sites are described in Chs III.2-15, others in Ch III.16. O = bronze age ● = iron age. See Table III.1.1

III.2 GRIME'S GRAVES, NORFOLK
(TL 820900; corpus no 11)

Two areas recently excavated (1972, 1975-6) at the important flintworking site at Grime's Graves produced abundant quantities of bronze age occupation and industrial debris (Mercer, 1981; I Longworth, pers comm). A similar range of material was recovered during the 1920s from the "black hole" excavated by A L Armstrong (1926; fig III.2.1). Activity at Grime's Graves dates mainly to the neolithic period, and covers at least 9ha, but the exact location and extent of the bronze age settlement is unknown. Despite meticulous excavation and an extensive phosphate survey, no structures have been identified, and Dr Longworth (pers comm) suggests that houses and workshops may either have been totally eroded, or perhaps removed by later agricultural activity, including forestry work. All bronze age material recovered to date would appear to represent secondary refuse.

The trench excavated by Longworth in 1975-76 was located over an infilled neolithic flint mine (Shaft X) at the north west edge of the known activity area. A shallow cone close to the surface of the shaft had been filled, perhaps over a short time period, with bronze age refuse. The pottery consisted almost exclusively of bucket urns, closely paralleled by Deverel Rimbury forms from the south and west of Britain. Only three small sherds from an undecorated globular urn were identified. Other finds included fragments of clay loomweights, perforated chalk fragments (possibly spindle whorls), a large quantity of worked bone and antler including many unfinished items, worked and burnt flint, and the metalworking debris described below.

Mercer's trench was located some 200m to the north east. Again in the upper fill of a disused neolithic mine shaft was a similar pottery assemblage, and evidence for bone, flint and textile working. Although no moulds or crucibles were found here, a droplet of casting waste and a collection of bronze tools (perhaps metalworkers' tools) suggested the presence of a smith in the vicinity (Mercer, 1981, 36).



<u>Fig III.2.1</u> Grime's Graves, Norfolk: location of excavated areas (drawing supplied by I Longworth).

Both trenches produced massive quantities of charcoal, and thirteen radiocarbon dates were obtained from the fill of Shaft X (Burleigh et al, 1979, 45-6). The calibrated dates indicate intense activity at Grime's Graves for some period around 1300 BC. Analyses to date of faunal remains and environmental evidence strongly suggest permanent middle bronze age settlement at the site (Mercer, 1981, 114). Arable farming was practiced, perhaps taking advantage of the chalky, disturbed ground in the vicinity of the flint mines, and a variety of animals was kept for meat and by-products. The Little Ouse, located 1.6km away from Grime's Graves, would have provided the inhabitants and their stock with a secure water supply.

III.2.1 The metalworking evidence

Over 150 fired clay fragments, representing mould, crucible and possibly hearth were found intermixed with abundant charcoal in the fill of Shaft X. No signs of intense burning or obvious furnace remains suggestive of a working area were detected. Although some clay fragments are very abdraded and thus difficult to assess other than on a fabric basis, most are well preserved, allowing the implements cast to be identified. Typological study (by S Needham) of the diagnostic mould fragments has revealed a remarkable homogeneity in the assemblage. The Grime's Graves metalworkers appear to have specialised in the production of channel-bladed basal looped spearheads. Thirty five fragments of spearhead blade mould (some with outer wrap attached) and 25 fragments of matrices for casting spearhead sockets have been identified. Several socket mould sherds extend to loop plates and blade sections. There is no evidence to suggest the casting of any other implements.

Crucible sherds are rare at Grime's Graves, only one certain and one possible fragment being identified. The remaining refractory ceramics include outer mould sherds (many with binding impressions), unidentified matrix fragments, and anomalous pieces of fired clay, some of which may represent furnace debris. A bronze knife and bent bronze pin were the only cast metal artefacts recovered from the fill of Shaft X, although a few droplets of bronze were found mixed with the ceramic casting waste. The lowest midden material in Mercer's 1972 trench included two bronze awls (perhaps punches for producing pointillé decoration or engraved ornament), two fragments of bronze rod, a saw fragment and a droplet of metallic casting waste (Mercer, 1981, 75).

III.2.2 Analytical results (see Table III.2.1)

Considerable difficulty was experienced in assessing the Grime's Graves metallurgical fabrics in hand specimen. With few exceptions, the sherds are fine, sandy and appear to contain few additional inclusions. Many fragments react with dilute HCl, but this could reflect the post-depositional percolation of ground water rather than the use of a chalky clay for manufacture. As few obvious fabric divisions could be made, it was decided to select sherds for thin section analysis from the various artefact categories identified on typological grounds.

The crucibles

One c 25mm thick-walled body sherd (GG 33) and a possible crucible rim (GG 6) were the only representatives of this artefact type identified at Grime's Graves. GG 33 is extremely hard-fired, silty textured and pale brown (5YR 7/6) throughout its thickness. A whitish film covers the inner surface and no slagging is visible. The sample is seen to contain a medium density (58%) of rounded quartz grains set in a partially isotropic clay matrix. Quartz grains are evenly distributed and an almost equal number of grains represent each Ø class from Ø5-5•5 to Ø1•5-2. Rare, ragged grains of limestone are present throughout, and two angular fragments of reddish flint are observed in the section. The matrix is calcareous and original cracks in the fabric (perhaps caused in use) contain recrystallised calcium carbonate.

The flat rim sherd GG 6 represents a vessel of much smaller capacity. A scatter of quartz grains is clearly visible with the hand lens, and the sherd is fired to a pale pinkish brown (10YR 7/4) throughout its thickness. Under the microscope the fabric of this crucible clearly resembles that of GG 33, containing 62% of rounded, evenly distributed quartz grains and rare flint fragments. The matrix again appears calcareous, but the sample is devoid of discrete limestone or chalk grains. Very little mica, and no detrital minerals are visible in the crucible sherds.

The moulds

Outer moulds are invariably oxidised, whilst considerable variation is apparent in the fired colours of inner matrices (reduced grey zones are not uncommon). Outer moulds tend, on the whole, to be somewhat coarser textured and more porous than inner valves, and generally contain more calcareous inclusions.

1. Inner-mould fabrics

Several fine inner valve fragments are clearly identifiable as blade and socket matrics for channel-bladed spearheads. These fragments are formed from a fine-textured, carefully worked clay, and matrices and contact faces are generally reduced to mid-grey. Outer faces of inner moulds are sometimes reduced, but more often oxidised either to brownish-yellow (7•5YR 7/2 to 7•5YR 7/4) or red (2•5YR 5/8). All inner valves feel sandy although the texture varies from fine, almost powdery, to hard and compact. Reaction with dilute HCl is again very variable. Most samples appear inclusionless, but quartz sand and rare flint are sometimes visible in the coarser samples. Most inner mould sherds appear to be somewhat micaceous.

Under the microscope, the Grime's Graves inner moulds are seen to consist predominantly of rounded quartz sand set in a generally anisotropic clay matrix. Matrices frequently appear calcareous, and as in the crucible sherds, recrystallised calcium carbonate is often visible in voids. Rare, discrete grains of limestone are seen in some sections. Considerable variation is apparent in quartz size range and packing density, but some patterning can be discerned (fig III.2.2). Most sherds contain a little mica, and a scatter of tiny rounded grains of detrital minerals including tourmaline, epidote, spinel, aegerine and colourless pyroxene occurs in various sections. Plagioclase and microcline felspar are occasionally visible and some sections contain fragments of brown or reddish flint. The occurrence of these detrital grains is sporadic, and this, together with the variable texture, suggests that the Grime's Graves mould makers exploited more than one source within the ubiquitous Norfolk Boulder Clays.

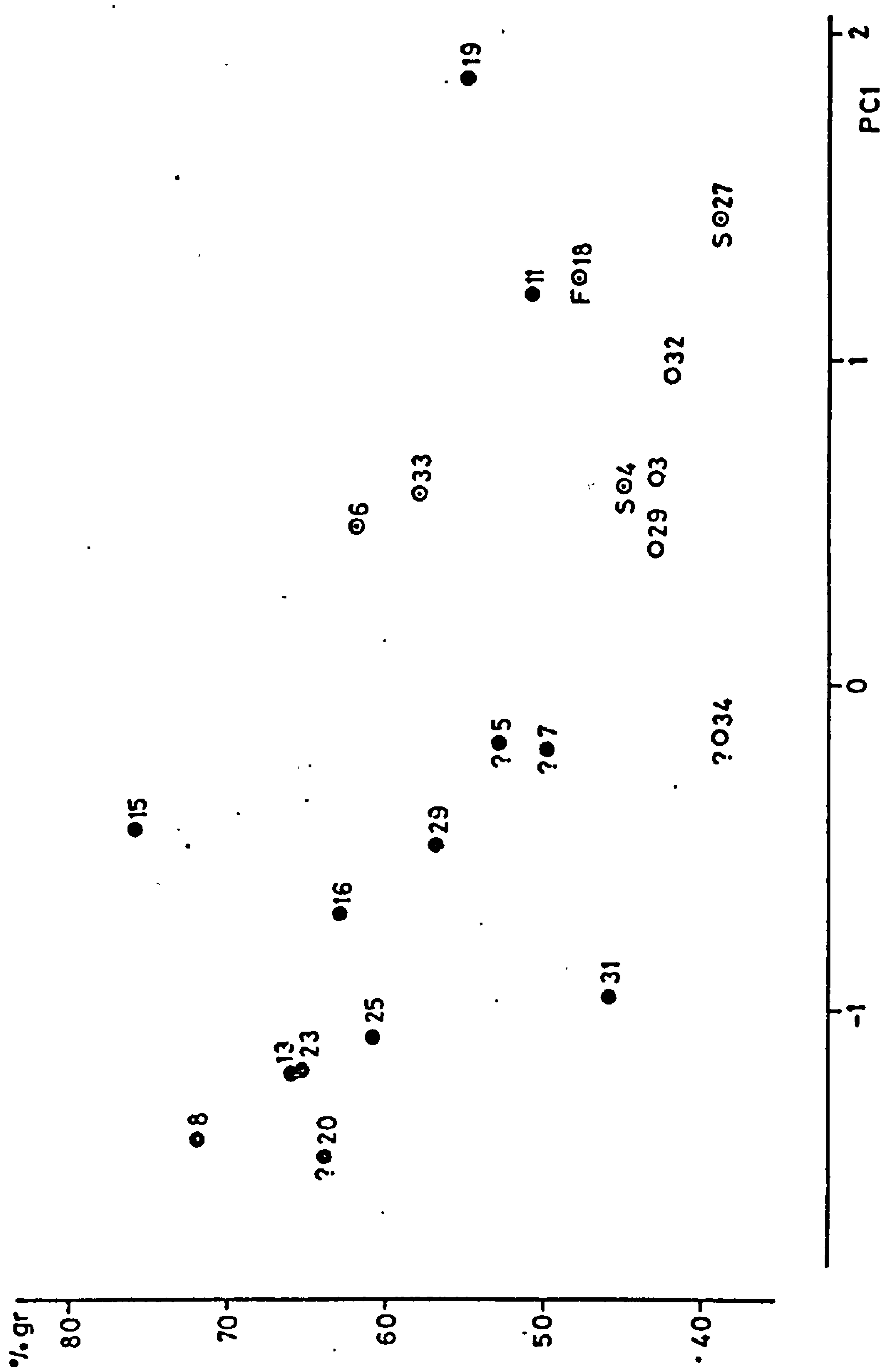


Fig III.2.2 Inner mould (●), outer mould (O), crucible (⊙), sprue cup (⊙S) and furnace (⊙F) sherds from Grime's Graves. Sherds are plotted against grain size (expressed by scores on the first principal component extracted from the ∅ counts) and the proportion of grains:matrix.

2. Outer mould fabrics

Outer wraps are invariably oxidised with surface colours varying from almost white (7•5YR 8/4) through brown (5YR 7/6) to bright red (2•5YR 5/8). With the exception of GG 17, all outer mould sherds examined effervesce freely with dilute HCl, and fragments of chalk or soft limestone are often visible in hand specimen. Under the microscope outer moulds are seen to contain a mineral suite virtually identical to that recorded in the inner valves. However, outer fabrics are coarser, contain more voids and the quartz content is noticeably sparser. Whereas quartz grain density in inner moulds averages 61% (with one example containing 76%), outer moulds contain an average of 42% quartz grains with little variation. Limestone fragments are slightly more abundant in outer moulds, although mica and detrital minerals appear in similar quantities. Two fragments identified as sprue cup (GG 4 and GG 27) are formed from outer mould fabric.

Unidentified clay fragments

Several anomalous fragments of fired clay, in many ways similar to the refractory debris, and found in association with them, were examined in hand specimen and thin section to assist identification. Three of these oxidised fragments (GG 2, 11 and 28) are inclusionless save for very rare quartz grains and recrystallised limestone. These sherds can safely be rejected as refractory fabrics. Sherds GG 5, 7 and 20 would seem, on the basis of inclusion suites and textural analystical results, to represent inner mould, whilst sherd GG 34 is tentatively identified as outer wrap on similar grounds. Sherd GG 30 is definitely part of the base of a bronze age pot, and from descriptions of analysed pottery from the site (see below) it would appear that GG 1 and GG 10 also derive from domestic or funerary ceramic vessels. Sherd GG 18 was tentatively identified as furnace debris on the basis of fired colour, texture and surface vitrification. In thin section, the sample contains a medium density of quartz sand, fragments of clear and brownish flint, and several rounded grains of fossiliferous chalk. This paste is not matched by any of the local clay samples, and thus the identification must, for the present, remain in doubt. It is unlikely that the large quantities of clay required for furnace construction would be transported over considerable distances.

The pottery

Twenty sherds of Grime's Graves pottery have been examined in thin section at the British Museum Research Laboratory. Clay matrices are typically brown, anisotropic and contain variable amounts of poorly sorted quartz sand. All the pottery examined thus far is tempered with angular flint, grog (some of which contains shell), and shell (I Freestone, pers comm, and see table III.2.2). It is clear from these results that completely different formulae were prepared for different categories of ceramic artefacts.

III.2.3 Resource ecology and raw material analysis

The superficial geology of the Breckland area of Norfolk is complex and has not been investigated or mapped in detail. During the Pleistocene, the area was covered by at least four separate ice sheets, and relics of these successive glaciations are now seen as thin mantles of sand, brickearths, Boulder Clays and gravels extending over the Middle and Upper Chalk rock (Chatwin, 1961). These superficial deposits, often mixed and containing erratics indicative of different ice sheet movements, have been worked for brick-making at various locations. Several brick-pits in the area of Grime's Graves are marked on the 1st edition OS map (published 1836) and those active at the close of the 19th century are described by Whitaker, Skertchly and Jukes-Brown (1893). A section of the brick-pit at Santon Downham, reopened in 1876, showed a basal 14" of fine chalky gravel overlain by a thin 4" seam of blue clay. This seam was capped by 13' of Boulder Clay and finally a surface 3-4' of sand and gravel (Whitaker et al, 1893, 46). Clay resembling Norwich Brickearth or Lower Boulder Clay (second Great Eastern Glaciation) have been dug for brickmaking at High Barn some 5km to the north west of Brandon, and pits have been opened since Saxon times at various points along a continuous strip of "loam" which extends from Broomhill, 2km north east of Brandon, to beyond the Grime's Graves flint mines (Whitaker et al, 1893, 47).

Attempts to locate most of the pits described in the 1893 memoir met with complete failure. Many (including the Santon Downham pit described above) have been backfilled and planted by the Forestry Commission. Others have filled with water and become stagnant ponds with only the upper, gravelly layers in evidence. Although overgrown, the brickpit at Broomhill, some 2km to the west of the Grime's Graves site, is still accessible, and the 19th century kilns, complete with wasters, were located. Two samples (GG 6 and GG 7) were taken from this pit, and brick wasters were collected for comparison. The remaining samples collected in the Grime's Graves area all came from clay pockets in open sand and gravel pits (fig III.2.3; table III.2.3).

In thin section the raw material samples bear little resemblance to the Grime's Graves refractory fabrics. The distinctive mica, red flint and detrital minerals are absent from the local clays collected. Whilst it is possible that matching materials may exist in the now inaccessible clay pits, it is equally feasible that the metalworkers may have travelled further afield for their supplies. With this possibility in mind, the Grime's Graves refractories were compared with thin sections of some 80 Boulder Clay samples from other areas of Norfolk. These samples were collected and processed by Andrew Russell (University of Southampton) in connection with a detailed investigation of East Anglian Saxon pottery. I am grateful to Mr Russell for access to his unpublished material. A close match was found for the fine inner mould fabrics in a sample from a drainage ditch at Watton (TF 928017, Russell C33) and outer mould fabrics are paralleled by samples from Narborough (TF 743127, Russell C29) and Beachamwell (TF 744028, Russell C38). The nearest of these sources (C38) is some 20km north of Grime's Graves. No match was found for the crucible fabric.

It is not suggested here that these were, in fact, the sources exploited by the Grime's Graves metalworkers. The great range of variability exhibited by the Norfolk Boulder Clays is well illustrated by four samples taken from a house foundation at Merton (TL 906988, Russell C40, C44, C49, C51). Considerable differences are observed in grain size and density, and presence/absence of sandstone, flint and detrital minerals among all these samples.

Although further intensive sampling in the Grime's Graves area may provide a close match for the refractories, the great variability

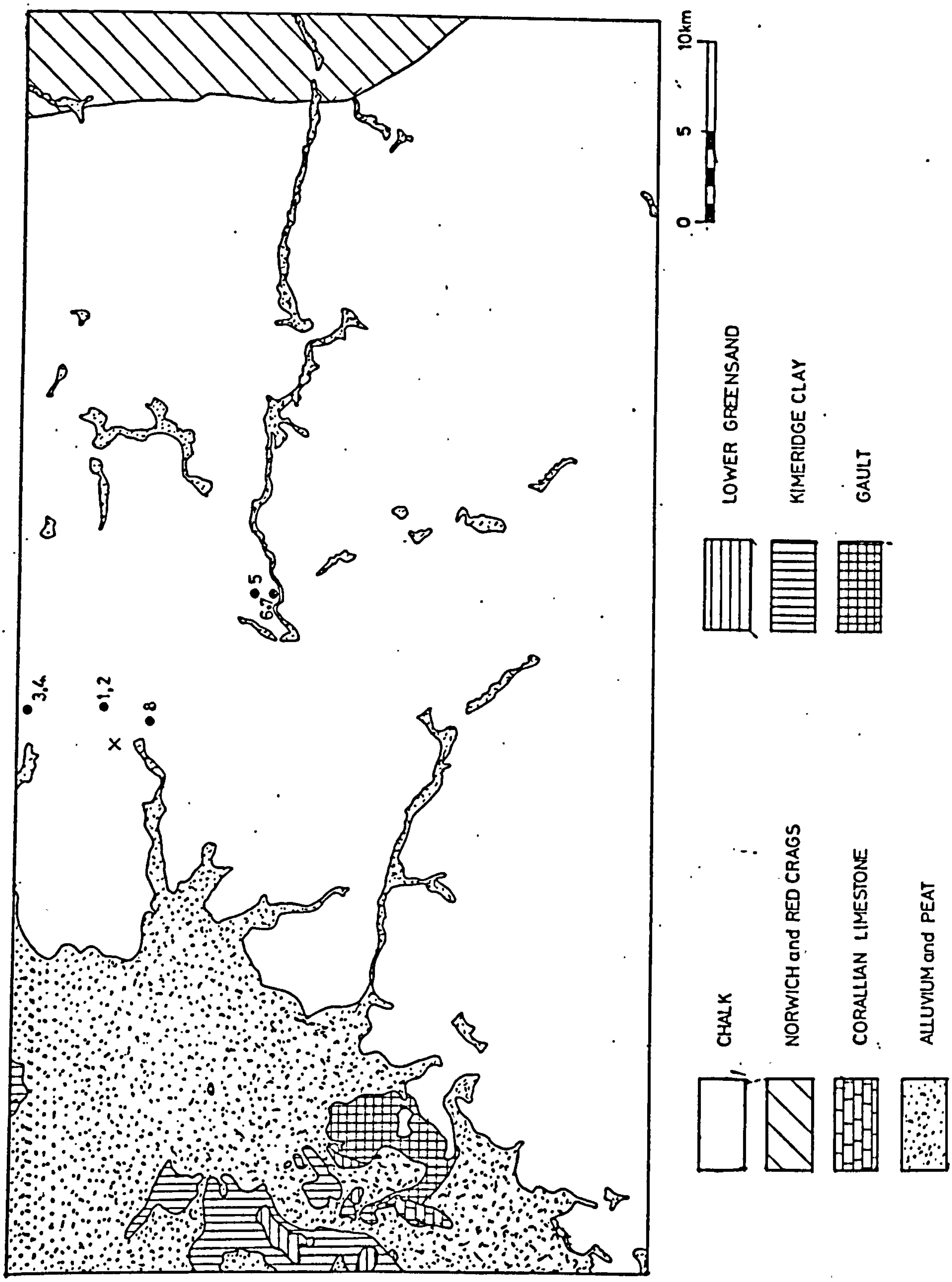


Fig.III.2.3 Geology around Grime's Graves, and location of raw material samples apparent among the Norfolk Boulder Clays means that precise source identification must always remain in doubt.

III.2.4 Discussion

Although it is now difficult to locate clays in the vicinity of Grime's Graves, it is clear from the geological literature that ceramic raw materials once existed in profusion and were commercially exploited. The availability of good clays (and perhaps sands) suitable for the manufacture of a wide functional range of ceramic artefacts may have been one factor deciding the location of the Grime's Graves settlement site.

A considerable degree of variation was observed in the mineralogical composition of the refractory fabrics, and similar variation is echoed in closely located samples of the Norfolk Boulder Clays. Hence, although results of petrological analysis provided an insight into the technology of refractory manufacture at the site, no distinct groupings suggestive of separate casting episodes could be discerned. This is especially unfortunate in view of the homogeneity of the implements cast.

All mould fragments identified at Grime's Graves were designed to cast basal-looped, channel-bladed spearheads. Rowlands has drawn attention to the technical skills necessary to cast these complex implements, skills which may not have been available to all smiths (Rowlands, 1976, 141). The distribution of basal-looped spearheads is concentrated on the Thames Valley and East Anglia, and the paucity of finds from other areas, together with minimal morphological variation, argues for circulation from specialist production centres in eastern England (Rowlands, 1976, 63). Although the Grime's Graves metalworking material had not been recovered at the time of Rowlands' study, he was able to predict from distributional and metal typological evidence "the presence [in the Cambridge region] of a more specialist category of smiths operating under different constraints from those working at local level for local production ... and ... more closely tied to those institutions that organised regional and long distance exchange" (Rowlands, 1976, 122). The mould assemblage described here strongly supports the case for a "specialist category" of resident smiths. Although it is possible that these smiths were producing channel-bladed spearheads primarily for an exchange network, it is also suggested that the Grime's Graves bronzeworkers may have been producing for an élite group, not for exchange, but to provide weaponry to assist that group to maintain its position of regional dominance. The role of the weapon-smith will be discussed in a broader context in Part IV of this study.

TABLE III.2.1 GRIME'S GRAVES: CONCORDANCE OF SECTIONED SHERDS

Sample number	Sherd number	Context	Typological identification
GG 1	GG 250	β7 (3)	Possible furnace
GG 2	GG 325	β7 (3)	Possible furnace
GG 3	GG 1032A	1275/900 (2)	Outer mould with binding impression
GG 4	GG 1033A	1275/905, topsoil	Gate support
GG 5	GG 1033D	1275/905, topsoil	Unidentified
GG 6	GG 1158C	1275/905 (4) G	Possible crucible rim
GG 7	GG 1162	1275/905 (4) J	Unidentified
GG 8	GG 1165A	1275/905 (4) K	Outer mould on flattish inner
GG 9	GG 1168A	1275/905 (4) L	Inner mould; socket. No definite contact face
GG 10	GG 1168B	1275/905 (4) L	Possible furnace
GG 11	GG 1182	1275/905 (4) I	Abraded blade of channel-bladed s/hd; outer and inner
GG 12	GG 1234	1275/905 (4) A	Unidentified
GG 13	GG 1261A	1275/905 (6) P	Inner mould; little matrix; slight bevel
GG 14	GG 1276C	1275/900 (5) A	Unidentified
GG 15	GG 1280A	1275/900 (5) E	Inner mould; socket
GG 16	GG 1310	1275/905 (5) A	Inner mould; socket side with possible loop
GG 17	GG 1311	1275/900 (5) A	Outer mould
GG 18	GG 1330A	1275/905 (5) J	Possible furnace
GG 19	GG 1339	1275/905 (5) E	Inner mould; channel-bladed s/hd
GG 20	GG 1394	1275/905 (5) L	Unidentified
GG 21	GG 1416	1275/900 (4) B	Inner and outer mould; channel-bladed s/hd
GG 22	GG 1468	1275/905 (5) K	Inner mould; small matrix fragment with sharp angle
GG 23	GG 1479A	1275/900 (5) F9	Inner mould
GG 24	GG 1479B	1275/900 (5) F9	Outer mould
GG 25	GG 1479E	1275/900 (5) F9	Possible inner mould
GG 26	GG 1479F	1275/900 (5) F9	Inner mould; thins rapidly to one edge
GG 27	GG 1495B	1275/900 (5) F9	Sprue cup rim
GG 28	GG 1496A	β43 (5)	Possible outer mould
GG 29	GG 1514A	β43 (4)	Inner mould; channel-bladed s/hd, small blade fragment; no contact face
GG 30	GG 1535	β41 (6)	Pottery base
GG 31	GG 1564	1275/905 (6) I	Inner mould; channel-bladed s/hd; straight blade edge
GG 32	GG 1575	1275/905 (6) K	Outer mould with binding impressions
GG 33	GG 1651	1270/900 (13) E	Crucible
GG 34	GG 1656D	1270/900 (13) D	Unidentified
GG 35	GG 1688	1285/910, topsoil	Small fragment of inner mould; probably socket

TABLE III.2.2 INCLUDED MATERIALS IN BRONZE AGE POTTERY FROM GRIME'S GRAVES (compiled by I Freestone, British Museum Research Laboratory)

Sample no	Coarse sand >0·5mm	Medium sand 0·5-0·25	Fine sand 0·25-0·06	Silt 0·06>	Flint in sand	Chalk	Flint temper	Grog	Shell in grog	Flint in grog	Shell
P264	xx	xx	xx	xx	p	-	-	xxx	p	p	xxx
L1366	-	x	xx	xx	-	-	xxxx	?xx	-	?p	-
L1467	-	xxx	xxx	xx	-	-	-	xxxx	p	-	xxx
L1324	-	xx	xxx	xxx	-	-	-	xxx	p	-	xxx
P254	-	xx	xx	xx	p	-	?x	?xx	?	-	xx
P256	x	xx	xx	xx	p	-	?xx	xxx	p	-	xxx
L1452	xx	xxx	xx	xx	p	-	-	xxx	-	-	xx
L2649	-	x	xx	xx	-	-	xxxx	-	-	-	-
P145	x	xx	xxx	xxx	-	xxx	-	xxx	p	-	xxx
P147	xx	xxx	xxx	xxx	p	xx	xx	xxx	p	p	xxx
P253	-	xx	xx	xxx	p	-	xx	xx	p	-	xxx
L1900	xx	xxx	xxx/x	xxx	p	-	-	-	-	-	xxx/x
P5	x	x	xx	xx	-	xx	xxx	xxx	-	p	-
P236	x	xx	xx	xx	-	-	-	xxx	p	-	xxx
P74	-	xx	xx	xx	-	-	x	xxx	p	-	xx
P72	x	xx	xx	xx	-	-	xxx/x	xxx	p	-	xx
P28	-	xx	xx	xx	?p	xx	?xx	xxxx	p	-	xxx
P69	-	xx	xx	xx	-	-	xxxx	xxx	p	-	xx
L2409	xx	xxx	xxx	xxx	-	-	-	-	-	-	xxx
P245	-	x	xx	xx	-	-	xxxx	-	-	-	xxxx

x = present, rare
xx = sparse/occasional
xxx = common
xxxx = abundant

**Relative abundance of inclusions has been subjectively assessed; these symbols should be used only as a guide

p = present (in variable amounts)
- = absent

TABLE III.2.3 RAW MATERIAL SAMPLES: NORFOLK

Sample no	Grid ref	Geological notes
GG 1 (C)	TL 827907	Sand, overlying Breckland Chalk (occasional clay pockets)
GG 2 (C)	TL 827907	Sand, overlying and interbedded with Chalk (occasional clay pockets)
GG 3 (S)	TL 822945	Thick sand deposit overlying Chalk (sand with flint and quartzite)
GG 4 (S)	TL 822945	Thick sand deposit overlying Chalk (sand with flint and quartzite)
GG 5 (C)	TL 812895	Chalk with pockets of clay
GG 6 (C)	TL 805891	Boulder Clay overlying Chalk, from brickpit
GG 7 (C)	TL 805891	Boulder Clay overlying Chalk, from brickpit
GG 8 (S)	TL 825873	Alluvium: sand from river bank
C33 (C)	TF 928017	Boulder Clay (sampled by A Russell)
C29 (C)	TF 743127	Boulder Clay (")
C38 (C)	TF 744028	Boulder Clay (")
C40 (C)	TL906968	Boulder Clay (")
C44 (C)	TL 906968	Boulder Clay (")
C49 (C)	TL 906968	Boulder Clay (")
C51 (C)	TL 906968	Boulder Clay (")

S = sand C = clay

OBJECT	SLIDE	% GR: MAT	NO. OF GRAINS	PHI -1 TO -.5	PHI -.5 TO 0	PHI 0 TO .5	PHI .5 TO 1	PHI 1 TO 1.5	PHI 1.5 TO 2	PHI 2 TO 2.5	PHI 2.5 TO 3	PHI 3 TO 3.5	PHI 3.5 TO 4	PHI 4 TO 4.5	PHI 4.5 TO 5	PHI 5 TO 5.5	MEAN GRAIN SIZE MM.	STD DEV
CRUCIBLE																		
	33	58	103	0	0	0	2	8	11	17	8	12	7	10	7	19	.1482	3.21
	6	62	111	0	0	0	5	5	17	9	5	14	8	8	10	19	.1522	3.70
N SLIDES			2															
N GRAINS			214															
FURNACE																		
	18	48	88	0	0	2	2	10	11	15	17	7	10	2	13	8	.1765	4.61
N SLIDES			1															
N GRAINS			58															
SPRU CUP																		
	27	39	67	0	0	0	4	10	15	21	9	12	6	6	4	12	.1828	4.40
	4	45	104	0	0	0	1	6	12	19	11	9	9	7	12	14	.1438	2.85
N SLIDES			2															
N GRAINS			171															
IN MOULD																		
	11	51	100	0	0	1	5	8	20	5	13	13	3	7	3	22	.1765	4.79
	13	66	94	0	0	0	1	1	3	2	10	12	19	13	18	21	.0835	1.09
	15	76	109	0	0	1	2	5	6	7	7	5	14	10	18	25	.1114	2.64
	16	63	110	0	0	0	2	5	3	5	6	5	6	14	17	36	.0873	1.80
	19	55	93	0	0	1	4	8	22	20	13	13	5	4	6	3	.2046	5.16
	23	66	81	0	0	0	0	0	0	4	12	12	11	14	19	28	.0657	.570
	25	61	83	0	0	0	0	0	4	7	7	16	13	16	13	24	.0796	.892
	29IN	57	103	0	0	0	0	2	8	11	8	19	11	15	9	18	.1069	1.59
	31	46	100	0	0	0	1	7	0	5	1	8	10	9	24	34	.0815	1.58
	8	72	87	0	0	0	0	0	1	3	7	11	14	13	18	32	.0631	.513
N SLIDES			10															
N GRAINS			960															
OU MOULD																		
	29OU	43	100	0	0	0	1	4	14	11	16	10	10	8	8	18	.1344	2.55
	3	43	96	0	0	0	2	6	16	15	17	6	10	9	13	10	.1495	3.16
	32	42	69	0	0	0	5	10	14	12	9	7	6	12	6	19	.1726	4.53
N SLIDES			3															
N GRAINS			265															
UNKNOWN																		
	20	64	93	0	0	0	1	1	0	3	4	19	16	16	17	22	.0720	.878
	34	39	66	0	0	0	2	3	9	12	9	12	12	12	14	15	.1211	2.30
	5	53	100	0	1	0	0	2	7	10	13	10	9	6	18	24	.1087	2.52
	7	50	102	0	0	0	0	2	11	9	14	9	7	10	19	21	.1077	1.71
N SLIDES			4															
N GRAINS			381															
			22															
			2079															

Table III.2.4 Grain size statistics for Grime's Graves.

III.3 FIMBER, HUMBERSIDE
(SE 887606; corpus no 10)

The site at Lady Graves, Fimber, is located on the east side of Wansdale, approximately two km west of Fimber village on the Yorkshire Wolds (fig III.3.5). In 1869, the well-known local antiquary, J R Mortimer, discovered pottery, animal bone and carbonised material in two pits cut through the eastern rampart of a linear earthwork. One of these two pits, some 1•3m across, additionally contained a quantity of strangely-shaped fragments of fired clay (Mortimer, J, 1899-90; 1905). Although he was unable to identify the nature of these sherds, Mortimer sensibly retained them, and deposited all material from OS160f68 (his personal field code) in a box labelled "Curious Pieces" in the Museum of Archaeology and Transport in Hull. Some 60 years later, this box aroused the curiosity of Mr T Sheppard, then curator of Hull museum. Sheppard (1930) recognised the sherds as fragments of clay moulds for casting bronze implements.

In 1981, a geophysical survey conducted in the probable area of the site resulted in the location of the pits together with other anomalies which may represent settlement evidence (M Ehrenberg, pers comm). Trial excavations took place at Fimber in August-September 1982, and will continue in 1983.

III.3.1 The metalworking evidence

Following Sheppard's identification of the moulds, the assistant curator, G K Beaulah, was able to identify at least seven different matrices for swords, sword chapes and two moulded-mouthed socketed axes. A complete core, probably from a spearhead was also recorded (Sheppard, 1930; fig III.3.1a). The reconstructed moulds were conserved and displayed in the museum at Hull, together with a model illustrating the casting methods employed (figs II.2.1 and III.3.1).

The Fimber material was later reexamined and republished by

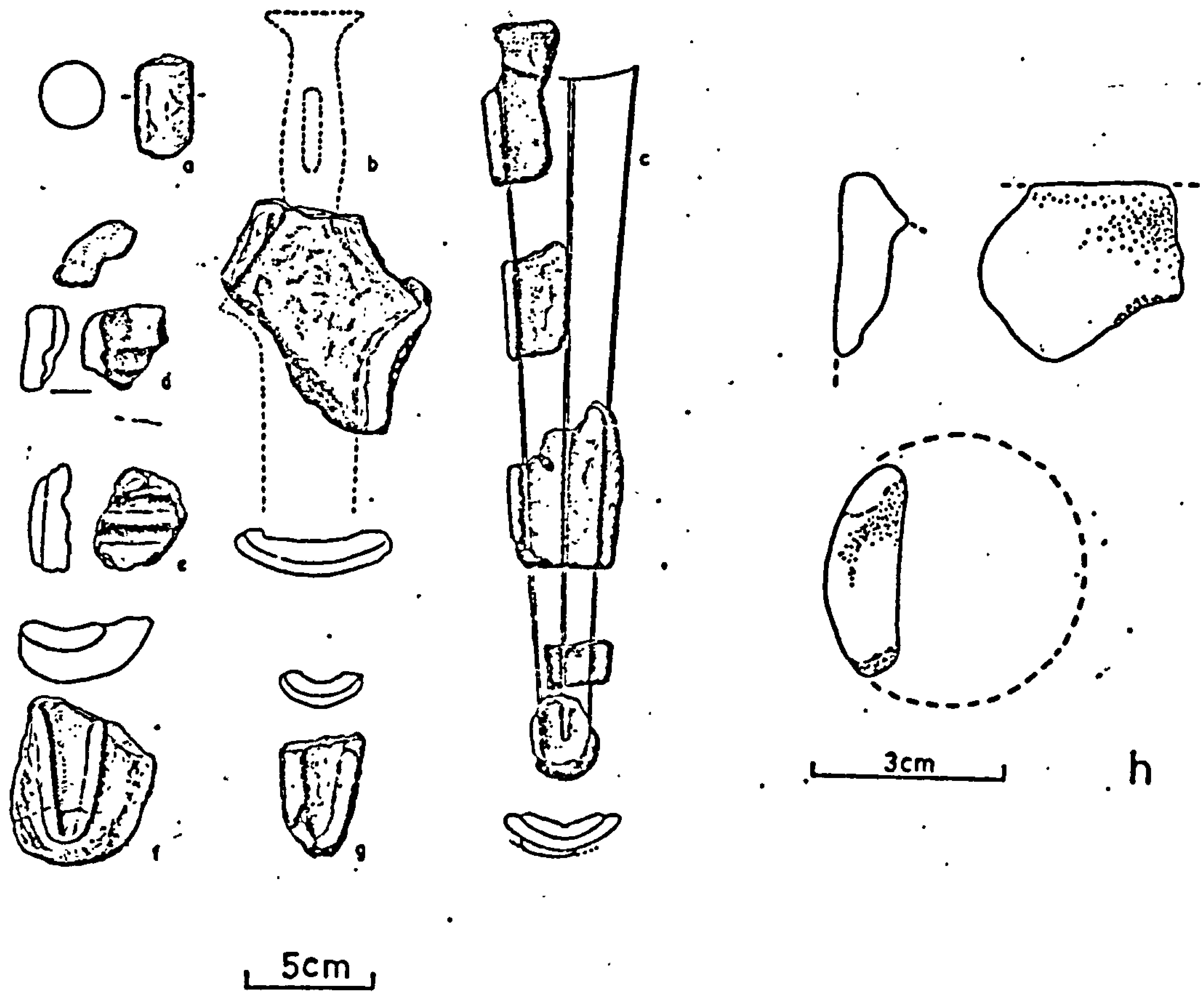


Fig III.3.1 a-g: mould fragments from Fimber (after Burgess, 1968, fig 21); h: pouring gate or sprue-cup from Fimber.

Colin Burgess who ascribed the cast weapon types to the (c 1000 bc) Wilburton metalworking tradition. He identified the socketed axes as belonging to the Wallington industry, the northern chronological equivalent of the southern British Wilburton complex (Birgess, 1968b, 28).

In 1978, all displayed and stored sherds were examined by the writer. The displayed pieces are permanently affixed to mounting boards and have been conserved with "Wolfite" (Sheppard, 1930, 351) which has obscured the original fired colour and much surface detail. Examination was thus extremely difficult, and fabric determinations of displayed material must be considered as tentative. The box marked "Curious Pieces" contained 64 fragments of clay mould in original (unconserved) condition with inner and outer wraps well preserved, a little charcoal and animal bone and a small quantity of potsherds. The stored moulds represent inner valve (ten sherds), outer wrap (18 sherds) and inner with outer attached (36 sherds). Many fragments are too small and abraded to allow identification of the objects cast, but sword and chape mould parts may be recognised. A single sherd would seem to derive from a gate or sprue-cup (fig III.3.1h). Several outer wrap sherds bear impressions on their concave surfaces of the material used to bind the inner valves together prior to casting (fig II.2.1).

III.3.2 Analytical results (see Table III.2.1)

Fabric 1: inner mould

Inner valves are uniformly fine, compact, and slightly sandy to the touch. Most examples are reduced to mid-grey throughout their thickness, but partially oxidised zones (5YR 6/8) are sometimes present. All inner mould sherds appear to contain finely divided mica, and most react mildly with dilute HCl. Six sherds were separated as a subgroup (1a) within Fabric 1. These sherds, which include the sprue-cup fragment FIM 25, are distinguished by an exceptionally fine texture and brighter surface colour (2•5YR 5/6).

Twelve samples of inner mould (representing both Fabric 1 and 1a) were removed for thin section analysis, including seven with outer wrap attached. Under the petrological microscope, the partially isotropic, red brown clay matrix is seen to contain abundant subangular grains of quartz sand interspersed with tiny threads of white mica. Fabric 1 sand inclusions are generally less than 0•09mm across, but occasional grains to 0•35mm are observed (figs III.3.2 and 3). Rare, tiny grains of cryptocrystalline limestone are visible in some samples. Inner mould paste is consistently well prepared; inclusions are evenly distributed, and little variation in quartz:matrix density is recorded between measured sherds. Fabric 1a (FIM 3, 18, 25) is distinguished only by an overall finer grade of quartz sand (fig III.3.2).

Fabric 2: outer mould

Outer wraps are generally more friable than inner valves, and consistently more open textured. Surface and core colours are variable,

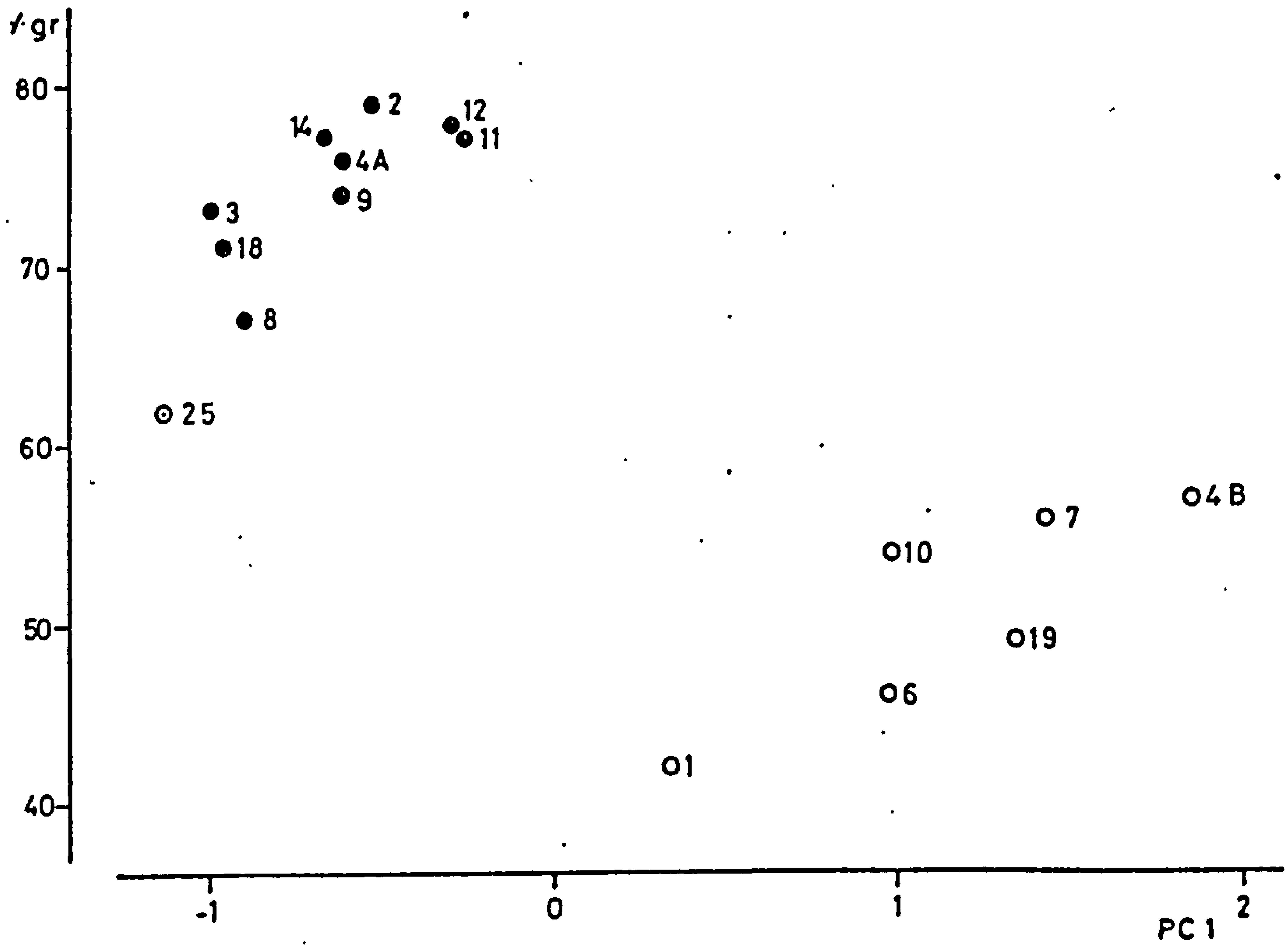


Fig III.3.2 Inner mould (●), outer mould (O) and sprue-cup (⊙) sherds from Fimber. Sherds are plotted against grain size (expressed by scores on the first principal component extracted from the Ø counts) and proportion of grains:matrix.

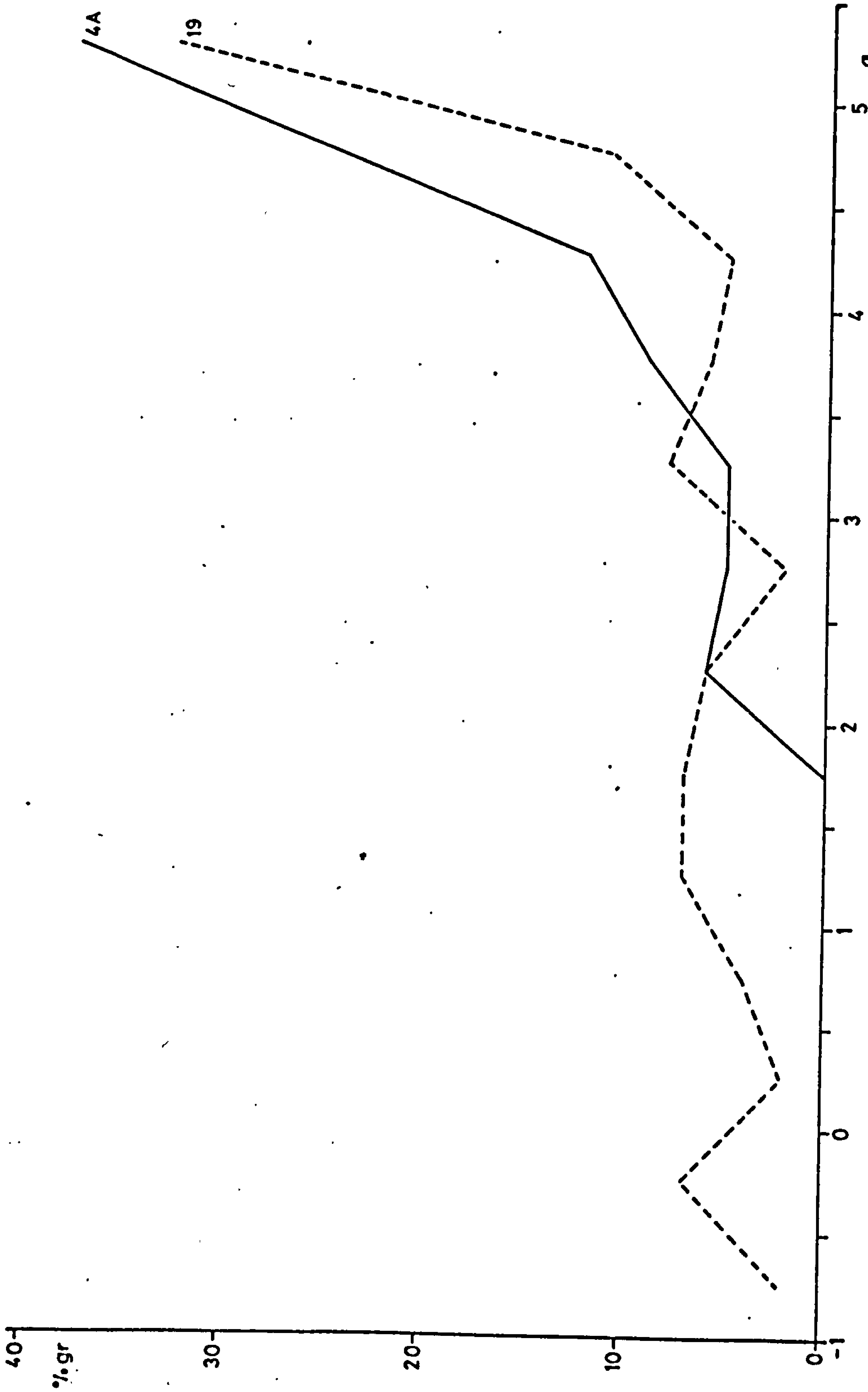


Fig III.3.3 Grain size curves for inner mould (4A) and outer mould (19) sherds from Fimber.

ranging from 10YR 5/4 (yellowish brown), through 5YR 5/3 to 5YR 5/6 (red-brown to yellowish red), to highly oxidised 2•5YR 6/6 (red). Considerable colour variation is often visible within a single sherd, and some samples are reduced throughout their thickness. Many outer wrap fragments contain a little carbonate in the form of sparse whitish inclusions or rounded and elongate voids which effervesce with dilute HCl. The most significant feature of these sherds, however, is the presence of abundant angular fragments of igneous rock to 3•0mm across. These fragments, visible in all 'outer' samples examined, are sometimes dark green-grey, but more often mottled grey and grey-green in hand specimen.

Thin section analysis of outer wrap sherds reveals that a different clay source was exploited for the production of the respective mould parts. The anisotropic 'outer' matrices contain variable amounts of fine quartz, about 30-40% of the fabric (Table III.3.2). Mica is present though very sparse in all samples, and some sherds contain rare sub-rounded grains (up to 1•4mm) of cryptocrystalline and microcrystalline limestone. The distinctive igneous rock, visible in hand specimen, is seen in thin section to consist of laths of fresh andesine-labradorite felspar, patches and interstitial grains of clear and pale brownish augite, and black ilmenite. Minor quantities of small quartz grains also occur, and the augite patches are sometimes fringed with chlorite which heat has turned brown. The rock is identified as a quartz dolerite, and is identical in thin section to the dolerites of the Whin Sill in Teesdale (Holmes and Harwood, 1928). Angular fragments of dolerite varying in size from 0•1mm to 2•0mm are present in all outer mould sections examined. Occasional free laths of felspar and angular grains, presumably detached from the parent rock, are also visible. The freshness and angularity of the rock inclusions suggest that dolerite was deliberately crushed and added to outer mould clays to increase the porosity and improve refractory properties (cf Table III.3.2 and fig III.3.4).

The pottery

Six potsherds were examined macroscopically and in thin section for comparison with the Fimber refractories. Five of these were found with the mould fragments whilst the sixth derived from a bronze age urn

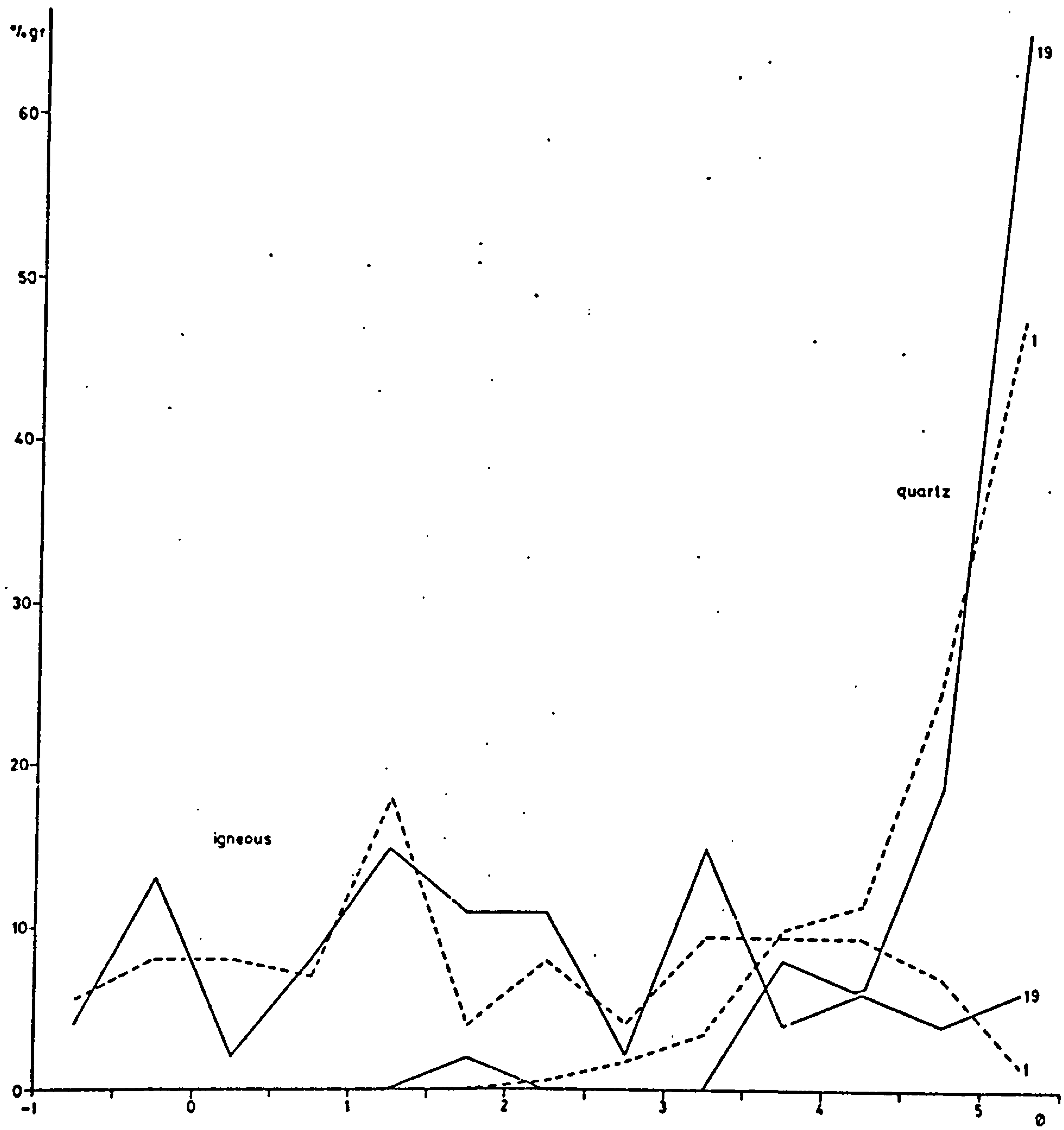


Fig III.3.4 Grain size curves for quartz and igneous inclusions in two Fimber outer mould samples (FIN 1 and 19).

recovered from a barrow beneath Fimber church (SE 894606). Three of the sherds from the mould pit are of similar fabric (FIM 16, 17, 24). The fine-textured clay contains little quartz silt and has been tempered with angular fragments (to 1·5mm) of crystalline calcite. A fourth sherd from the same context (FIM 22) is again poor in quartz, but contains instead of calcite, angular fragments of flint of similar size. The fifth sherd from the pit (FIM 13) is exceptionally hard fired and was originally identified as a hone (Sheppard, 1930). The sherd is probably of Roman date, and therefore intrusive. The urn fabric (FIM 23) is extremely friable, reduced to black throughout its thickness, and contains abundant rounded quartz sand (c 0·3-0·5mm), a scatter of chalk, and considerable organic material.

III.3.3 Resource ecology and raw material analysis

Programme

A notable feature of the Senonian Chalk of the Wolds area around Fimber is a series of shallow depressions containing Drift deposits of non-fossiliferous sand and brickearth (fig III.3.6). These deposits have been variously described as "Upper Eocene" and Oligocene (R Mortimer, 1886; Versey, 1937), but the results of recent work have shown that all sandy deposits thus far examined may be attributed to Pleistocene glacial and periglacial processes, and the original derivation is unclear (Bray et al, 1981; Catt et al, 1974).

The inclusion suite represented in the inner valve sherds suggested that fine silty deposits such as those mapped by Mortimer and described by Bray et al (1981) were exploited for the production of these mould components. The modern settlement of Fimber is located on one such clay deposit (of unknown extent) which was supposedly dug during the bronze age for the building of a burial mound, and is now surmounted by the village church (J Mortimer, 1905, 189). The mound construction and subsequent clay digging have left a large depression which became Fimber pond (early spellings Fimmar and Fimmere). A local resident recalls the existence some years ago of two ponds, known as Upper Pond and Lower Pond. These ponds were renowned in the Wolds area for containing water when other artificially created dewponds had run dry in times of drought.

Fimber was also well known for the ease with which rainwater cisterns could be sunk into the ground. The extensive and thick clay deposits meant that cistern pits could be dug with a spade, rather than with the pick and crowbar necessary in other villages (Mr Wright, of Fimber, pers comm). Samples were taken from Upper Pond (Lower Pond has been backfilled) and from pipe-trench excavations some 200m distant on the same clay deposit. Further samples were taken from similar drift clays located within 10km of Lady Graves (R Mortimer, 1886; fig III.3.5).

The dolerite present in the outer mould sherds suggested a source somewhat further afield. Despite Mortimer's description of "foreign stones being thrown out of a clay bed at Fimber" in the 1830s (quoted in a letter from J L Rome, reproduced in Bisat, 1939), recent field work has failed to locate any such material in the Wolds' clays (Bray et al, 1981; Catt et al, 1974). Igneous erratics are, however, common in the extensive Boulder Clay deposits which form the Yorkshire coastal cliffs and the Plain of Holderness. Geologists examining these erratics have noted that boulders of Whin Sill dolerite dominate the range of foreign rocks in the purple, or middle Boulder Clay layer (Stather, 1928), and that large quantities of this material may be found strewn along the beach from Flamborough to The Wash.

Four main questions determined sampling design in the coastal area:

1. What is the mode of occurrence of Whin Sill dolerite in the Boulder Clay?
2. Is this rock sufficiently distinctive among the erratics to have been purposefully selected as a tempering agent?
3. Are any or all of the Boulder Clay strata of refractory quality in their raw state?
4. Could any of the Boulder Clays, if appropriately prepared and tempered, have been used for mould production at Fimber?

Geological literature concerning both the variability of erratic distribution and the interbanding of the various Boulder Clay strata along their extension (Carruthers, 1939; Lamplugh, 1889; Reid, 1885; Stather, 1928) suggested the selection of three different sampling areas (fig III.3.5). Twenty one coastal clay samples, represnting all strata encountered, were collected, together with numerous rock fragments from both the clay and the beach.

Results (see Table III.3.3)

Considerable variation is observed within the seventeen clay samples taken from the Pleistocene Wolds deposits. Virtually all samples cotain a high tenor of fine subangular quartz, and all save YK 10, YK 30, and YK 37 contain varying quantities of mica. Although quartz size ranges vary between deposits (from average 0•02mm to 0•25mm), each sample is internally homogeneous. Sample YK 9, for example, only contains quartz grains form 0•01-0•03, whilst the grains present in YK 42 range from 0•15mm to 0•27mm.

When the fired, thin sectioned clays were compared with the mould fabrics, it was possible to eliminate several samples from further consideration by the presence of angular inclusions of flint and abundant carbonates (YK 8, 10, 12, 13, 31, 32, 35, 38, 40). Samples YK 28, 34 and 36 all closely resemble inner mould fabric 1a in quartz size, packing density and abundance of matrix mica. Any of these deposits could have been exploited by the Fimber mould makers.

The grain size range recorded in Fabric 1 was not found in any of the Wolds samples examined. However, the exceptionally sandy YK 42 from Westfiled Farm near Lady Graves (kindly supplied by Dr P Walsh of Imperial College, London; cf Bray et al, 1981) contains sand grains all similar in size to the largest grains represented in inner mould Fabric 1. From the evidence, two possible methods of inner mould (Fabric 1) preparation may be suggested. Firstly, a quartz-rich clay encompassing grain size ranges present in sample YK 42 and, say, sample YK 36 (these two are located approximately 1km apart, and probably are derived from the same drift deposit) may have been used in 'as dug' state, without any additives. Secondly, clays from closely located deposits with slightly different average grain sizes may have been mixed and thoroughly wedged to produce the Fimber inner moulds. Extensive and detailed auger sampling and experimentation is required to test these possibilities.

Although several of the coastal Boulder Clays (notably those from the Hessle and 'Purple' layers) contain a high tenor of quartz sand, and

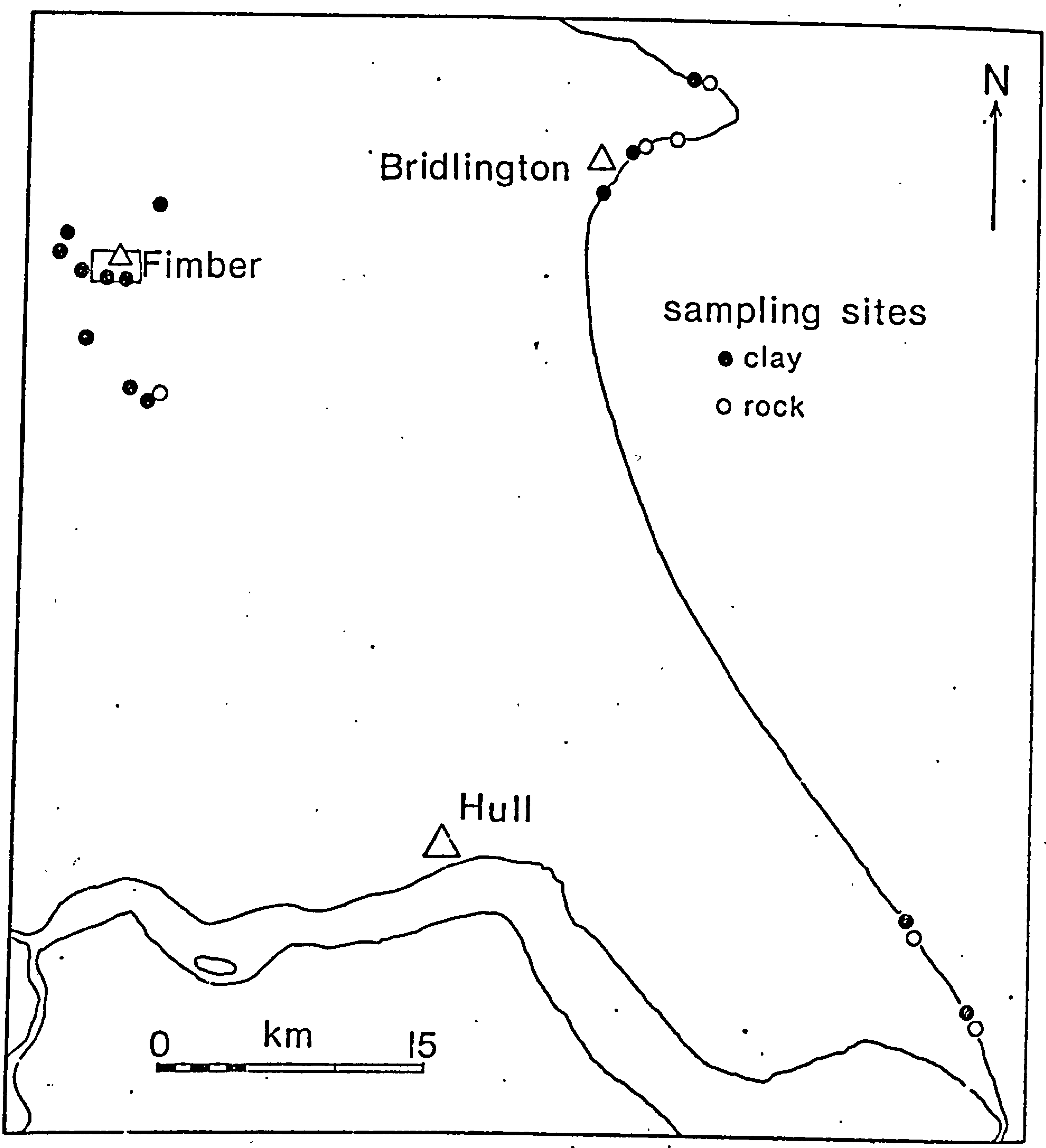


Fig III.3.5 Clay and rock sampling sites in Yorkshire. Most sites provided more than one sample. For detail of Fimber area, see fig III.3.6.

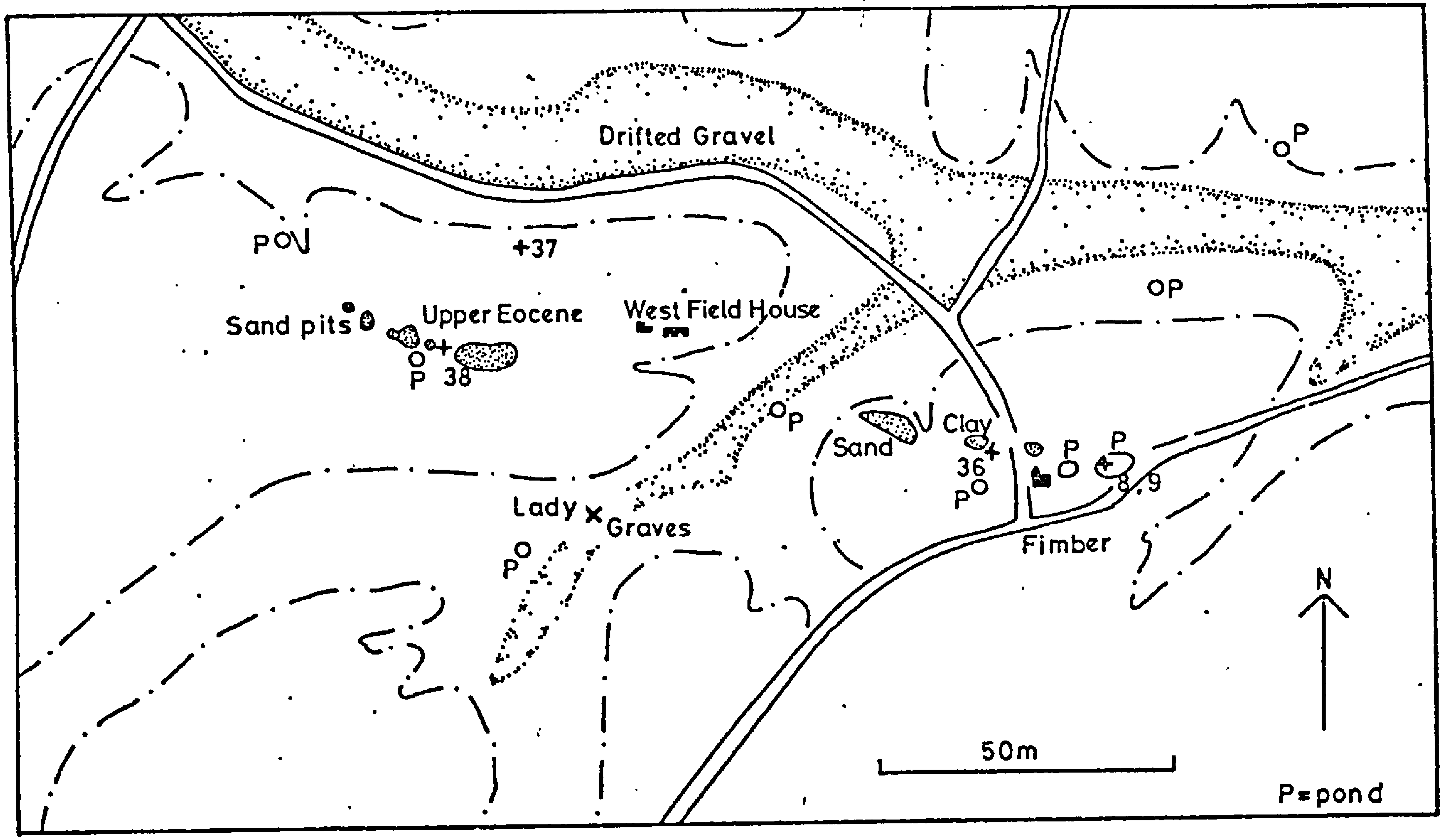


Fig III.3.6 Area around Fimber, copied from R Mortimer's map (1886). Lady Graves was not marked by Mortimer, but has recently been located by M Ehrenberg from J R Mortimer's records. Numbered crosses are the writer's clay samples. The other notations are all on the original map. The sand and clay outliers are now known to be Quaternary, not Eocene.

fire satisfactorily to 1100°C, none contains sand in comparable density to that present in mould Fabric 1. Whilst the possibility that additional sand was worked into one of these clays to produce the inner mould paste cannot be discounted, an origin local to Fimber would seem more likely on the basis of available evidence.

As observed above, no "foreign stones" have been located in the Wolds clays of the Fimber region. Thin sections of the seventeen Pleistocene Wolds clays collected by the writer not only lack erratic rock fragments, but also visible detrital minerals other than very rare grains of tourmaline and epidote. Analysis of both clays and rocks from the various coastal sampling points revealed the mode of preparation of the Fimber moulds. Only four of the coastal clay samples examined contain distinctive igneous rock fragments. A single subangular fragment of lava was recorded in each of YK 2 and 3, a fragment of iron-stained, amorphous greenstone in YK 4, and a ragged piece of granite in YK 11. All these samples were taken in the Bridlington-Flamborough area, and no rock fragments at all appear in the more southerly Hollym and Dimlington Boulder Clays. Whin Sill dolerite, prolific but not especially distinctive (in contrast, for example, to Scandinavian syenite: Harker, 1889, 303) occurs along the entire length of the coastline examined, in sizes ranging from massive boulders (often more than 2m in length) to small pebbles (down to 2cm across). Pebbles and boulders are invariably extremely hard, and show no signs of weathering into clay-like substances. It is clear that the Fimber metalworkers purposefully mixed crushed Whin Sill dolerite with a silty clay to produce the outer mould casings. Unfortunately it was not possible to locate the source of this matrix clay. The density of quartz present in all the coastal Boulder Clay samples exceeds that recorded in the outer moulds. Two inland clay samples with low quartz content (sample YK 9 from Fimber pond, and sample YK 30 from Huggate brickpit) may have served as the basic raw material, but this is not possible to verify. The writer's experiments have shown that quartz grains detached from the dolerite during crushing become incorporated in the clay, and cannot be distinguished from matrix quartz.

In sum, raw material sampling and analysis has shown that sandy clays suitable for the production of inner mould components were readily available at various locations in the Fimber area; that inner moulds in Fabric 1a were probably made from a naturally sandy clay source close to the find spot; that Fabric 1 moulds were either formed from a hitherto unlocated clay, or a deliberate mixture of two (or more) local clays; that matrix materials for outer moulds may well have been dug in the vicinity of Lady Grave; and that the distinctive dolerite fragments present in these mould components represent the deliberate selection of a particular igneous rock for crushing and adding as temper.

III.3.4 Discussion

The Fimber mould assemblage and the technology it implies are distinctive in British late bronze age contexts. In addition to moulds for spearheads, swords and sword chapes, Fimber has produced two sherds of moulds for socketed axes. Clay axe moulds are known from only two other late bronze age sites in southern Britain: Gwithian (Cornwall) and Runnymede Bridge (Surrey). The technology of weapon mould production, specifically that expressed in outer mould casings, is elsewhere unparalleled.

Two mould fragments from Fimber in an apparently unusual fabric seem to derive from artefacts designed to cast a distinctive form of Wilburton axe. It is suggested, on the basis of visual examination of the fabrics, that these moulds (and thus the axes) were produced by a different smith from that, or those, producing weapons at Fimber. It is unfortunate that the axe mould sherds could not be examined under the petrological microscope.

The technology of weapon mould manufacture is difficult to explain. Whilst inner moulds appear to have been produced from carefully selected and prepared local raw materials, outer casings contain inclusions obtainable, at minimum, 30km from the site. The only essential technological requirements for outer mould production are porosity and adequate refractoriness to withstand the heat of molten bronze after this heat has dispersed through the inner valve. A wide range of fillers could be added to a silty clay to fulfil these requirements, and the selection of crushed erratic rock is technologically unnecessary. The particular outer mould formula adopted at Fimber can only be explained in terms of 'cultural' choice. However, the factors determining this choice are not at present understood.

Recent work on late bronze age pottery assemblages has shown that erratic tempered vessels were widely distributed throughout the Wolds during this period. Igneous fabrics were superceded by wares containing distinctive crystalline calcite such as that present in the pottery found alongside the mould at Fimber (I Freestone, pers comm). It is tempting to suggest that the conservative metalworkers, in the habit of visiting the same sources as the potters, continued to exploit these sources after pottery technology had changed. However, pending the results of further excavation, it is not possible to verify the contemporaneity of the moulds and ceramic vessels in the Lady Graves pit. Furthermore, all evidence from other late bronze age metalworking sites shows that pottery and refractories were invariably formed from different pastes. Until the detailed results of Wolds' pottery analysis are known, and until further information is available concerning the chronological and depositional context of the Fimber moulds, further inferences cannot be drawn.

TABLE III.3.1 FIMBER: SECTIONED SHERDS

Sample no	Artefact type
FIM 1	outer mould
FIM 2	outer + inner mould - probably sword
FIM 3	inner mould
FIM 4	outer + inner mould
FIM 5	outer + inner mould
FIM 6	outer mould
FIM 7	outer + inner mould
FIM 8	inner mould - chape
FIM 9	outer + inner mould
FIM 10	outer mould
FIM 11	inner mould - probably sword
FIM 12	outer + inner mould
FIM 13	pottery, probably Roman; originally identified as a hone (Sheppard, 1930)
FIM 14	outer + inner mould
FIM 15	amorphous lump of lightly fired clay - perhaps furnace
FIM 16	pottery, bronze age
FIM 17	pottery, bronze age
FIM 18	inner mould
FIM 19	outer mould
FIM 20	furnace
FIM 21	furnace
FIM 22	pottery, bronze age
FIM 23	ceramic urn, bronze age
FIM 24	pottery, bronze age
FIM 25	pouring gate or sprue cup

TABLE III.3.2 FIMBER: INCLUSIONS IN OUTER MOULD SHERDS

Slide	n grains	% igneous grains	%quartz: matrix	% all grain matrix
1	220	33	32	42
4	137	55	37	57
6	145	49	31	46
7	140	51	38	56
10	125	42	39	54
19	103	51 (also 2% lime-stone)	30	49

TABLE III.3.3 RAW MATERIAL SAMPLES: YORKSHIRE

Sample no	Grid ref	Geological notes
YK 1 (C)	TA 238720	Boulder Clay; Hessle (coastal sample)
YK 2 (C)	TA 233723	" ; " "
YK 3 (C)	TA 182664	" ; Purple "
YK 4 (C)	TA 182664	" ; " "
YK 5 (C)	TA 182664	" ; " "
YK 6 (C)	TA 202686	" ; Hessle "
YK 7 (R)	TA 225692- TA 230692	Erratic rocks from coast (includes Whin Sill dolerite)
YK 8 (C)	SE 896607	Pleistocene drift deposit, Fimber Pond (Wolds)
YK 9 (C)	SE 896607	" " " (deeper than YK 8)
YK 10 (C)	SE 871624	Pleistocene drift deposit (Wolds) (with pond silt)
YK 11 (C)	TA 238720	Boulder Clay; Hessle (coastal sample)
YK 12 (C)	SE 872626	Pockets of clay in face of chalk pit
YK 13 (C)	SE 872626	" " "
YK 14 (C)	TA 368247	Boulder Clay; Purple (coastal sample)
YK 15 (C)	TA 367248	Boulder Clay; ?Hessle (slump) (coastal sample)
YK 16 (C)	TA 367248	Boulder Clay; Hessle (coastal sample)
YK 17 (C)	TA 367248	Boulder Clay; Purple (coastal sample)
YK 18 (C)	TA 368247	Boulder Clay; Purple (coastal sample)
YK 19 (C)	TA 397210	Boulder Clay; Basement (coastal sample)
YK 20 (C)	TA 394215	Boulder Clay; Basement (coastal sample)
YK 21 (C)	TA 394215	Boulder Clay; Basement (coastal sample)
YK 22 (C)	TA 390219	Boulder Clay; Basement (black clay) (coastal sample)
YK 23 (C)	TA 391218	Boulder Clay; ?Purple (slump) (coastal sample)
YK 24 (C)	TA 392217	Boulder Clay; Purple (purple clay) (coastal sample)
YK 25 (C)	TA 392217	Boulder Clay; Purple (brown clay))coastal sample)
YK 26 (C)	TA 391218	Boulder Clay; ?Hessle (slump) (coastal sample)
YK 27 (C)	TA 367248	Boulder Clay; Purple (coastal sample)
YK 28 (C)	SE 894545	Silty drift deposit in hollow in Senonian Chalk (Wolds)
YK 29 (C)	SE 894545	As YK 28
YK 30 (C)	SE 889551	Silty drift overlying Chalk (claypit) (Wolds)
YK 31 (C)	SE 889551	Silty drift deposit in hollow (claypit) (Wolds)
YK 32 (C)	SE 889551	As YK 31
YK 33 (B)	SE 889551	Silty drift deposit in hollow (brick wasters)
YK 34 (C)	SE 874587	Drift deposit on Chalk, new exposure (Wolds)
YK 35 (C)	SE 874586	Drift deposit on Chalk (gravel pit) (Wolds)
YK 36 (C)	SE 893606	Silty drift deposit on Chalk (pipe trench) (Wolds)
YK 37 (C)	SE 885611	?drift deposit, on Chalk (sheep creep) (Wolds)
YK 38 (C)	SE 883609	Drift deposit on Chalk (sand/clay pit) (Wolds)
YK 39 (C)	SE 926462	Drift deposit on Chalk (claypit) (Wolds)
YK 40 (C)	SE 925641	Drift deposit on Chalk (claypit) (Wolds)
YK 41 (C)	SE 926640	As YK 40
YK 42	SE 888609	Drift deposit in hollow in Chalk (Wolds) (sample supplied by P Walsh)

OBJECT	SLIDE	% GR: MAT	NO. OF GRAINS	PHI -1 TO -.5	PHI -.5 TO 0	PHI 0 TO .5	PHI .5 TO 1	PHI 1 TO 1.5	PHI 1.5 TO 2	PHI 2 TO 2.5	PHI 2.5 TO 3	PHI 3 TO 3.5	PHI 3.5 TO 4	PHI 4 TO 4.5	PHI 4.5 TO 5	PHI 5 TO 5.5	MEAN GRAIN SIZE MM.	STD DEV
SPRJ CUP																		
	25	62	71	0	0	0	0	0	Q	0	0	1	9	17	31	42	.0348	.121
N SLIDES			1															
N GRAINS			71															
IN MOULD																		
	11	77	85	0	0	0	0	0	4	11	5	5	11	16	15	33	.0737	.685
	12	78	101	0	0	0	0	1	1	7	8	9	11	14	20	29	.0699	.772
	14	77	82	0	0	0	0	0	0	4	5	4	7	12	29	39	.0481	.357
	18	71	79	0	0	0	0	0	0	0	0	4	10	13	23	51	.0353	.140
	2	79	94	0	0	0	1	1	2	1	5	4	6	18	19	43	.0567	.785
	3	73	69	0	0	0	0	0	0	0	0	3	7	15	32	43	.0349	.128
	4A	76	81	0	0	0	0	0	0	6	5	5	9	12	25	38	.0531	.440
	8	67	82	0	0	0	0	0	0	0	1	3	9	10	25	52	.0343	.140
	9	74	73	0	0	0	0	1	0	3	8	6	14	13	28	27	.0600	.558
N SLIDES			9															
N GRAINS			746															
OU MOULD																		
	1	42	220	2	3	2	3	5	2	3	2	6	10	11	19	32	.1582	9.29
	10	54	125	1	5	2	5	6	3	1	8	6	4	4	20	34	.1926	11.5
	19	49	103	2	7	2	4	7	7	6	2	8	6	5	11	33	.2287	14.4
	4B	57	137	5	4	5	8	6	9	4	5	4	3	10	11	25	.2867	19.2
	6	46	145	5	2	1	8	2	5	4	10	4	8	11	16	24	.2123	13.8
	7	56	140	3	7	6	5	7	4	2	6	4	5	10	12	29	.2658	18.1
N SLIDES			6															
N GRAINS			870															
			16															
			1687															

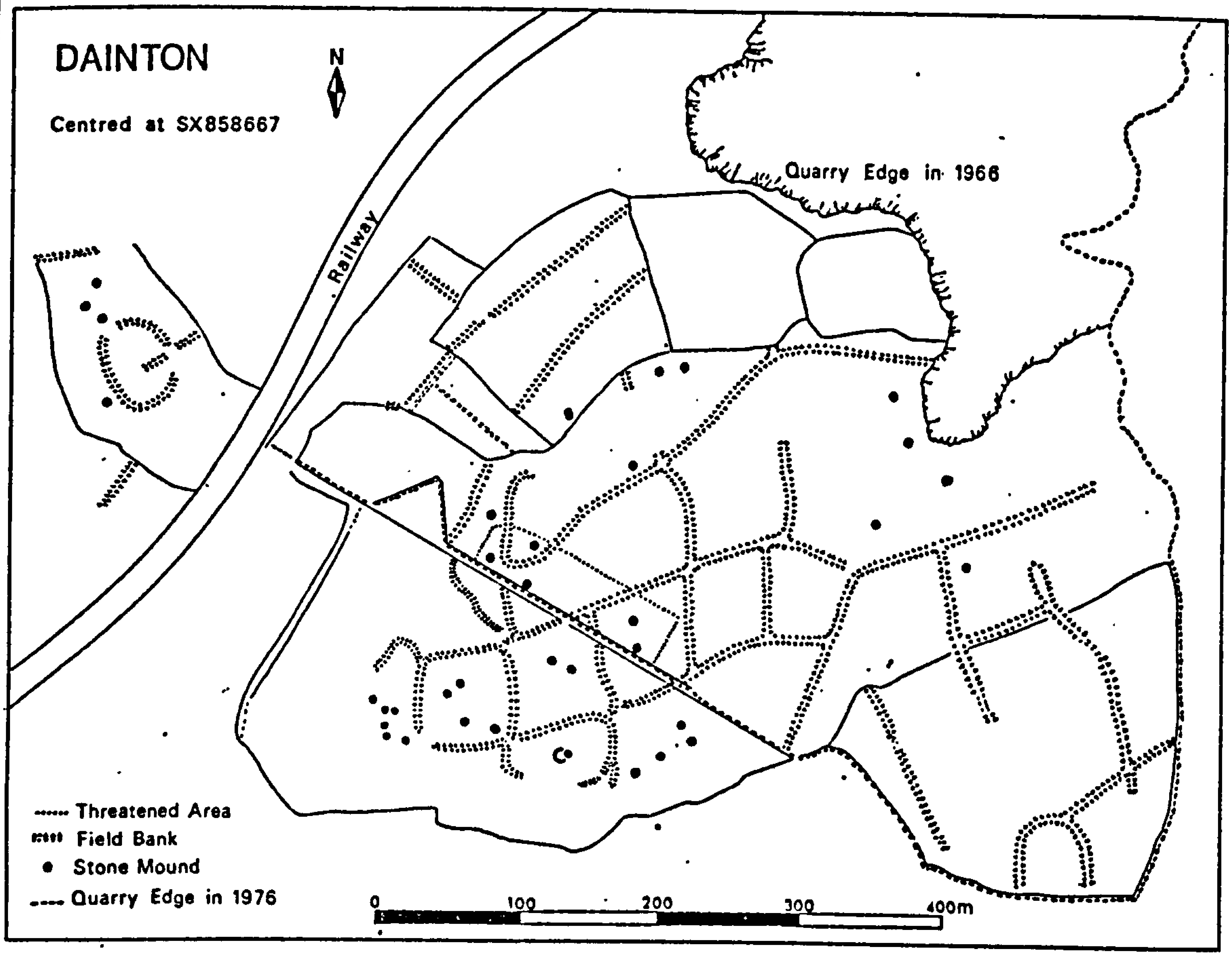
Table III.3.4 Fimber: grain size statistics.

III.4 DAINTON, DEVON
(SX 859668; corpus no 7)

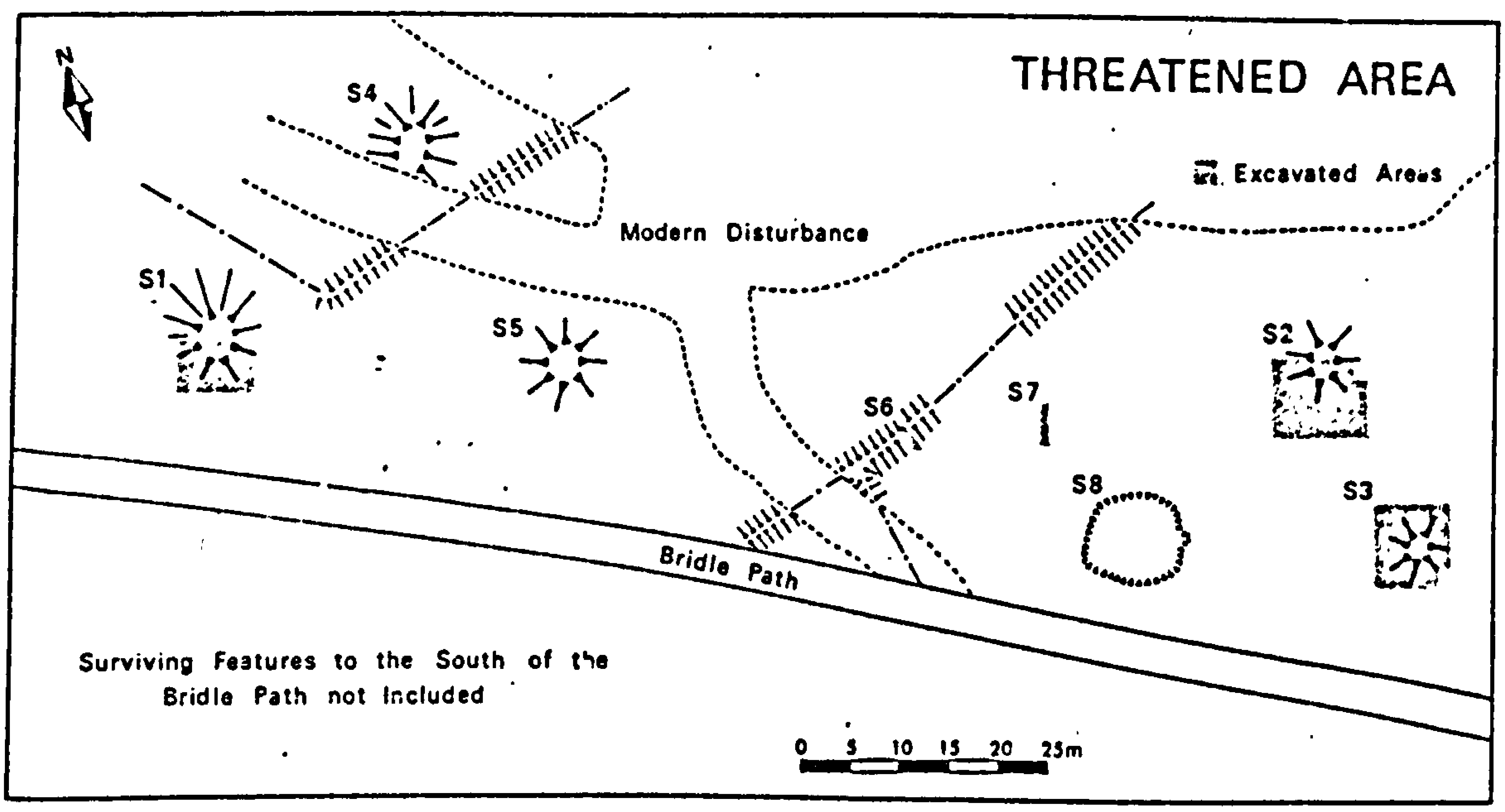
The 'open settlement' at Dainton consists of a minimum of ten fields, each about 0•4ha in area, randomly interspersed with limestone cairns. The site is located on a limestone plateau, and is believed originally to have covered some 20ha.

Limited excavation, including the examination of four cairns, took place in the 1930s (Willis and Rodgers, 1951). Two of the carins were interpreted as hut platforms, and an early iron age date was inferred from the pottery assemblage which included cable rims, haematite-coated ware, and shoulder sherds with incised decoration (Willis and Rodgers, 1951, 97-98). Excavation in advance of destruction by limestone quarrying took place in 1975, when three carins were examined to determine the nature of the settlement (fig III.4.1, S1, 2, 3). No structural evidence was found, and the cairns have since been interpreted as field clearance heaps, perhaps with secondary functions (cairn S2 contained human remains). It has been suggested that cairns, fields, and a considerable quantity of occupation debris are all facets of a long-lived settlement, perhaps inhabited throughout most of the first millennium BC (Silvester, 1980, 45). Although no hut platforms were found within the relatively small area examined, pottery scatters and other artefacts including quern fragments indicate occupation. The pottery recovered in 1975 is generally different from that recorded by Willis and Rodgers, and would appear on the basis of typology (Silvester, 1980, 29) and fabric (Howard, 1980d, 42; Appendix III.4.1) to be somewhat earlier in date. This suggest a possible shift in area of occupation through the lifespan of the site.

A dense scatter of coarse pottery immediately to the south east of cairn S2 prompted the 1975 excavator to open a wider area (70 sq m) outside the cairn locale in search of structural remains. During the course of this excavation, a small pit, dug into the natural limestone, was discovered some 1•4m from the cairn. The pit was packed with clay



The field system on Dainton Common (after L. Gallant).



The threatened area, 1975.

Fig III.4.1 Settlement and areas of recent excavation at Dainton (after Silvester, 1980).

mould and crucible fragments, several small pottery sherds and a few slabs of local tuffaceous rock.

III.4.1 The metalworking evidence

The metalworking assemblage from Dainton is of especial significance. Despite subsequent discoveries of bronze age metallurgical activity, at no other site of this period in Britain have those ceramic objects integral to the bronze casting process been found in such an excellent state of preservation.

The debris comprise a large quantity of fragments derived from bivalve clay moulds (both inner valves and outer wraps are represented), at least 43 crucible sherds and three small fragments of bronze. The greater portion of the well-preserved material was recovered from the pit adjacent to S2, but a large number of severely abraded refractory fragments were also scattered around this feature (fig III.4.2).

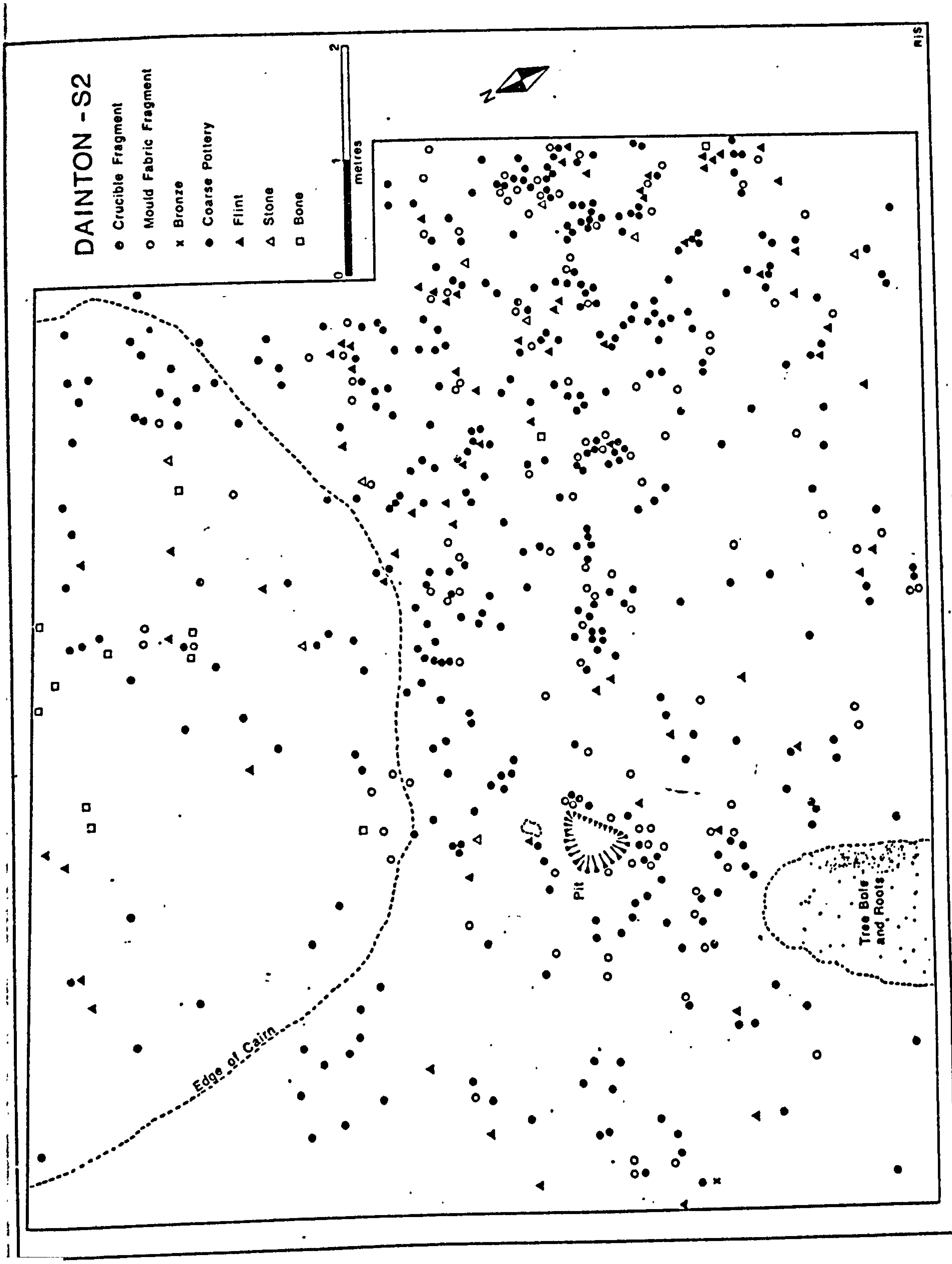
Two forms of crucible, and at least three separate vessels have been identified:

Vessel A - flat-topped rim (Class 1). This thick-walled crucible, circular or slightly oval in plan, was supported on three integral legs and had a capacity of c 316cc, or 2800-3000gm of molten bronze (fig III.4.3 and 4b). Traces of at least five relining layers were found on the inside of the bowl and over the rim.

Vessel B - rounded rim (Class 2). A few rim sherds with traces of three relining layers are believed to derive from a single vessel of uncertain form with a diameter of c 60mm (fig III.4.4a, bottom right). At some point during the lifespan of this crucible, the bowl height had been significantly increased, perhaps to provide a larger capacity or to compensate for loss of volume through slagging.

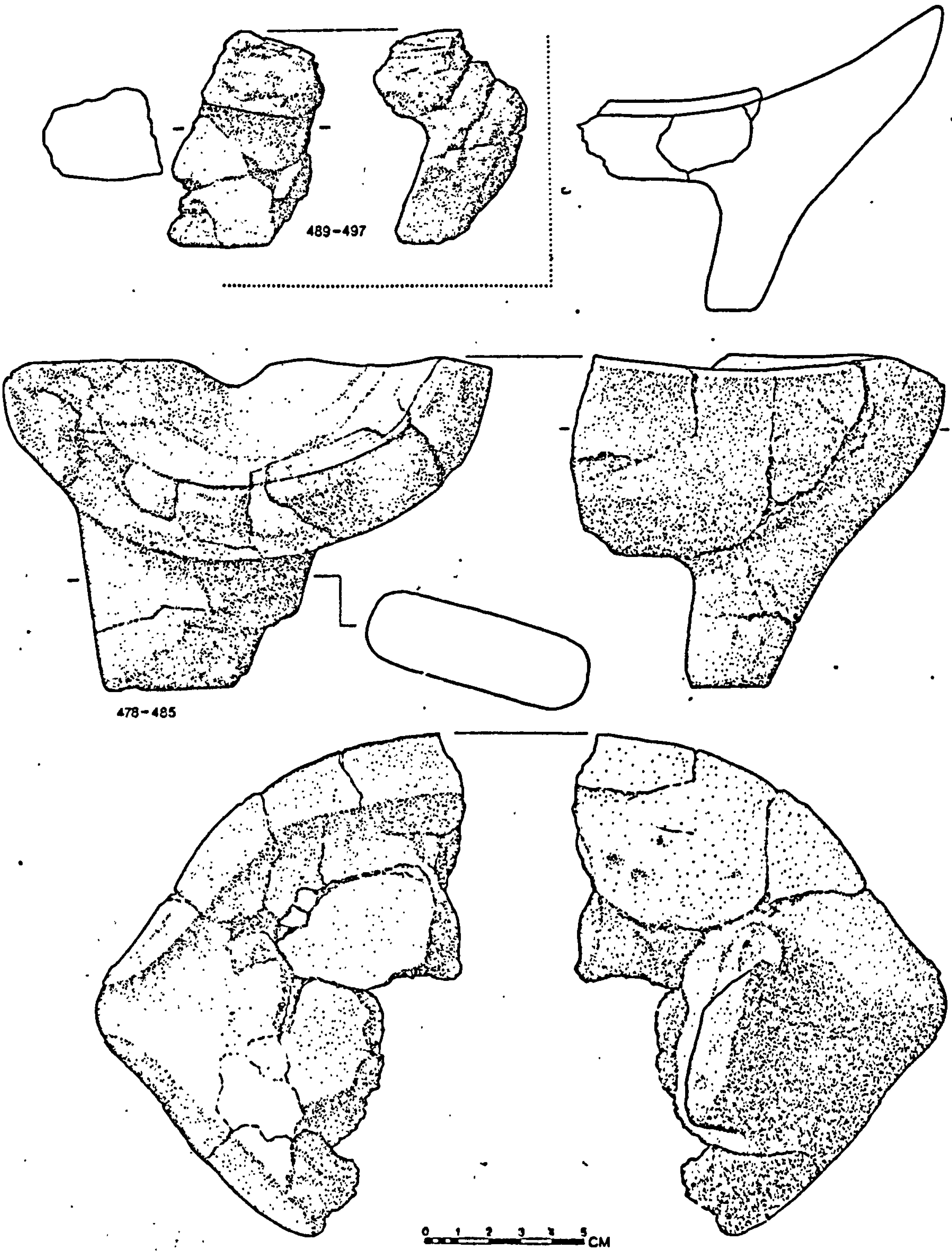
Vessel C - rounded rim (Class 2). A single rim sherd, once relined, of slightly different form from crucible B, probably represents a third vessel (fig III.4.4a, sherd no 498).

The surviving mould fragments attest the casting of at least five different bronze weapon and ornament 'classes' (figs III.4.5-7); no tool moulds were identified:



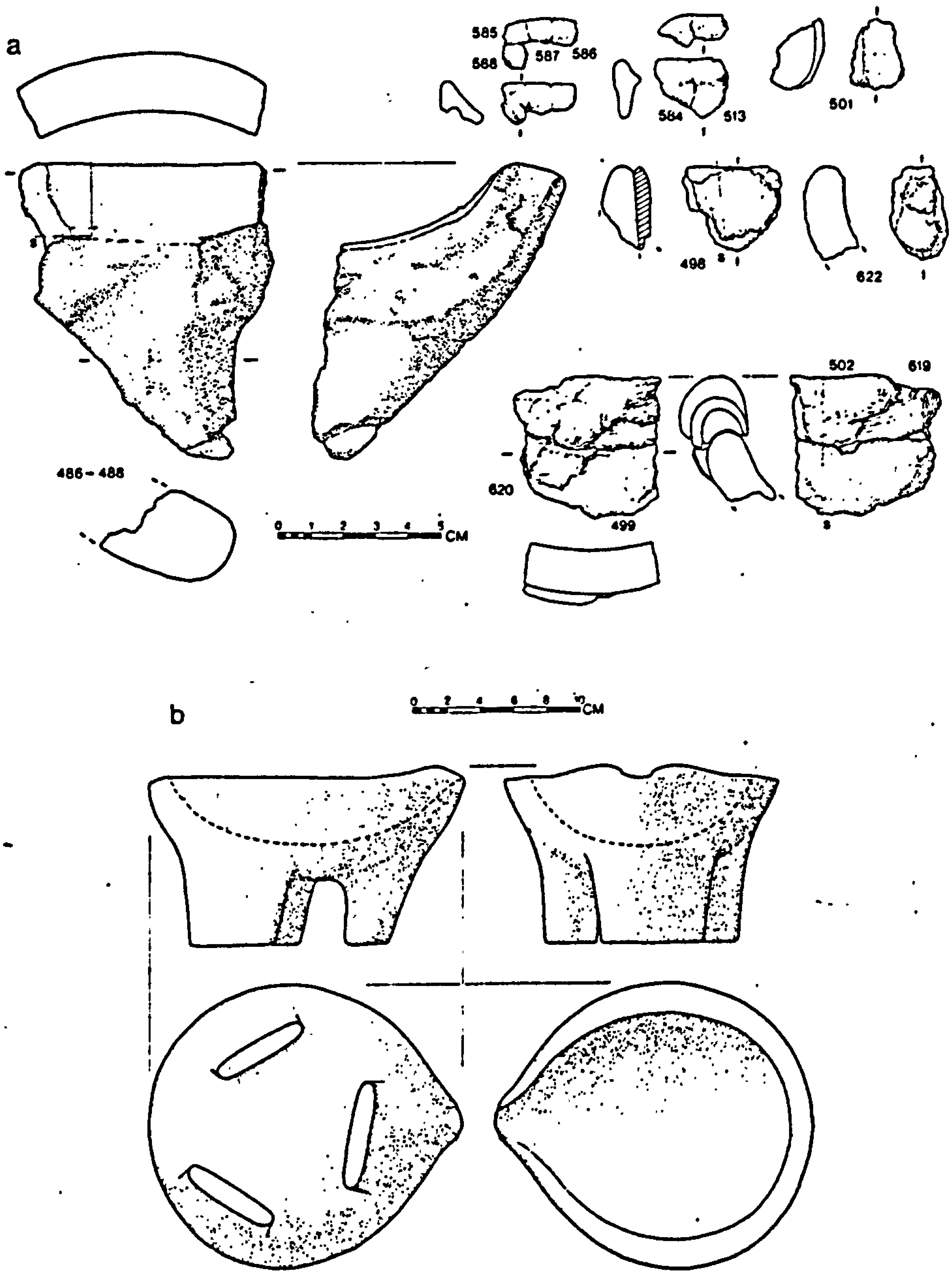
Distribution of finds on S2.

Fig III.4.2
(after Silvester, 1980)



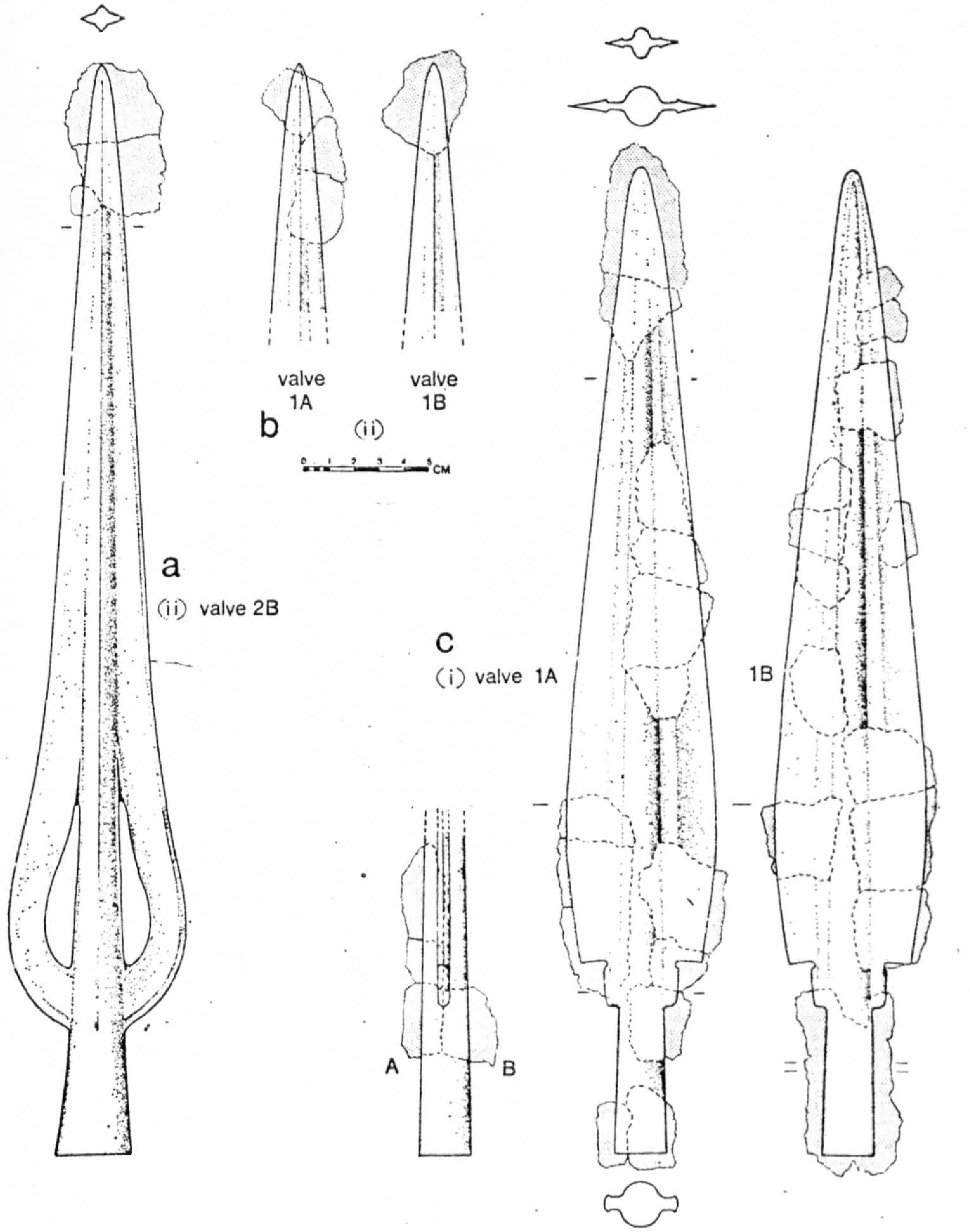
Crucible fragments: all probably derived from vessel A.

Fig III.4.3 (after Needham, 1980a)



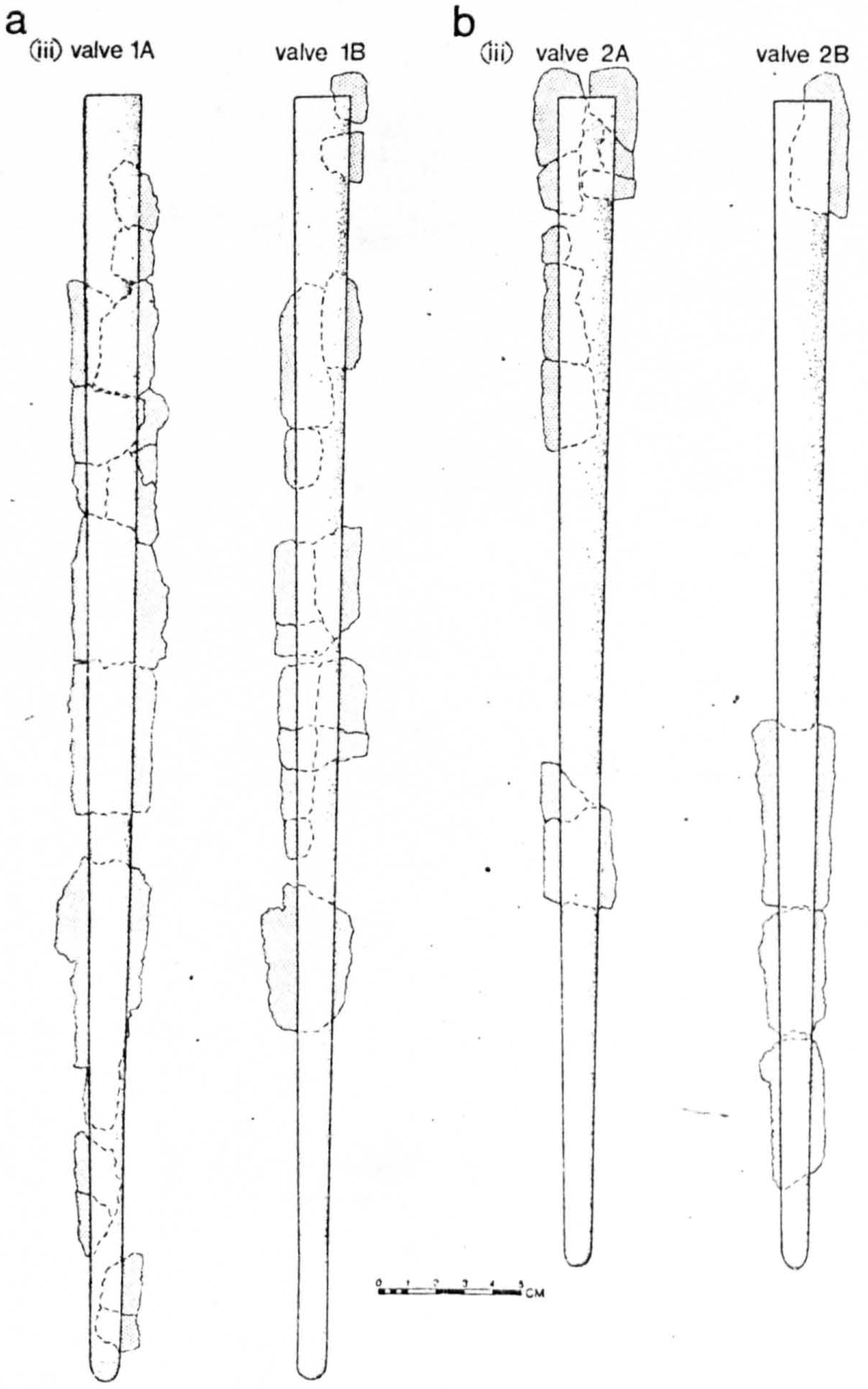
(a) Crucible fragments: Class 1, X486–488; Class 2, X501, 498, 622, 499/620, 502/619; Possible crucible lip or gate fragments, X585–588, X584/513 (all ½). (b) Reconstruction of Class 1 crucible A (¼). S indicates the line of sections taken for analysis.

<u>Fig III.4.4</u> Dainton crucibles (after Needham, 1980a)



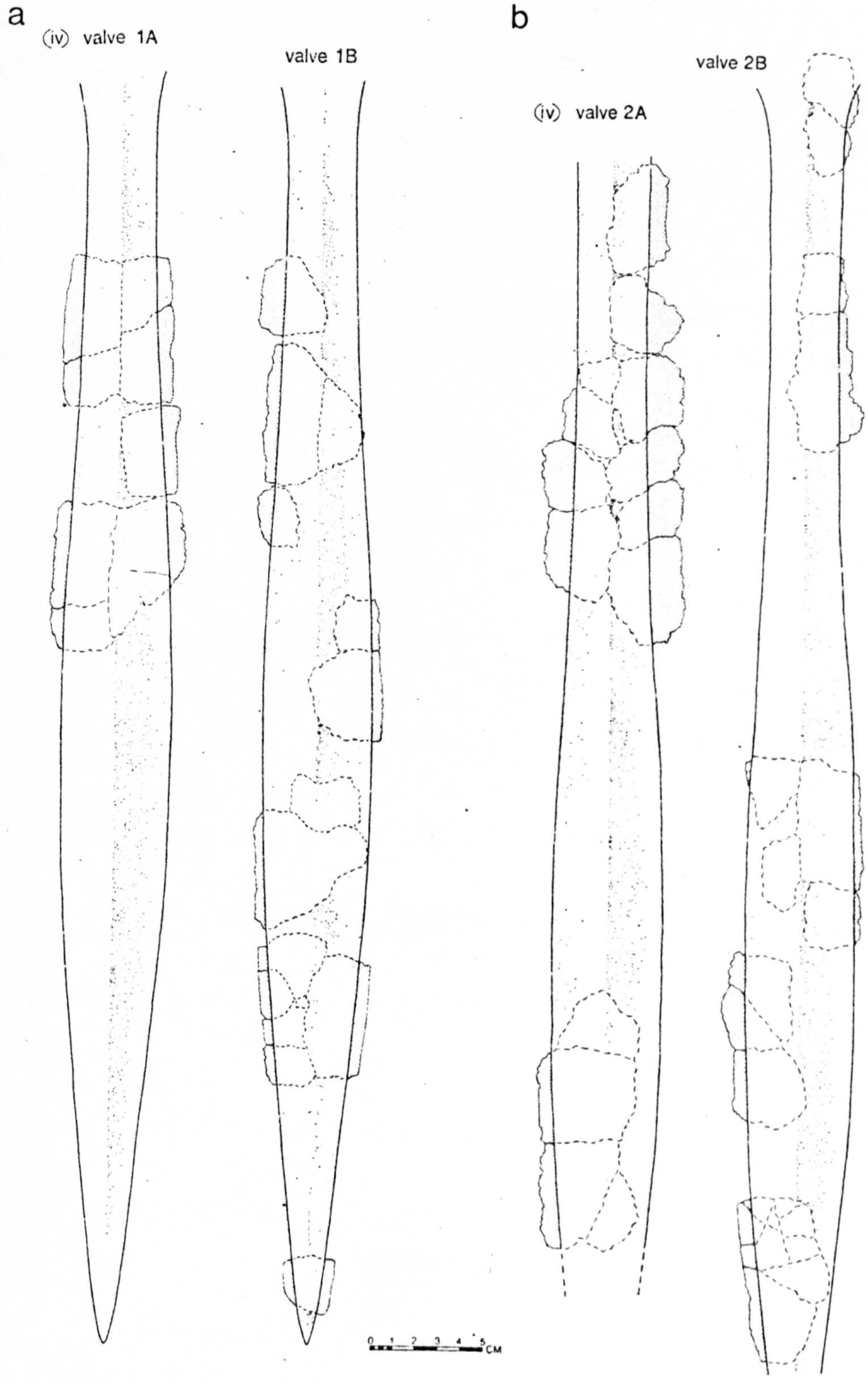
Spearhead types manufactured at Dainton: surviving mould fragments are shown in outline. a. and b. lunate-opening spearheads. c. basal-looped spearhead.

Fig III.4.5 (after Needham, 1980a)



Ferrule types manufactured at Dainton: surviving mould fragments are shown in outline.

Fig III.4.6 (after Needham, 1980a)



Leaf-shaped sword blade type made at Dainton: surviving mould fragments are shown in outline.

Fig III.4.7 (after Needham, 1980a)

1. basal looped spearheads (a single mould unit seems to be represented (fig III.4.5b,c)
2. lunate opening spearheads (three valves represented) (fig III.4.5a)
3. cylindrical ferrules (at least two mould units) (fig III.4.6)
4. leaf-shaped swords (at least two mould units) (fig III.4.7)
5. plain rings (two units which together may have cast four rings).

The only bronze finds from the pit comprised a tapered rod, believed to have been part of a cast object, and a single droplet of casting waste, 6mm in maximum dimension. An irregular lump of bronze (42•5mm maximum dimension) was found a short distance away.

The period of metalworking activity at the site is dated to the tenth century BC (LBA1) on the basis of the bronze artefacts being produced (Needham 1980a, 210-12). With the exception of the Class 1 spearhead (fig III.4.5b,c), which is typologically related to two examples in hoards dated overall to the Ewart Park phase (LBA2-3, eighth-ninth centuries BC), all weapons being cast at Dainton fall into the Wilburton-Wallington bronzeworking tradition (Coombs, 1975; Burgess, 1968b). The material is regarded by Needham as representing a regionalised Wilburton industry (Needham, 1980a, 211).

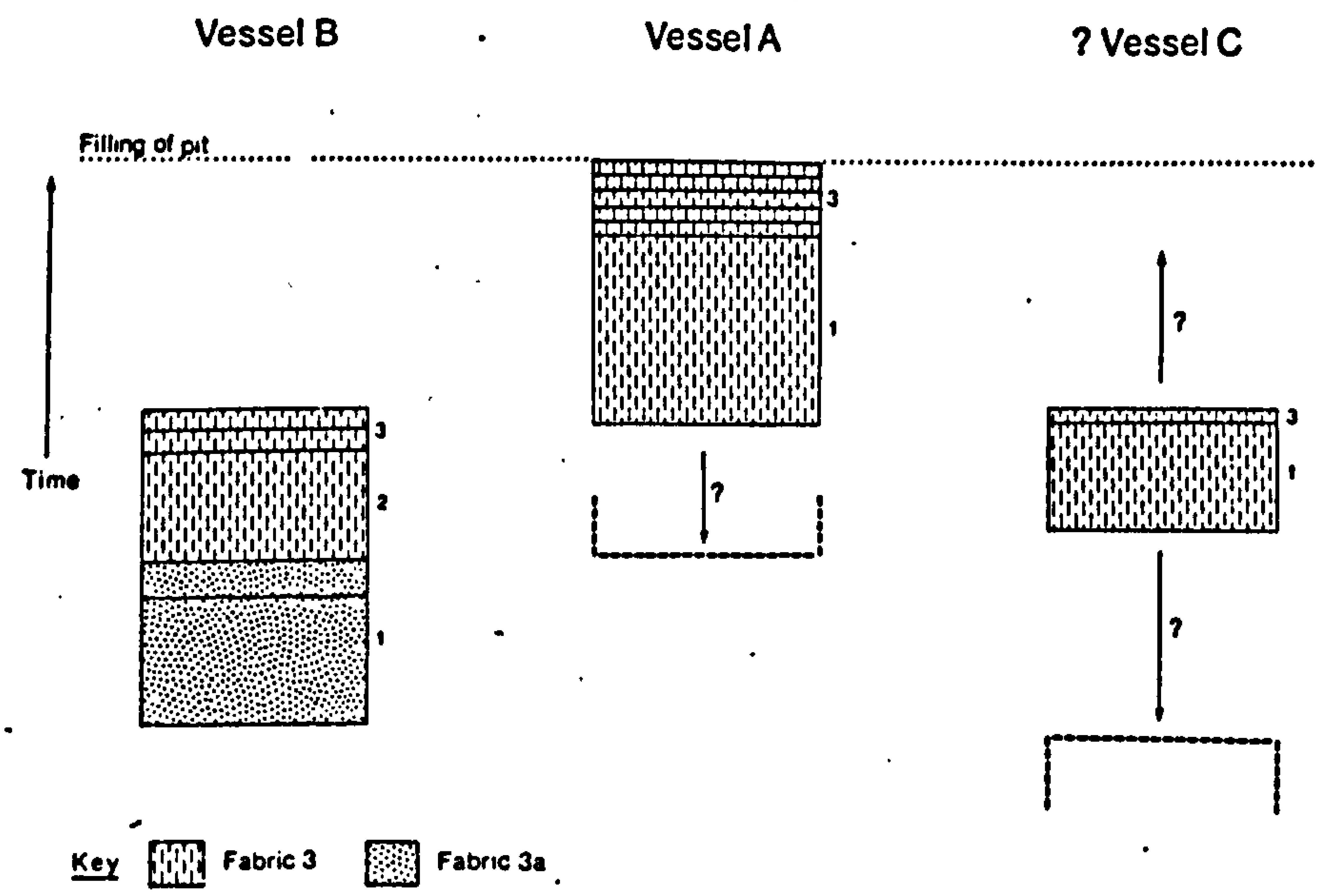
III.4.2 Analytical results (see Table III.4.1)[1]

The crucibles (Fabrics 3 and 3a)

Crucible fabrics are exceptionally sandy and harsh to the touch. The larger, outer portions show a yellowish brown colour (10YR 5/4) to be the result of original firing, whilst the core and those areas in contact with the molten metal are reduced to medium grey.

Five crucible sherds were examined in thin section, representing the three defined vessels: Class 1, Vessel A (sample X486; fig III.4.4a); Class 2, Vessel B (samples X502, X499; fig III.4.4a); Class 2, Vessel C (samples X498, fig III.4.4a, and X621, not illustrated). All samples (save X621 which is preserved as a single layer structure) were sectioned

1. To avoid confusion, the fabric numbers used in the published reports (Howard, 1980c; Needham, 1980a) are retained; the order of object description, however, follows that adopted for all site studies.



Suggested sequence of use of Dainton crucibles: 1 underlying bowl, 2 wall heightening, 3 re-lining slips.

Fig III.4.8 (after Needham, 1980a)

through body and relining layers. A 2mm band of slaggy material visible between the component parts of X498 confirms that the crucibles were, in fact, relined. No mineralogical differences can be discerned between the layers of individual crucibles, save in the case of the "extra walling" and original body portions of Vessel B (samples X499, X502) (fig III.4.8). Again with this exception, paste preparation appears to have been consistent throughout cores and relinings.

All five samples are seen to contain abundant angular and subangular quartz sand (c 80% in all samples save X499 - original body of Vessel B - which has about 60%), a uniform scatter of orthoclase felspar and occasional grains of quartzite or metamorphosed siliceous sandstone. Sample X498 (Vessel C) contains a few fragments of highly altered biotite and a singel grain of coarse quartz sandstone almost embedded in the slaggy layer. Similar rare sandstone grains also occur in samples X621 (Vessel C), with a single lath of heat-altered biotite in X502. The large crucible (Vessel A) sample X486 contains two large

(1•2mm and 1•3mm) grains of altered arkose sandstone.

On the basis of the above description it may be suggested that the same or closely similar raw material sources were exploited for all stages of crucible manufacture at Dainton. It is interesting that the "extra walling" portion of Vessel B (X502, Fabric 3) differs in inclusion size range and inclusion: matrix ratio from the original body (X499, Fabric 3a). It is suggested that these differences represent chronological variation in paste preparation rather than diverse clay and temper sources (fig III.4.8).

<u>The weapon moulds</u> (Fabrics 1 and 2)

All weapon mould fragments examined had been fired prior to the casting process. Refiring experiments showed that 650°C was the maximum temperature reached through the outer wraps. Contact with the molten metal has resulted in a dark grey reduction band (average thickness 3-4mm) on the inner valves, whilst the outer wraps are invariably oxidised throughout. Outer colours vary from light red (2•5YR 6/6) through yellowish brown (10YR 5/8). The fine, sandy clay used for inner valves appears to have been thoroughly wedged and carefully cleaned of any large inclusions and extraneous organic matter. The appearance of the outer casings suggests the application of a similar clay, poorly mixed and with minimal preparation.

Differential preparation is confirmed when joining fragments of inner valve and outer sheath are examined in thin section. Without exception, both elements of individual moulds are mineralogically identical, but whilst inner valves are compact with evenly distributed inclusions, outer wraps contain rounded and occasionally elongate voids, probably caused by a combination of poor working of the clay and burning out of residual organic material. The infrequency of organically produced voids precludes the possibility that chopped straw, grass etc was deliberately added to a raw clay. Additionally, inclusions in outer wraps frequently show a tendency towards banding, and argillaceous pellets are common, again indicative of poor clay preparation. Both weapon mould fabrics display adequate refractory properties, up to 60% of the inclusion suite in Fabrics 1 and 2 consisting of fine angular and subangular quartz grains.

Fabric 1 is characterised by a tenor of 50-60% very fine quartz grains, almost invariably less than 0•05mm, and abundant laths of finely divided white mica. All samples contain a scatter of heavily iron stained clay pellets (predominant in outer wraps) with inclusions similar to those of the matrix. Rare, subrounded orthoclase felspar grains and isolated fine-grained micaceous sandstone and quartzite fragments, all less than 0•2mm, are visible in most sections.

Fabric 2 is characteristically coarser and contains a much broader range of mineral inclusions. In addition to quartz (generally to 0•1mm and representing about 60% of the inclusion suite) all Fabric 2 samples contain considerable plates of biotite, usually heat-altered to dark brown, and numerous threads of white mica. This fabric is also characterised by minor amounts of potash felspar (some of these subhedral 0•3-0•6mm grains being of the sanidine variety), rare angular fragments of plagioclase and microcline, phyllite, quartzite, sandstone (sometimes micaceous, sometimes felspathic) and ragged grains of both blue and greenish brown tourmaline. Accessory minerals visible as single grains in some specimens include zircon, sphene and ?garnet (Plate 4c). Differential clay perparation is again evident between inner valves and outer wraps.

The ring moulds (Fabric 3)

In both hand specimen and thin section this fabric is indistinguishable from the crucible fragments analysed. The identification of ring mould fragments is thus based on typological classification, and tiny abraded sherds in this fabric may represent either crucible or ring mould debris. Positively identified ring mould is invariably reduction fired, and no outer wraps can confidently be associated with this matrix type. A single inner valve was thin sectioned.

<u>The pottery</u> (Fabrics 4-8)

Alongside work on the refractories a detailed study of the Dainton pottery assemblage was undertaken, incorporating selective thin section analysis. Material from both the 1939 and 1975 excavations was examined with unexpected and interesting results. These results shed considerable light on the organisation of pottery production, and aided the interpretation of metalworking at the site. The Dainton pottery fabrics differ in all respects from pastes used for refractory production. Five distinct groups were identified in hand specimen and thin section: Fabric 4 - "basic igneous", Fabric 5 - "grog", Fabric 6 - "chlorite schist", Fabric 7 - "sandstone", Fabric 8 - "quartz and chert" (these appelations refer to the identified inclusion suites). A detailed account of the pottery anlysis is set out as AppendixIII.4.1.

III.4.3 Resource ecology and raw material analysis

Dainton is located on a plateau of thick-bedded dolomitised limestone (Devonian) known as Miltor Mator Common. The limestone gives way to the south to Middle Devonian slates and the volcanic tuffs of Blair Hill (Ussher, 1913, 17). The geology of south Devon is extremely complex. The area was never glaciated, and myriad rock formations, ranging in age from the Devonian to the Post-Tertiary may be studied free from the encumbrance of the glacial drift which overlies so much of Britain. The great lithological diversity of the area, and both residual and transported clay deposits provided a potentially wide choice of raw materials for prehistoric craftsmen (figs III.4.9-10).

The lack of diagnostic inclusions in Fabric 3/3a, and the abundance of quartz sand visible in this pale yellow-brown, hard-firing paste suggested the Oligocene clay of the Bovey Basin as a possible source of raw materials (fig III.4.10). The finest Bovey ball clays are white in colour and used to be extensively quarried for pipe making (Searle, 1912, 89; Ussher, 1913, 135). Today large quantities are dried and sent out to the potteries. The Bovey Beds are complex, and bands of fine clay are often found juxtaposed to or interspersed among parallel bands of muddy clay, silt, sand and gravel. At Aller (SX 879690), for example, the pipe clay is mixed with sand and stained with ochre, and was used

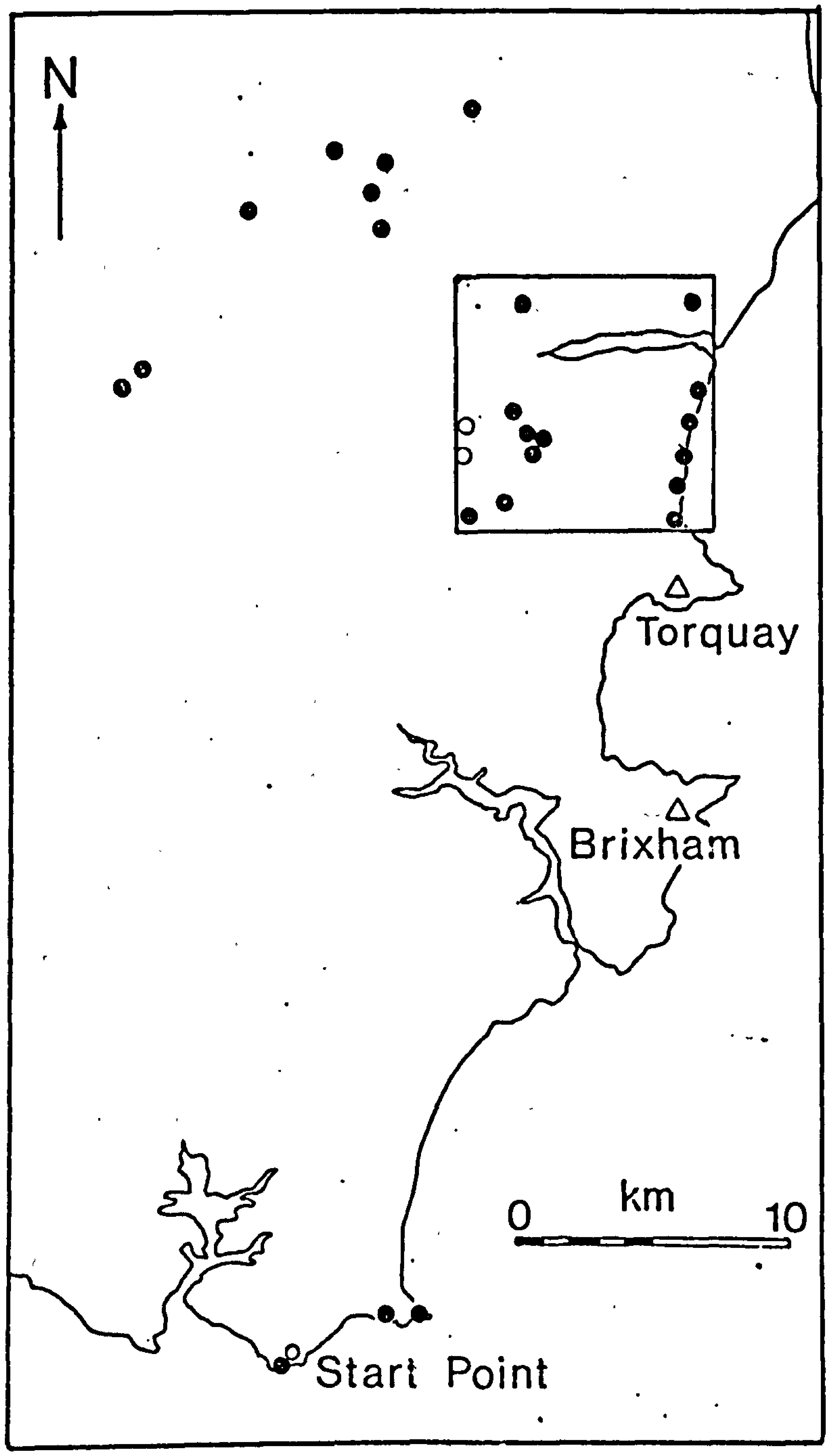


Fig III.4.9 Location of clay (●) and stone (O) sampling points, Devon. A total of 53 samples were collected. For detail of area around Dainton, see fig III.4.10.

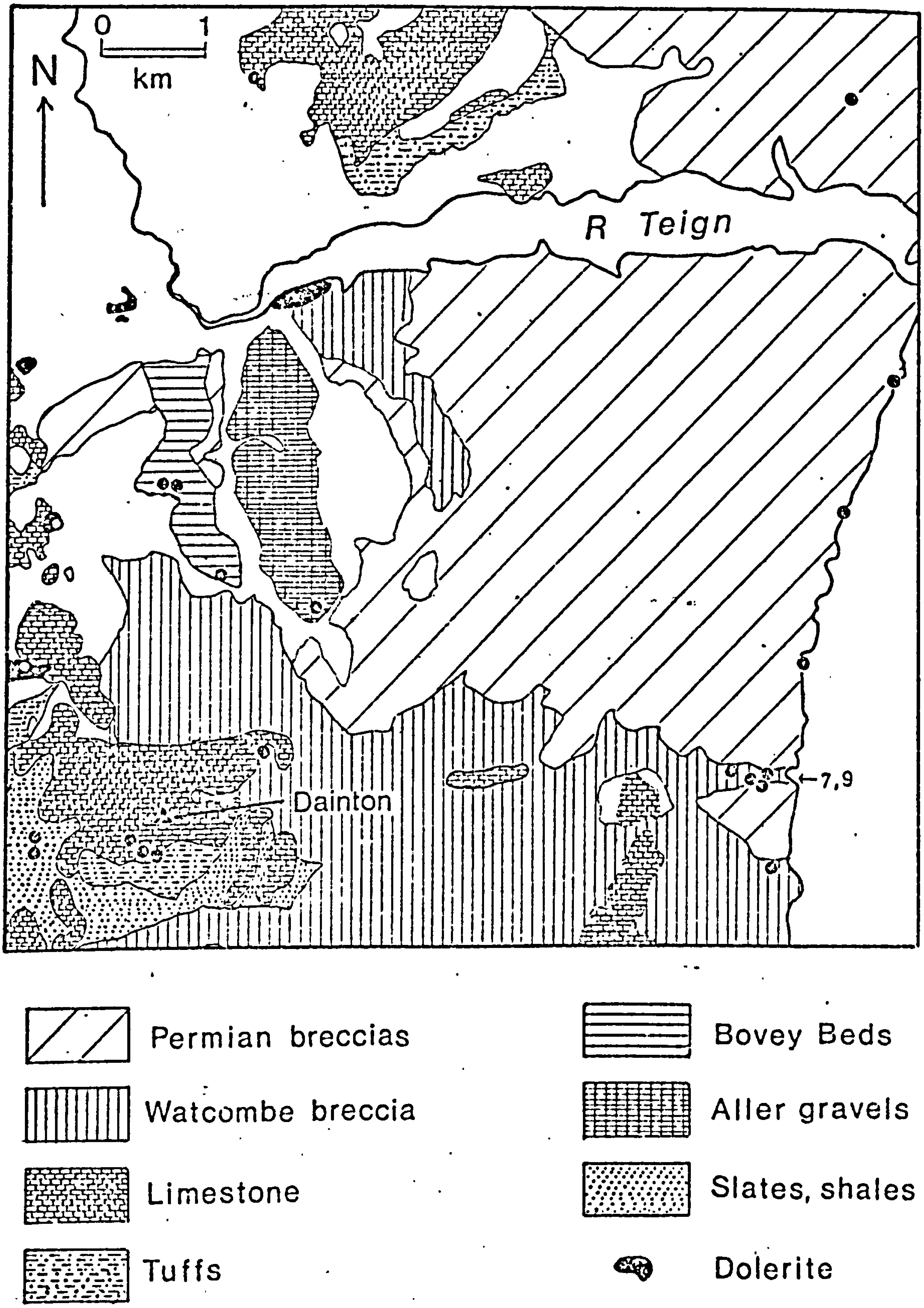


Fig III.4.10 Clay (●) and stone (O) sampling points around Dainton.

during the 19th and early 20th centuries for pottery making (Brears, 1971). Five clay types used to be commercially exploited in the Bovey region. Two of these are refractory, and have supplied the manufacturers of building bricks , drain pipes and firebricks (Edwards, 1970). They are generally coarser in texture than the pipeclays or "blackbody" (pottery clay associated with lignite) and one refractory series contains granules of iron carbonate and thus weathers pale brown (Ussher, 1913, 135).

Eight samples (Table III.4.2 and fig III.4.10) representing both the white and pale brown ballclays were taken and processed. Although all display good refractory properties when refired to 1100°C, all fire more or less white and contain inclusion suites not recorded within the Dainton archaeological refractories. A sample from Decoy Lake (DA 6) contains a high tenor or quartz sand similar in angularity and size range to that present in Fabric 3, but the presence of considerable tourmaline in thin section precludes the identification of this clay as crucible raw material. A more extensive programme of sampling and analysis in the Bovey area may yield more positive results, but it must be remembered that the entire deposit has been extensively quarried over the last two centuries, and that the precise clay used by the Dainton metalworkers (if, indeed, the original Bovey Beds hypothesis is correct) may well have been completely removed.

The red-firing Fabric 2 again contains few diagnostic minerals, but the sampling programme has produced a matching raw material. Samples of Watcombe clay (until recently exploited for utilitarian and tourist pottery production) taken from coastal exposures at SX 923674 (DA 7) and SX 925673 (DA 9) 6km to the east of the site (fig III.4.10) are virtually identical in thin section to Fabric 1. A high tenor of naturally well-sorted angular quartz sand grains, set in a silty siliceous matrix, provided the Dainton metalworkers with an easily accessible source of material of adequate refractoriness for mould manufacture.

Fabric 2 contains an assemblage of rocks and minerals which are likely to be derived from the Dartmoor granite massif and its aureole. The discovery of a few grains of sanidine is of particular interest. This mineral has been recorded from the Permian rocks of the Newton Abbott area (Ussher, 1913, 82-83), and described as Murchisonite. This suggests a derivation at least in part from that system, and a fairly local origin is implied. Samples were taken from the aureole (DA 16-22: fig III.4.9) and from coastal exposures of Permian clays on the Breccia (DA 33, 53, 53: fig III.4.10). On the basis of a high-firing test, it was possible to eliminate most of these samples (in unmodified form) from further consideration. For example, all but one of the aureole clays from the Holne Chase area exhibited such marked dunting and warping when fired to 1100°C as to render them totally unsuitable for refractory production. In thin section, none of the individual Permian or aureole samples contains an inclusion suite similar to that observed in the Fabric 2 moulds. Although, on this evidence, a single source cannot be ruled out, mixing of raw materials, as yet unlocated, may be a possibility.

III.4.4 Discussion

Petrological analysis has revealed a considerable degree of ceramic complexity at Dainton. Raw materials for crucible and mould production were carefully selected for their refractory properties from relatively local clay sources. A wide range of transported and residual clays is available within the vicinity of the site, the majority of which (including the fine ferruginous clay overlying the limestone of Miltor Mator Common itself) would not have been sufficiently strong or thermal shock resistant to withstand the impact of molten bronze. The use of the Watcombe clays, positively identified as the source of mould Fabric 1, the aureole origin of Fabric 2 indicated by the mineral suite present, and the probable exploitation of the highly refractory Oligocene clays for the production of crucibles and ring moulds all imply a thorough knowledge of the local enviornment. The Dainton smiths were familiar with the working properties of the diverse deposits in the vicinity of the site, and were thus able to select and prepare the best raw materials to meet their specialised requirements.

Mould fabric analysis has also revealed that at least two distinct episodes of prestige weapon casting took place at Dainton. However, allowing for no chronological overlap in crucible use, vessel representation, relinings and renovations attest a minimum of eleven melts (fig III.4.8). As the weights of implements similar to those cast in mould Fabrics 2 and 3 total 2000 and 1850 gm respectively - both well within the 2900gm (of leaded bronze) maximum capacity of crucible A - it is conceivable that the extant mould debris represents the final two melts for which this vessel was used. It has been suggested that these two melts might equate with the final two relining layers on crucible A, or perhaps the uppermost one if relinings protected the crucible through more than one melt (Needham, 1980a, 214). The homogeneity of the vessel fabrics (including relinings) together with the probable exploitation of the same raw material for all crucible making and refurbishing, suggest that the earlier castings in crucible A and melts may perhaps be attributed to deposition in a different area, unlocated during excavation. It is interesting that no vitrified clay or other possible furnace evidence was recovered, and that meticulous excavation yielded only a single droplet of bronze waste. Furthermore, no traces of burning were found across the entire excavated area. All this indicates that casting took place some distance away from the pit where the crucibles and moulds were discarded. It is not inconceivable that a similar pit may have been dug elsewhere on the site to accomodate earlier casting waste. It would seem likely from all evidence that specialist weapon smiths were active at Dainton, perhaps sporadically, over a considerable period of time.

Unfortunately relationships between areas and periods of occupation, areas and sequences of metalworking activity, and acts and points of discard, could not and cannot now be traced. It is hoped that future excavation in the unquarried areas to the south of the bridle path will shed more light on industrial organisation at this site.

TABLE III.4.1 DAINTON: CONCORDANCE OF SECTIONED SHERDS (after Needham, 1980a)

TABLE I. FABRIC DETERMINATION OF THIN-SECTIONED CLAY FRAGMENTS AND CONCORDANCE WITH TYPE

Identification number	*Artefact type*	*Reconstructed valves*	*Fabric*	*Comments*
X67	Spearhead (i)	1A	2	outer wrap also
X69	Spearhead (i)	1B	2	outer wrap also
X52	Spearhead (ii)	1B	2	outer wrap also
X282	Spearhead (ii)	1A	2	outer wrap also
X55	Spearhead (ii)	2B	1	outer wrap also
X210	Socket terminal	1A	1	fabric supports the view that these belong to a ferrule mould unit, perhaps valves 2A + B, rather than to a spearhead
X17	Socket terminal	1B	1	
X25	Ferrule (iii)	2A	1	
X21	Ferrule (iii)	2B	1	outer wrap also
X40	Ferrule (iii)	1A	1	outer wrap also
X12	Ferrule (iii)	1B	1	outer wrap also
X117	Sword (iv)	1A	1	
X81	Sword (iv)	1A	1	
X306	Sword (iv)	1B	1	outer wrap also
X75	Sword (iv)	1B	1	
X85	Sword (iv)	2A	2	
X114	Sword (iv)	2A	2	outer wrap also
X296	Ring (v)		3	outer wrap also
X486	Crucible Class 1	vessel A	3	
X499	Crucible Class 2	vessel B (first phases)	3a	one re-lining sampled also
X502	Crucible Class 2	vessel B (later phases)	3	wall addition plus two re-linings sampled
X498	Crucible Class 2	vessel C	3	one re-lining sampled also
X621	Crucible body sherd	? vessel C	3	
D5A	unidentified		1	inner and outer sampled
D720*	unidentified		1	
D730*	unidentified		1	
D2A*	unidentified		2	
D3A	unidentified		2	inner and outer sampled
D4A	unidentified		2	
D75*	unidentified		2	
D83*	unidentified		2	
D183*	unidentified		2	
D275*	unidentified		2	
D390*	unidentified		2	
D425*	unidentified		2	
D430*	unidentified		2	
D747	unidentified		3	

* denotes that the fragment was completely destroyed in analysis.

N.B.—Identification numbers preceded by 'D' are the site context numbers of fragments which have not been catalogued by the author and thus lack an 'X' number.

TABLE III.4.2 RAW MATERIAL SAMPLES: DEVON

Sample no	Grid ref	Geological notes
DA 1 (R)	SX 854698	Dolerite
DA 2	SX 863666	Clay on limestone (lime-free clay)
DA 3	SX 863666	As DA 2
DA 4	SX 874677	Clay on Littleham Mudstone (Permian)
DA 5	SX 865703	Bovey Beds
DA 6	SX 865702	"
DA 7	SX 923674	Watcombe Clay
DA 8	SX 922675	"
DA 9	SX 925673	"
DA 10	SX 928662	Junction of limestone and Watcombe Clay (poor, stony clay)
DA 11	SX 874739	Upper Greensand (clay pockets in sand quarry)
DA 12	SX 813768	Bovey Beds)
DA 13	SX 813768	Bovey Beds)
DA 14	SX 813768	Bovey Beds) (different depths, different coloured clays)
DA 15	SX 813768	Bovey Beds)
DA 16	SX 715711	Metamorphic aureole surrounding Dartmoor Granite
DA 17	SX 716711	" "
DA 18	SX 717711	" "
DA 19	SX 719715	" "
DA 20	SX 722714	" "
DA 21	SX 723715	" "
DA 22	SX 724713	" "
		(DA 16-22 = various samples from Holne Chase Estate)
DA 23	SX 817790	Hyner Shale (Devonian) (rare pockets of clay)
DA 24	SX 816790	" "
DA 25	SX 800783	Aller Gravel (Eocene) (disused claypit)
DA 26	SX 800782	" "
DA 27	SX 798797	Shales and sandstones (Carboniferous)
DA 28	SX 849812	Dolerite (transported clay on rock)
DA 28 (R)	SX 849812	Dolerite
DA 29	SX 843772	Bovey Beds (Ballclay)
DA 30	SX 879690	Aller Gravel (Eocene)
DA 31	SX 879690	"
DA 32	SX 870694	" (disused claypit)
DA 33	SX 870694	Permian breccia
DA 34	SX 806807	Dartmoor Granite (rare clay in eroded pockets)
DA 35	SX 776354	Mica schist/Chlorite schist)
DA 36	SX 776354	" ") (different depths from
DA 37	SX 776354	" ") clifftop)
DA 38	SX 767357	Chlorite schist
DA 39	SX 865666	Base of limestone plateau (limefree clay)
DA 40	SX 864660	Volcanic tuffs
DA 41	SX 864660	"
DA 42	SX 820370	Chlorite schist)
DA 43	SX 820370	")
DA 44	SX 820370	") (different depths from clifftop;
DA 45	SX 820370	") variable coloured and textured clays)
DA 46	SX 820370	")
DA 47	SX 820370	")
DA 48	SX 934705	Mica schist/Chlorite schist)
DA 49	SX 934705	" ") (different depths from
DA 50	SX 934705	" ") clifftop; variable coloured
DA 51	SX 934705	" ") and textured clays)
DA 52	SX 928686	Permian breccia
DA 53	SX 928686	"

APPENDIX III.4.1

(after Howard, 1980d)

The Dainton Ceramic Assemblage: A Petrological Report

by Hilary Howard, Department of Archaeology, University of Southampton

Introduction

The exceptional assemblage recovered from the metal-working pit at Dainton provided a unique opportunity for detailed study of Bronze Age refractory technology. At no other site of this period in Britain have those ceramic objects intègral to the bronze casting process been found in such an excellent state of preservation.

The writer's initial general aim was to concentrate on the refractories, analysing all mould and crucible fragments from Dainton, in order to establish raw material exploitation patterns and to assess the technical expertise of the producers. Results were then to be compared with those obtained from analyses of similar material from contemporary and later contexts. However examination of the fabrics of four pottery sherds from the site, supplied by the excavator for comparison with the metalworking debris, suggested expansion of the research design. These four sherds recovered from the periphery of the pit represented three distinct fabric types, indicating that in addition to bronze-casting, a complex pottery production and/or acquisition system was operating at Dainton. In view of the potential interest of all ceramic evidence from the site, it was decided to conduct an extensive analytical programme incorporating both refractory and non-refractory remains.

All crucible and mould fragments and the majority of potsherds from both the 1939–49 and 1975 excavations were examined macroscopically with a 10x lens. The extremely small size and abraded nature of virtually all fragments rendered an initial sorting into fabric groups always difficult, and at times impossible. For example, every pottery sherd recovered with the metalworking debris from the pit weighs less than 1 gm, and lacking either original face, is aptly described as ceramic gravel! Thin sections were made of all fabric types which seemed to be represented and a number of 'miscellaneous' sherds were also sliced. Possible raw material sources suggested by microscopic identification of constituent mineral suites, were tested by means of extensive clay sampling in the south Devon region.

The Refractories

Analysis of mould fragments revealed that inner valves and outer wraps of individual moulds were formed from the same clay, although the outer wrap material was poorly prepared, containing unevenly distributed inclusions and evidence of accidentally incorporated organic matter. Three distinctive clay bodies were used for mould manufacture, all displaying good refractory qualities. Fabrics 1 and 2 (both used for casting a range of implements) are difficult to separate macroscopically, both containing extremely fine inclusions, and both firing to the same colour range (Munsell 2.5YR6/6 – 10YR/5/4). Microscopically, however, fabric 1 contains inclusions closely matched by those present in the Watcombe clays, whilst the mineral suite present in fabric 2 strongly suggests the aureole surrounding the Dartmoor granite massif as the likely raw material source. Fabric 3, apparently restricted to ring mould manufacture, resembles that used for crucible production.

All crucible samples (and the two mould fabric 3 sherds analysed) contain a high tenor (60–80%) of fine angular quartz set in a sparse anisotropic clay matrix. Other inclusions are rare in this highly refractory paste, and the same, or a closely related raw material source (as yet not established), is suggested for all samples.

The three distinct mould fabrics and the highly refractory crucibles indicate careful raw material selection and preparation reflecting a sophisticated level of pyrotechnology, lasting through at least two casting phases. The specific aims, procedures followed, and results of the refractory analyses are described in detail elsewhere (Needham 1980).

The Pottery

Sherds from the 1939–49 excavations (housed in Rougemont House Museum, Exeter, and Torquay Natural History Society Museum) and the 1975 season (in Exeter Museum) were divided when possible into fabric groups. At least five groups were identified, and sampled for thin section analysis. Several samples from each group were sliced, as considerable within-group variation was noted during macroscopic sorting.

Pottery fabric group 1: 'Basic igneous'. Of the eighteen group 1 samples analysed, ten were completely oxidised (Munsell 2.5YR/5/6, with some minor variation within the 2.5YR range), three were black-cored, and five had been fired under total reduction conditions. The fabric is generally low-fired, soft or very soft, and varies in thickness (when this could be measured) from 4 mm to 15 mm. Angular, sometimes platy fragments of igneous rock (usually about 1.5 mm, but occasionally reaching 3 mm) are visible on the surface and in fresh fracture. Blackened 'haloes' caused by the burning out of carbonaceous residue occur in most oxidised samples, and dark mica flecks are present though rare throughout the range.

Under the microscope the rock fragments are seen to consist of highly altered laths of plagioclase felspar, a little pyroxene (identified as augite in some sections) and additional ferromagnesian minerals, completely altered to brown amorphous 'clumps'. Mineralogically, therefore, the fragments may be classified as altered dolerite, a member of the 'greenstone' group. Free clinopyroxenes, yellow-brown? amphiboles, elongated grains of altered plagioclase and a little potash felspar, presumably derived in part from the basic rock fragments, are sometimes visible within the anisotropic clay matrix. The matrix additionally contains subangular quartz (0.5 mm or less), considerable iron ore, and rare yellow and brown plates of biotite. The large size, angularity and generally even distribution of the greenstone fragments suggest that rocks were deliberately crushed and added to a relatively fine clay to increase its working properties and fired strength. The discovery of several pieces of altered dolerite (one weighing about 5 gms) amongst the pit material supports this theory. Several small outcrops of dolerite occur within a few hours' walking distance of Dainton, the nearest being found north of the site near Abbotskerswell (SX 850684). These outcrops are not easy to locate, and the selection of dolerite as a pottery temper implies an intimate knowledge of local resources and their properties.

Two clay samples collected from the slopes of Dainton Hill and the stream below (SX 863666 and SX 865669) bear a close resemblance, in thin section, to the matrix material of the basic igneous pottery. It thus seems reasonable to suppose that this group represents domestic production exploiting both local and non-local raw materials.

Pottery fabric group 2: 'Grog'. Macroscopically, in both fired colour range and in general appearance, this group is virtually identical to group 1. However, the angular black inclusions (0.5 mm–1.5 mm) visible in fresh breaks can be nail scratched with difficulty. In thin section, these inclusions are identified as grog set in a local clay matrix. In two of the four samples confirmed as grog tempered (DA28P and DA54P), the crushed sherd fragments contain inclusions similar to those in the matrix. However, fine-grained sandstones characterise the temper of sample DA43P; and the well-distributed grog in sample DA6P contains sandstone, felspar, a little free pyroxene, and a single tiny fragment (0.3 mm) of basic igneous rock, in addition to subangular quartz.

Group 2 again seems to have been locally produced. Despite the small sample, we may infer from the range of inclusions observed within the temper fragments, that there was no preferential selection of fabrics for use as grog. Why crushed pottery was sometimes added to the local clay instead of greenstone is presently unknown. The different pastes perhaps represent different vessel functions, and experimental firing and fabric tests are in progress to examine this possibility.

Pottery fabric group 3: 'Chlorite schist'. The four samples representing this group are difficult to describe in hand specimen. The sherds are very small and much abraded, neither original surface being preserved. The friable fabric is generally heavily reduced (only sample DA4P shows any trace of oxidisation), and inclusions are not easy to distinguish with the aid of a hand lens. In this section, the paste is seen to be dominated by elongated plates of chlorite schist (to 4 mm) which have turned brown on firing. Free, altered plagioclase felspar, white mica, and subangular quartz grains are visible in the groundmass. The presence of chlorite schist is unexpected and interesting, for the nearest outcrops of this rock occur in the Start Point region, some 30 km (straight line distance) from Dainton. Fired samples of clays derived from the chlorite schist at Prawle Point (SX 781355) compare very closely with the sherds sectioned.

Pottery fabric group 4: 'Sandstone'. Both macroscopically and under the microscope, group 4 sherds show considerable variation in clay matrix, firing technology and inclusion range. Hard, well-fired, completely reduced fabrics are occasionally found, but uneven, low firing is more generally observed. The clay body predominant within this group fires at low temperature under oxidising conditions to greenish yellow (10YR/5/4). Black cores are common, and some of the very soft sherds are dark grey or black throughout. A minority of sherds with reddish (2.5YR/6/6) surfaces are classified as group 4 on the basis of inclusions identified within the matrix, but whether this colour variation represents different firing technology or a dissimilar clay body is not yet known. In fresh fracture, anhedral grains of sandstone are visible in most group 4 samples.

Under the microscope all sections are seen to contain abundant sandstones varying in grain size, metamorphism and content. Sheared, foliated sandstones with siliceous cement occur alongside ferruginous varieties and other crypto- and microcrystalline examples with micaceous content. Additionally, some sherds contain an acid devitrified volcanic glass, altered slate, or fragments of tuff. Rare euhedral grains of sanidine felspar, previously called Murchisonite (Ussher 1913, 82–3) are also visible in some samples. Poorly sorted subangular quartz grains in varying amounts, and occasional threads of white mica are scattered throughout the generally ill-worked clay matrix.

The range of inclusion permutations and matrix variation renders it impossible to make any justifiable intra-group subdivisions. The minerals identified are suggestive of an origin within the Permian Breccias and Conglomerates of the Teignmouth region. Clay samples collected at Coombe, and from the cliffs south of Teignmouth (SX 933738, SX 932698, SX 929692, SX 928685) contain a range of sandstones similar to those observed in the sherd sections. Sanidine too is present though rare. However, the absence of rhyolite, altered slates, and tuff from the sampled clays, together with their consistent pink-red (10R/5/6 – 10R/4/6) colouring throughout the 0–850°C temperature range, suggests that Permian and possibly other rocks were added, as temper, to less ferruginous clays yet to be located.

Interestingly, the matrix material of the quartz-porphry saddle querns (see Dr. Selwood's comments, p. 26), when examined microscopically, bears a strong resemblance to the often porphyritic rhyolite inclusions in the pottery, thus confirming the Breccia as the likeliest temper source. It is hoped that a further raw material sampling programme, now in progress, will help to elucidate the production mechanisms embodied in this complex fabric group.

Pottery fabric group 5: 'Quartz and chert'. Three oxidised samples of a comparatively fine sandy fabric were sectioned and found to represent a homogenous group. The matrix contains a high tenor of subangular quartz grains, all less than 0.2 mm, considerable fine white mica, and occasional angular fragments of chert or flint. A Cretaceous source might be suggested, and samples of fired greensand clay from the Milber Down area (SX 884698) are now being compared with the pottery sections.

Remainder. In addition to the fabrics described above, nine sherds were analysed which are dissimilar one to another and which cannot be ascribed to any known groups. Space prohibits a detailed description of the paste constituents, and ideally more similar samples would be necessary before any raw material origins could be suggested for these miscellaneous fragments.

Discussion and Conclusion

Petrological analysis has revealed a surprising degree of ceramic complexity at Dainton. Raw material for mould and crucible manufacture were carefully selected

Table of sherds and rock fragments sectioned

Key to suffixes

A—Sherd from 1939–49 excavation, Torquay Museum
B—Unnumbered sherd from 1939–49 excavation, Exeter Museum
C—Sherd from 1975 excavation, found in bronze-worker's pit, Exeter Museum
D—Sherd from 1975 excavation, found outside bronze-worker's pit, Exeter

Repetition of numbers with suffix C results from groups of very small fragments from the pit being assigned the same number.

Rock fragments

Section No.	Excavation No.
DA1	412C
DA61	156C
DA62	156C
DA63	775C

Group 1: basic igneous

DA2	224D
DA7	203D
DA8	535D
DA9	172D
DA10	B
DA11	56D
DA12	832D
DA34	411C
DA35	A224/15A
DA36	735C
DA37	735C
DA38	615C
DA39	A210/8A
DA40	573C
DA41	156C
DA52	615C
DA53	412C
DA58	694C

Group 2: grog

DA6	406D
DA28	68D
DA43	655C
DA54	672C

Group 3: chlorite schist

DA3	828D
DA4	657D
DA44	672C
DA45	156C
DA46	573C

Group 4: sandstone

DA5	96D
DA13	B
DA14	B
DA15	B
DA16	B
DA17	B
DA18	B
DA19	B
DA20	B
DA21	104D
DA23	B
DA24	B
DA27	52/2D
DA29	B
DA50	412C
DA59	A241A
DA60	A211A
DA66	652C

Group 5: quartz and chert

DA48	A245A
DA51	A229/20A
DA67	197C

Unassigned

DA32	156C
DA42	596C
DA47	735C
DA49	674C
DA56	694C
DA57	156C
DA64	156C
DA65	A244A
DA68	58D

or their refractory properties by either the bronze-smiths, the resident potters, or specialist refractory producers. Refractory fabrics were never used for pottery production.

The above results show that the on-site potters were familiar with at least two paste compositions. Greenstones were transported to Dainton specifically to be crushed and added to local raw material, and broken potsherds were also recycled to strengthen the fine clay overlying the limestone of Miltor Mator Common. Pottery vessels tempered with chlorite schist were perhaps imported to the settlement from a manufacturing centre situated somewhere in the Start Point region.

It is equally possible that the sandstone fabric group represents trade in ceramics at some stage of the site's occupation. This complex group is difficult to interpret. Distribution patterns on the site (the vast majority of sandstone tempered sherds were recovered from the 1939–49 excavation area) suggest that these fabric types became much more important in the later occupation phase. None of the sandstone sherds was locally produced (unless both clay and temper were transported to a clay-rich site!); thus it may be suggested that a change in both ceramic manufacture and distribution took place at Dainton after the bronze-casting era, probably reflecting a change in social and economic organisation at the site.

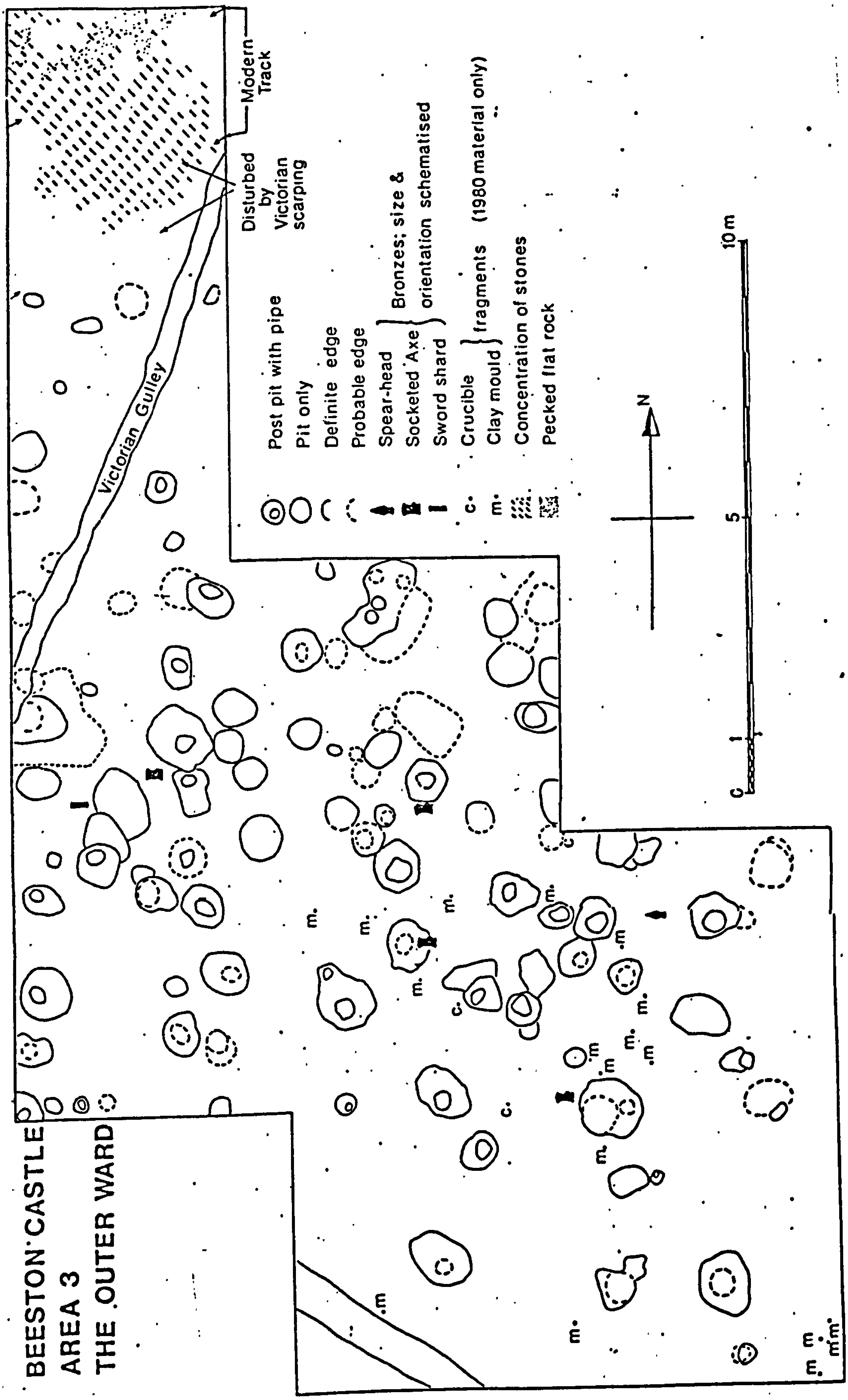
Work completed to date in connection with the Dainton ceramic assemblage has emphasised the importance of raw material sampling to the interpretation of ancient clay artifacts. This sampling programme continues, and it is hoped that the results, together with analyses of other contemporary south-western ceramic material, will help us to understand more clearly the complexities of the Dainton economy.

III.5 BEESTON CASTLE, CHESHIRE
(SJ 537593; corpus no 2)

In 1979, a bronze socketed axe was handed over to O J Weaver (Inspector of Ancient Monuments) by a member of the public who claimed to have found it, with the aid of a metal detector, in the outer ward of the thirteenth century castle at Beeston. In 1980, a 100 sq m area was opened in the locale of the findspot, and considerable evidence of prehistoric activity was recovered. Excavations revealed at least two, and possibly three structural phases, a large quantity of pottery (typologically dated to the later bronze and iron ages and perhaps including VCP or briquetage), stonework including upwards of 200 flint artefacts, and bronzeworking debris. Two more socketed bronze implements were found within the area investigated (Hough, unpublished a). An adjacent 100 sq m excavated in 1981 yielded a similar range of artefacts, but no additional interpretative evidence was recovered, and the exact nature and extent of the prehistoric settlement is as yet unknown (Hough, unpublished b). Three radiocarbon dates have been obtained from the prehistoric occupation levels: 910 ± 80 bc (HAR 4405); 660 ± 90 bc (HAR 4401); 330 ± 80 bc (HAR 4406).

III.5.1 The metalworking evidence

Metalworking debris recovered during the 1980 excavations (the 1981 finds are not yet processed) included some twenty fragments of bivalve clay moulds, and four crucible sherds (fig III.5.1-4). A fifth crucible body sherd was later recognised by the writer (fig III.5.2, sherd 468). Mould fragments are generally poorly preserved, but parts of matrices for casting swords (fig III.5.3, sherds 636, 751) and a socket or ferrule (fig III.5.3, sherd 73) were tentatively identified. Metal finds comprised two socketed axes (including the original uncontexted find) of Ewart Park type, and a squat socketed spearhead of either the Ewart Park or Wilburton metalworking tradition. The excavated axe was found beneath a large block of sandstone, and may have been deliberately concealed (Hough, unpublished a), whilst the spearhead was found lying, seemingly



BEESTON CASTLE
AREA 3
THE OUTER WARD

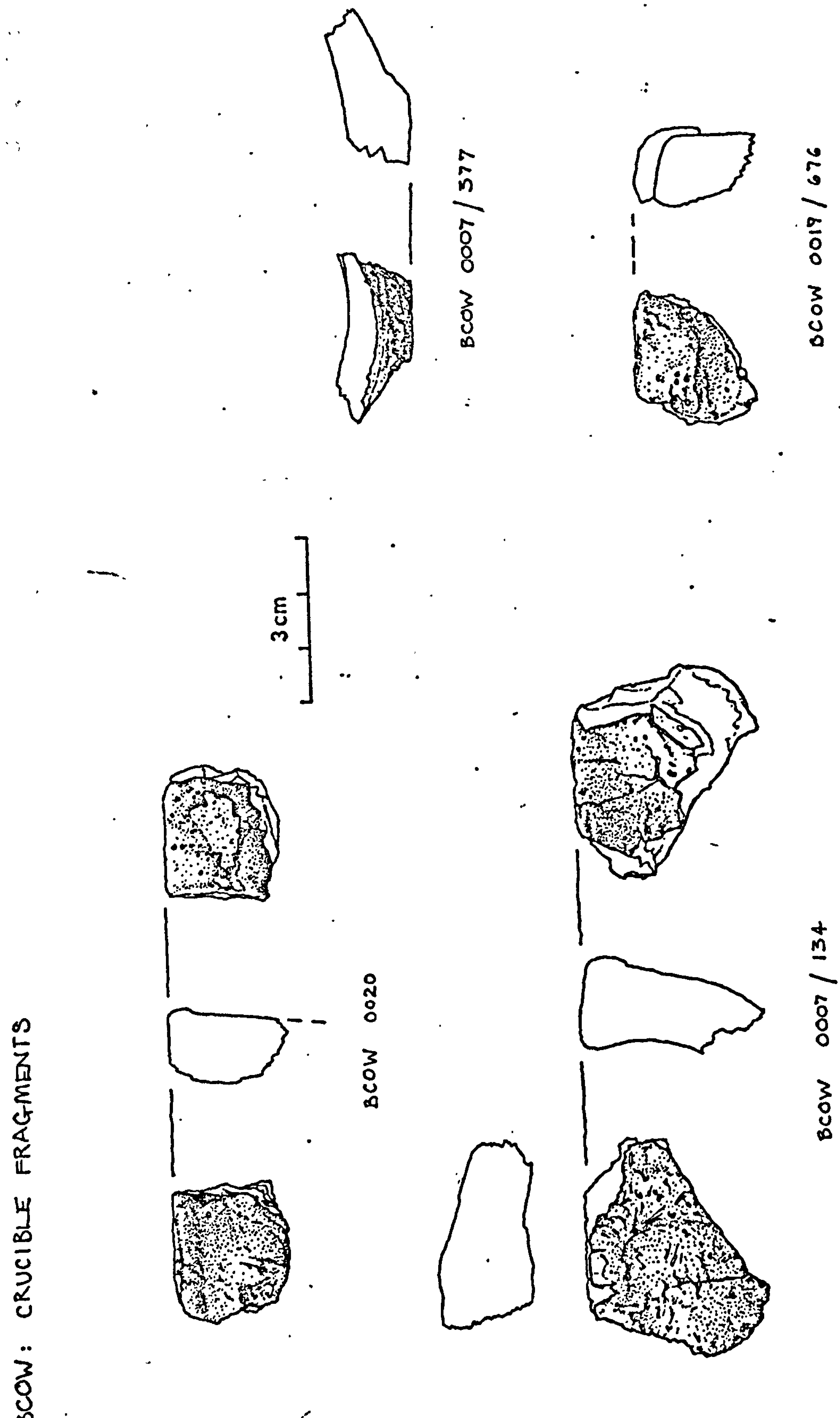


Fig III.5.1 Beeston Castle: crucible sherds. Drawn by M Sasanow.

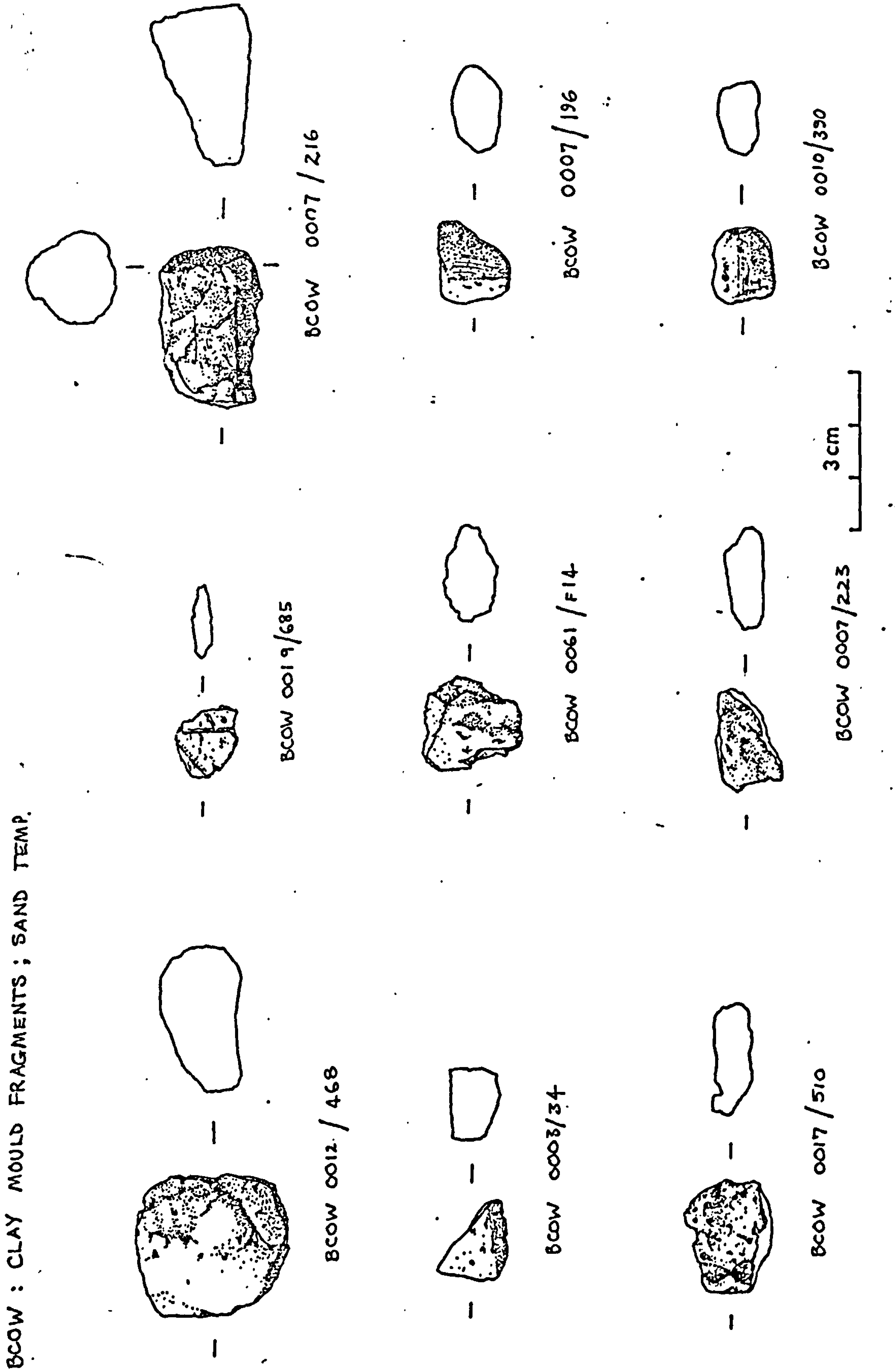


Fig III.5.2 Beeston Castle: crucible sherd (468), possible core locating device (216) and mould sherds (others). Drawn by M Sasanow.

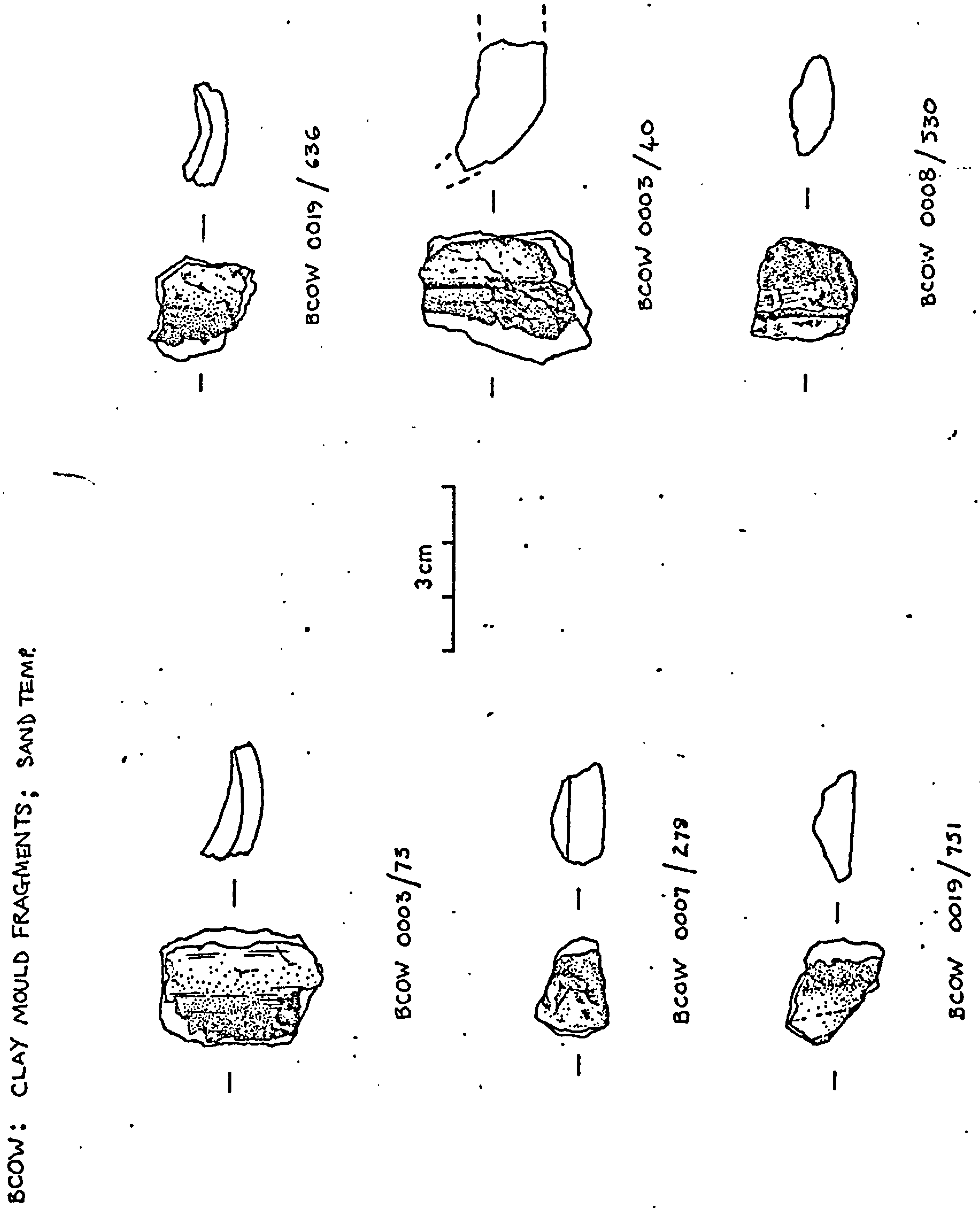


Fig III.5.3 Beeston Castle: mould sherds. Drawn by M Sasanow.

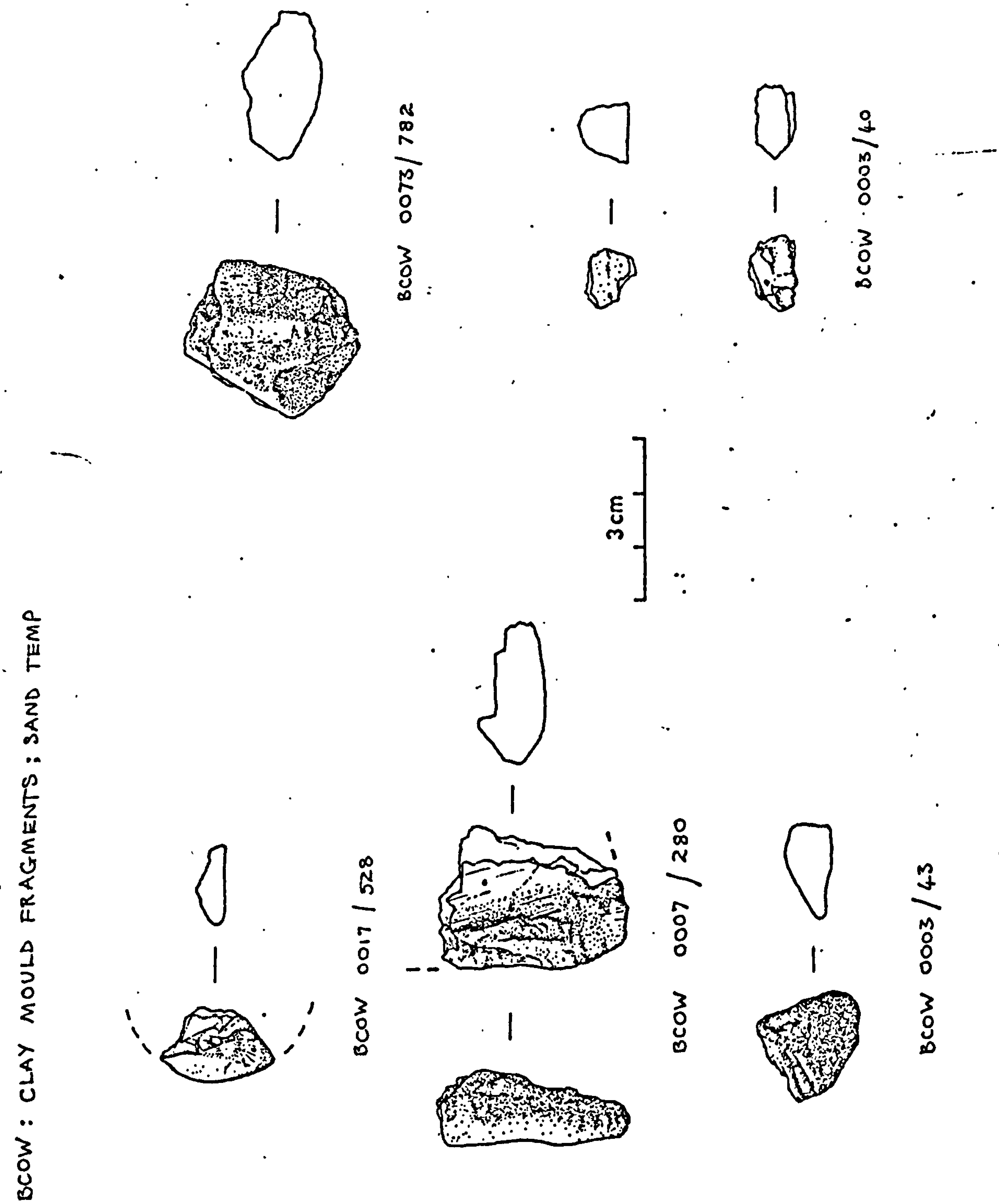


Fig III.5.4 Beeston Castle: sherd of unknown origin (528) and mould sherds. Drawn by M Sasanow.

abandoned, on a buried surface.

III.5.2 Analytical results (see Table III.5.1)

The crucibles

X-ray flourescence determinations confirm that the four analysed prehistoric sherds from Beeston Castle were used for the melting of copper alloys (J Bayley, pers comm). Two rim sherds were recovered, one of which (BC 7, crucible body; BC 16, relining layer) had been relined. All crucibles are reduction fired to greenish-black, although oxidised zones (5YR 6/6 - reddish yellow) occur on the outer surfaces of sherds BC 4, 15 and 17. All save sample BC 17 are harsh textured and somewhat vesicular, and despite high firing in use, all are extremely friable. Rounded quartz sand grains of varying size are visible in all samples, and sherds BC 15, 4 and 7 (relined with sample 16) contain a scatter of carbonaceous fragments and voids probably caused by the burning out of organic matter.

Two crucible fabrics are clearly defined in thin section. Fabric 1 (samples BC 17, 20 and the relining layer, 16) contains only abundant rounded and sub-rounded quartz sand and a scatter of iron oxide set in an optically isotropic, ferruginous clay matrix. Matrix:inclusion ratios suggest that fine grade sand and iron rich clay (in approximate proportions of 60:40) were mixed to prepare this refractory paste (fig III.5.5). Crucible Fabric 2 (samples BC 4, 15, 7) is seen in thin section to contain a scatter of ill-sorted, rounded grains of quartz, quartzite and sandstone (some of which is metamorphosed) and abundant fragments of carbonised organic material, up to 3mm in length. The matrix of all three samples is isotropic indicating prolonged or repeated heating at high temperature. Unfortunately, slag penetration and the presence of artificial minerals hindered the reliable determination of inclusion density, but mineral inclusions are visibly sparser and generally less well sorted than those present in crucible Fabric 1 (fig III.5.5).

The moulds

Clays selected for mould making at Beeston are generally extremely fine, sandy and slightly micaceous. Although mould fragments can be clearly distinguished from other ceramic artefacts from the site on the basis of form, texture and lack of large mineral inclusions, it is often difficult to separate inner valves and outer wraps in hand specimen. Considerable variation in fired colour is apparent throughout the mould assemblage, and colour gradations through the thickness of a single sherd are common (Table III.5.2). Hard-fired inner valves are dense and tend to be fine textured, whereas outer wraps feel slightly rough and sandy. Inner pastes are generally well mixed and lack voids and visible mineral inclusions. Outer wraps appear more porous and contain scattered, hard, white inclusions and visible quartz sand. Sparse flecks of carbon and a little fine mica are seen in all mould samples.

Two mould fabrics, corresponding to inner valves and outer wraps, may be broadly distinguished microscopically on the basis of size range and density of quartz sand, distribution of inclusions and the occurrence of sandstone grains. Considerable variation is apparent within each of these fabric groups (figs III.5.5, 6) and subdivisions may be possible when more material has been analysed.

Mould Fabric 3 (inner valves) contains an average 57% of fine sand set in a generally anisotropic ferruginous clay matrix. Isotropic zones are visible in some samples. The filler consists in the main of well-sorted rounded and subangular quartz grains, but tiny fragments of plagioclase felspar, clinopyroxene and epidote are scattered throughout most sections. All samples contain infrequent white mica laths to 0•1mm in length.

In thin section, outer wrap matrices (mould Fabric 4) are invariably anisotropic, indicating firing temperatures not exceeding 850°C. The sparsely-distributed, ill-sorted inclusions consist of subrounded grains of quartz sand and sandstones with ferruginous cement, varying in size from 0•01mm to 0•75mm. Rare threads of mica occur in most samples. Rounded grains of iron oxides are scattered throughout all sections

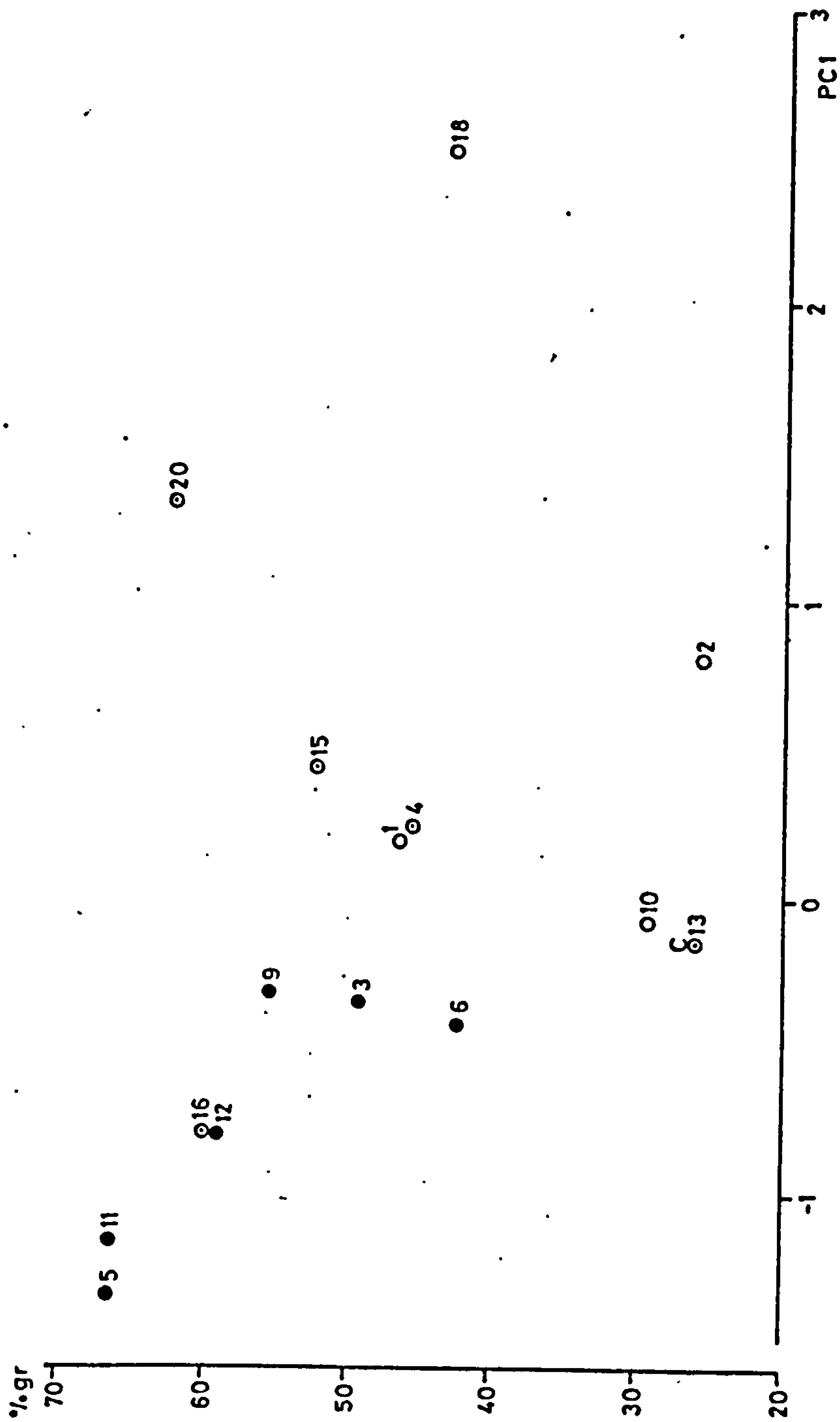


Fig III.5.5 Beeston Castle: inner mould (●), outer mould (O), crucible (ʘ) and core·(ʘC) fragments. Sherds are plotted against grain size (expressed by scores on the first principal component extracted from the ∅ counts) and proportion of grains:matrix.

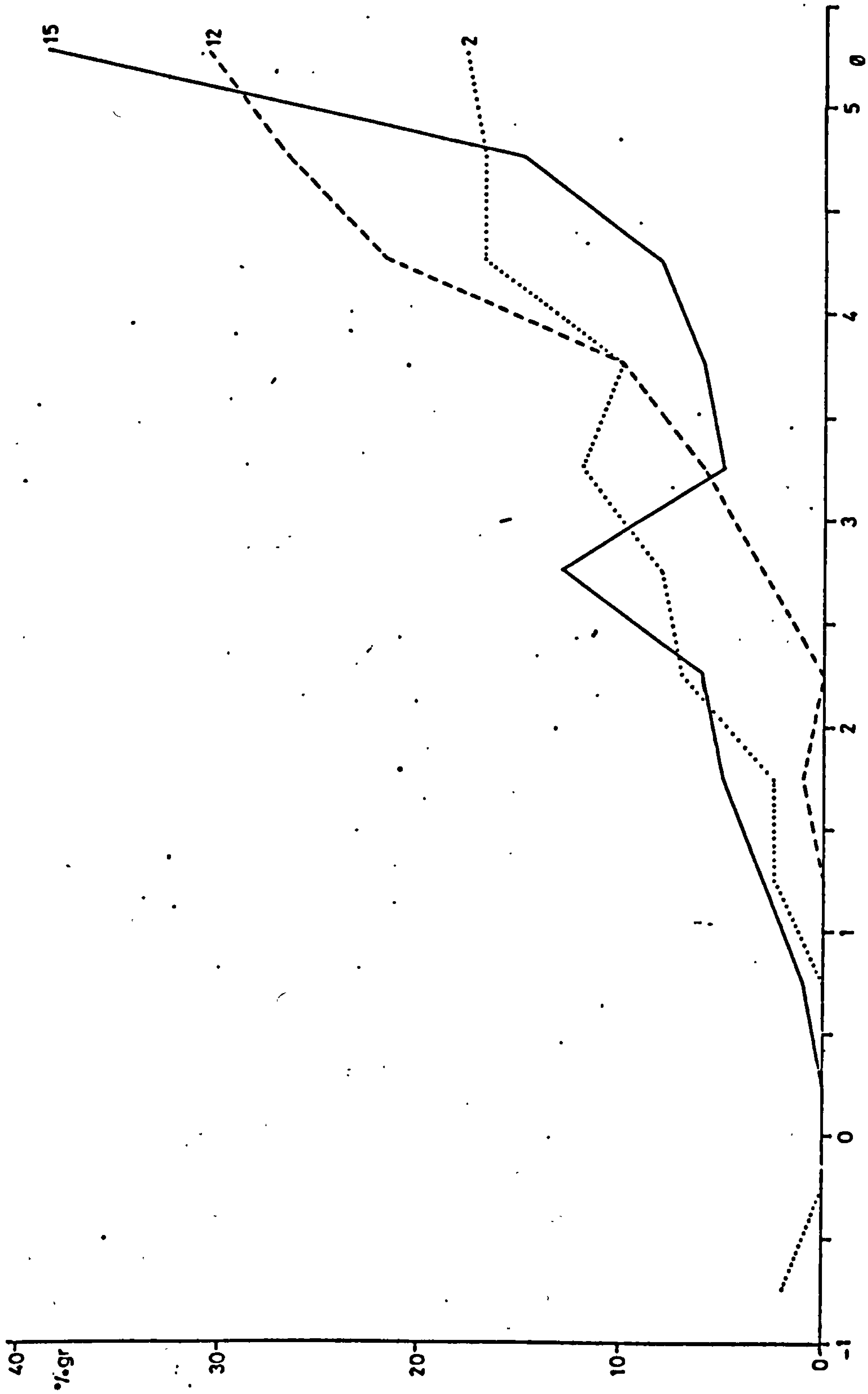


Fig III.5.6 Beeston Castle: representative grain size curves for inner mould (Fabric 3: 12), outer mould (Fabric 4: 2) and crucible (Fabric 2: 15).

examined, and ferruginous clay pellets are common. A little finely divided carbon is visible, but generally not in sufficient quantity to suggest the deliberate addition of an organic filler. The sporadic occurrence of carbon is more likely to represent the exploitation of a superficial clay deposit contaminated with organic debris. Clay matrix outweighs inclusions in this fabric by an average 63% (fig III.5.5).

Sample 13 (fig III.5.2, sherd no 216), although certainly not mould, is nevertheless formed from outer mould fabric. The form and 'D' shaped section suggest that this unusual fragment may represent a device for holding the core of a socketed implement in place during the pouring process. Pending recovery and examination of similar artefacts, this identification must remain tentative.

III.5.3 Resource ecology and raw material analysis

Beeston Castle is sited on an imposing hill of Keuper Sandstone overlooking the Cheshire Plain (fig III.5.7). Keuper marl lies to the east, and Keuper sandstone and Bunter Beds outcrop to the east, and Keuper sandstone and Bunter Beds outcrop to the west (Hains and Horton, 1969, 68). The area was heavily glaciated, and thick deposits of upper and lower Boulder Clays (believed to correspond to separate incusions of the ice sheets) occur to the south and east of Beeston. These contain a diverse suite of erratics derived in the main from Scotland and the Lake District (Poole and Whiteman, 1966, 60-69). It is clear from the geological map (fig III.5.7) that clays and sands of varying age and derivation abound in the Beeston area. Many of these deposits have been extensively quarried in recent times for the production of bricks and tiles, and medieval and pre-industrial maps show many small clay pits, now long disused. Four such clay pits are indicated on the 1732 local estate map of Sir Thomas Mostyn, together with field names suggestive of a ceramic connection (I am grateful to Peter Hough for access to a copy of this map). Twenty nine raw material samples were taken in the Beeston area, including clays, sands, and wasters from the now disused brickyards. All clays were processed and thin sectioned, but time prevented experimentation with the various sand samples.

The results of thin section analysis of the clays were disappointingly inconclusive. Aside from clay samples BC 10 and 11 (weathering products of the Keuper sandstone of Beeston Hill itself) which were found to contain abundant angular fragments of plagioclase felspar, few of the remaining samples could be eliminated as possible sources of refractory materials. Clays from the Beeston area contain no far-travelled rock fragments, and inclusions are limited to rounded and subangular quartz, white and sometimes brown mica, quartzite and various sandstones. Clay samples BC 8, 18, 19, 22, 23, 24 and 27 contain a sparse scatter of detrital grains, predominantly epidote. Interestingly, samples taken from different drift formations are often virtually identical in thin section, illusrating the extremely mixed nature of the surface geology in the Cheshire-Shropshire Basin.

Comparing the refractory thin sections with those cut from the various clay samples, it is clear that the Beeston metalworkers may have exploited various different deposits for the production of their ceramic equipment. Sample BC 8, taken from a pocket of clay in the glacial sand quarry at Beeston, closely resembles inner mould sherds BC 5, 9, 11, 12 and 14 in grain size, packing density and the presence of mica and detrital minerals. Outer moulds, however, show a similar range of variation to that observed in most samples taken from the Boulder Clay along the course of the Shropshire Union Canal, and from glacial deposits to the north, east and west of the Beeston site. The mould makers may have used any of these materials with minimal preparation. Inner moulds could conceivably have been prepared from associated silty clays (eg BC 20 or 25) with added sand.

The virtually non-micaceous, naturally bonded sand from Claycrofts (BC 18) closely resembles crucible Fabric 1, and this deposit may have served as the raw material source for that category of artefact. The quantity of carbon present in crucible Fabric 2 suggests that this material was deliberately added to improve the refractory quality of the paste. However, clay samples BC 1 and BC 2 from the glacial sand and gravel and Boulder Clay junction at Bunbury contain a considerable amount of naturally included, rotted organic matter, and although neither is identical in thin section to the crucible samples, it is suggested that a mixture of these clays, perhaps with a little added sand, would produce a precise match.

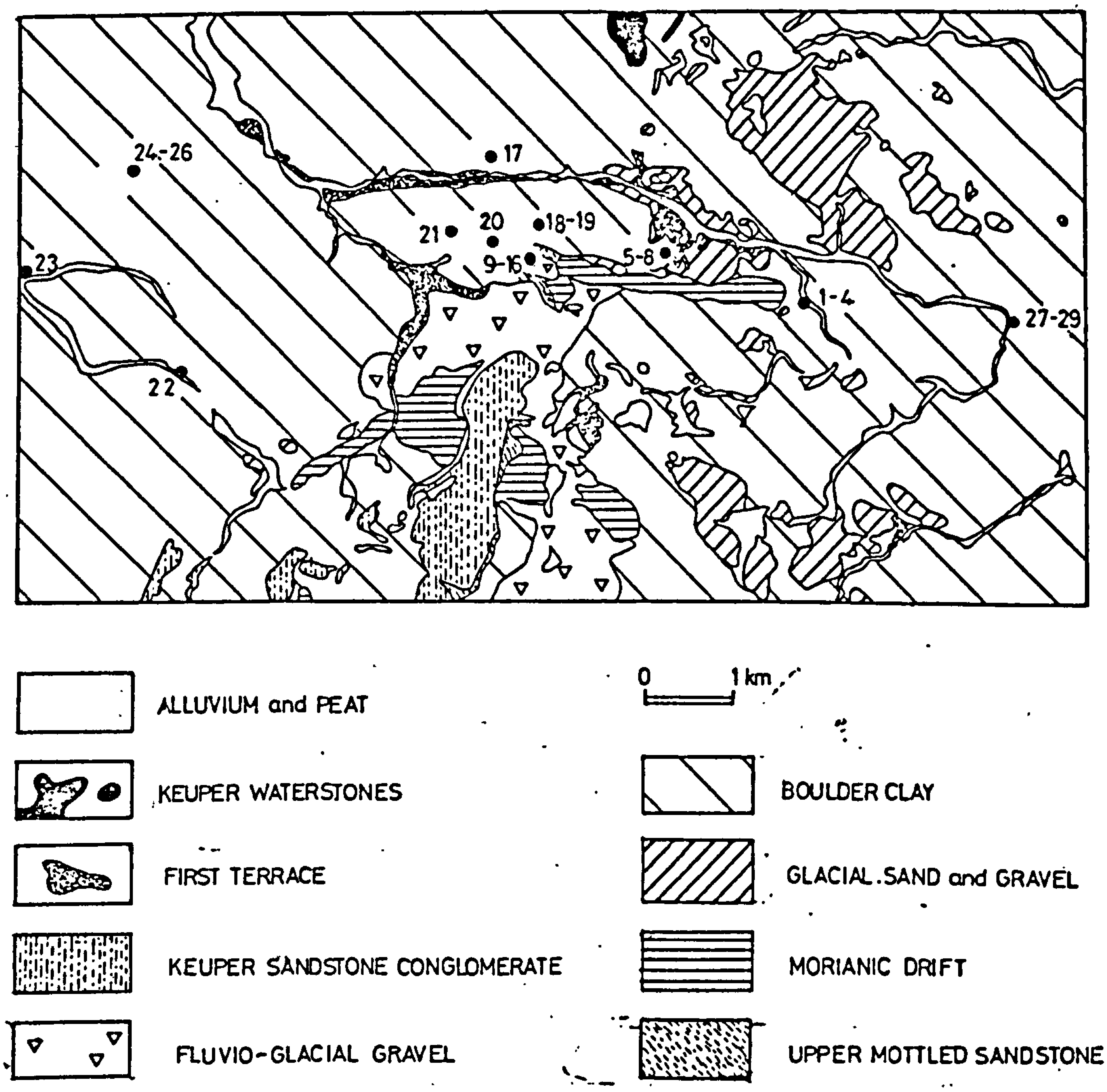


Fig III.5.7 Geology around Beeston Castle (the location of raw material samples nos 9-16) and location of raw material samples

It is clear from the above that a wide range of local raw materials would have been available for refractory production at Beeston. The close similarity between various drift deposits has been noted, and it is stressed that the 'sources' suggested above are hypothetical, and based only on the results of petrological analysis. More precise characterisation might be achieved through a quantified analysis of the detrital mineral content of clays, sands and refractories, but the quantity and nature of the archaeological material renders this impossible.

III.5.4 Discussion

The small collection of refractories from Beeston is extremely difficult to interpret. Although a bivalve technology and the presence of spearhead and ferrule matrices point to a late bronze age date, little more can be inferred from the mould evidence at present available. Most moulds are too abraded for identification of the range of implements cast, and the lack of stratigraphic relationships precludes any suggestion of separate casting phases. A measure of technological information was obtained from fabric analysis (different clay preparation and slightly different inclusion suites for inner and outer mould components), but, at this stage, no distinct groups can be defined on mineralogical grounds. All mould fragments recovered at Beeston in 1980 could, conceivably, be derived from a single casting episode.

The crucible evidence, however, suggests a longer period of activity. Two crucible fabrics were identified with inclusions different from those in the Beeston moulds. Variation in grain size range and matrix density show that at least three (and possibly five) vessels are represented. The use of an organic crucible paste is unique in British bronze age contexts, and illustrates the individuality of smithing groups during this period. Whilst it is possible that the Beeston smiths added charcoal or other organic material to a ferruginous clay, it is equally likely that naturally carbonaceous clays such as those occurring in abundance at Bunbury may have been deliberately selected for crucible making. The relining of organic and sand tempered crucible BC 7 with a more siliceous carbon free material (BC 16) is especially interesting, and suggests the concurrent use of two distinct pastes for crucible production by the Beeston smiths. X-ray flourescence detected trace amounts of lead in Fabric 2 samples BC 4 and 15, and a little tin in sample BC 7/16 (presumably in the relining layer), but the amounts detected were very small and near the detection limits for the machine used (J Bayley, pers comm). Although it would be unwise to deduce that the selection of different crucible pastes was related to the composition of the metal to be melted, the possibility cannot be entirely discounted. Further X-ray flourescence and petrological analyses of crucible material from the 1981 excavations should help resolve this problem.

The individual requirements of bronze age crucible and mould makers are emphasised when the Beeston refractory fabrics are compared with those of the various pottery groups from the site. Eight prehistoric pottery fabrics (including one restricted to VCP or salt containers) have been recognised, each of which is tempered with a suite of angual rock fragments, presumably derived from the glacial drift (Morris, unpublished). No rock fragments are present in the Beeston refractories which, with the exception of the organic-rich crucible sherds, consist exclusively of sand, sandstone, a little quartzite and moderately micaceous or non-micaceous clay. Raw material studies have shown that all these refractory ingredients could be obtained with ease in the vicinity of Beeston Castle. Although the deposits exploited cannot be identified with certainty, close matches between clays and refractories have been made. It is clear, that as at other bronze production sites of this period, the bronze age smiths at Beeston were familiar with the range of locally available materials, and were able to adapt these materials to meet their own stringent requirements.

TABLE III.5.1 BEESTON CASTLE: CONCORDANCE OF REFRACTORY SHERDS

Sample no	Excavation no (all BCOW)	Identification
BC 1	003/73	mould: inner valve for socket or ferrule
BC 2	0017/510	mould: outer wrap
BC 3	0003/34	mould: inner valve
BC 4	0007/377	crucible
BC 5	0010/390	mould: inner valve
BC 6	0003/43	mould: inner valve
BC 7	0019/676.	crucible with relining layer (BC 16)
BC 8	0017/528	not refractory (originally identified as ring mould)
BC 9	0019/751	mould: inner valve, ? for sword
BC 10	0018/530	mould: outer wrap with impression of binding material
BC 11	0073/782	mould: inner valve + outer wrap
BC 12	0007/280	mould: inner valve
BC 13	0007/216	possible core locating device
BC 14	0007/278	mould: inner valve
BC 15	0007/134	crucible
BC 16	0019/676	relining layer of crucible BC 7
BC 17	0020	crucible
BC 18	0061/F14	mould: outer wrap
BC 19	0003/40	mould: inner valve + outer wrap
BC 20	0012/468	crucible: body sherd
BC 21	0019/636	mould: inner valve + outer wrap, ? for sword

TABLE III.5.2 BEESTON CASTLE: COLOUR VARIATION IN MOULD FRAGMENTS

Sample no	Mould part	Colour
BC 1	inner valve	dark grey-black inner face; outer face 2•5YR 5/6 (red)
BC 3	inner valve	medium grey throughout
BC 5	inner valve	dark grey-black throughout
BC 6	inner valve	dark grey throughout
BC 9	inner valve	7•5YR 6/6 (reddish yellow) throughout
BC 12	inner valve	7•5YR 6/6 (reddish yellow) throughout
BC 14	inner valve	medium grey inner face; outer face 2•5 YR 5/6-5/8 (red)
BC 11	(inner valve	7•5YR 7/6-6/6 (reddish yellow) throughout
	(outer wrap	2•5YR 5/6-5/8 (red) throughout
BC 19	(inner valve	dark grey throughout
	(outer wrap	mainly dark grey; outer face 7•5YR 7/4 (pink)
BC 21	(inner valve	dark grey-black throughout
	(outer wrap	2•5YR 5/6 (red) throughout
BC 2	outer wrap	mainly 7•5YR 7/6 (reddish yellow)
BC 10	outer wrap	2•5YR 5/6 (red) with reduced, medium grey patches
BC 18	outer wrap	7•5YR 6/6 (reddish yellow) grading to 2•5YR 5/6 (red)
BC 13	? core locating device	mainly 7•5YR 6/6 (reddish yellow)

TABLE III.5.3 RAW MATERIAL SAMPLES: CHESHIRE

Sample no	Grid ref	Geological notes
BC 1	SJ 568588	glacial sand and gravel/Boulder Clay: grey clay, oily smell
BC 2	SJ 568588	" " : light grey clay
BC 3	SJ 568588	" " : brown clay
BC 4	SJ 568588	" " : grey clay, almost black
BC 5 (S)	SJ 552594	glacial sand and gravel: fine glacial sand
BC 6 (S)	SJ 552594	" " : glacial sand
BC 7 (R)	SJ 552594	" " : erratics in 20cm band
BC 8	SJ 552594	" " : pocket of sandy clay
BC 9 (S)	SJ 537593	Keuper sandstone: sand at base of Medieval ditch Beeston Castle
BC 10	SJ 537593	" " : weathering product
BC 11	SJ 537593	" " : weathering product
BC 12 (R)	SJ 537593	" "
BC 13 (S)	SJ 537593	" " : yellow sand at outer gateway
BC 14 (S)	SJ 537593	" " : pale brown sand at outer gateway
BC 15	SJ 537593	" " : silt (not processed: insufficient colloidal material)
BC 16 (R)	SJ 537593	" " : erratics from outer gateway area
BC 17	SJ 532604	Boulder Clay
BC 18	SJ 538597	" : disused claypit
BC 19	SJ 538597	" : disused claypit
BC 20	SJ 532595	"
BC 21	SJ 528596	"
BC 22	SJ 498581	"
BC 23	SJ 479592	"
BC 24	SJ 493603	" : disused claypit
BC 25	SJ 493603	" : disused claypit
BC 26 (B)	SJ 493603	" : brick wasters
BC 27	SJ 591587	" : clay from old brickworks
BC 28 (B)	SJ 591587	" : brick waster
BC 29 (B)	SJ 591587	" : brick waster

S = sand R = rock B = brick waster others = clay

OBJECT	SLIDE	% GR: MAT	NO. OF GRAINS	PHI -1 TO -.5	PHI -.5 TO 0	PHI 0 TO .5	PHI .5 TO 1	PHI 1 TO 1.5	PHI 1.5 TO 2	PHI 2 TO 2.5	PHI 2.5 TO 3	PHI 3 TO 3.5	PHI 3.5 TO 4	PHI 4 TO 4.5	PHI 4.5 TO 5	PHI 5 TO 5.5	MEAN GRAIN SIZE MM.	STD DEV
CRUCIBLE																		
	15	53	103	0	0	0	1	3	5	5	13	5	6	8	15	39	.0884	1.55
	16	60	90	0	0	0	0	0	2	0	2	7	9	19	28	33	.0432	.347
	20	63	112	1	0	0	2	3	4	4	13	15	17	9	14	17	.1163	3.43
	4	47	94	0	0	0	2	2	3	3	3	9	13	7	15	43	.0734	1.33
N SLIDES			4															
N GRAINS			399															
CORE																		
	13	25	96	0	0	0	0	1	3	5	3	8	5	7	14	52	.0586	.728
N SLIDES			1															
N GRAINS			96															
IN MOULD																		
	11	68	69	0	0	0	0	0	0	1	1	3	4	17	29	43	.0362	.169
	12	59	90	0	0	0	0	0	1	0	3	6	10	22	27	31	.0475	.299
	3	49	85	0	1	0	0	4	5	4	4	1	5	12	23	42	.0808	2.20
	5	68	74	0	0	0	0	0	0	0	0	0	3	5	27	61	.0267	.067
	6	43	91	0	0	0	0	2	1	4	4	4	9	8	24	44	.0557	.666
	9	57	87	0	0	0	1	2	0	3	8	2	11	14	26	31	.0635	.907
N SLIDES			6															
N GRAINS			496															
OU MOULD																		
	1	42	93	0	0	0	1	0	3	10	3	9	13	14	22	26	.0774	1.06
	10	29	93	0	0	0	0	2	8	3	3	5	13	8	22	37	.0739	1.10
	18	44	90	0	0	0	0	13	26	17	8	11	8	1	4	12	.1913	4.29
	2	27	60	2	0	0	0	5	5	7	8	12	10	17	17	18	.1250	4.81
N SLIDES			4															
N GRAINS			336															
			15															
			1327															

TABLE III.5.4 BEESTON CASTLE: GRAIN SIZE STATISTICS

III.6 BRAMBER, WEST SUSSEX
(TQ 182107; corpus no 5)

The Bramber site is located on grey alluvial clay on the ancient flood plain of the river Adur (fig III.6.1). Finds recovered thus far include the bronze hoard and metalworking debris described below, human and animal bones, burnt and worked flint, and a single late bronze age potsherds. The contemporaneity of these artefacts, and the nature and extent of the site, will be investigated through area excavation scheduled to take place in 1983.

III.6.1 The metalworking evidence

In early 1981, a hoard of cast and beaten bronze artefacts, many in broken condition, was recovered from a spoil heap of clay removed mechanically during the creation of an artificial lake. A search of the heap and surrounding area produced domestic artefacts, bone and three crucible sherds, all of which seem, on circumstantial grounds, to be associated with the bronzes. The hoard comprises 80 pieces of spearhead of various forms including complete and fragmentary examples, eleven spear ferrules and fragments of same, several cast tools (which together seem to represent a craftsman's tool kit), tubes of unknown function, and an assortment of small items including ornaments and harness fittings (fig III.6.2). The hoard is dated on typological grounds to the Ewart Park phase (c 900-700 BC) of the late bronze age. A complete, illustrated catalogue, with discussion of the metalwork, has been published elsewhere. In the catalogue, Needham describes this classic Broadward Hoard (defined by an overwhelming predominance of spearheads) as "the finest and largest to have been brought to light this century" (Aldsworth et al, 1981).

The majority of the bronze sockets retain fragments of compact clay cores, the colours of which are invariably distinct from the local grey-green alluvium. These are the remains of cores used in the casting process to form hollow sockets for spears and ferrules. There would have

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<u>Fig III.6.1</u> Location of Bramber hoard findspot (after Aldsworth et al, 1981).

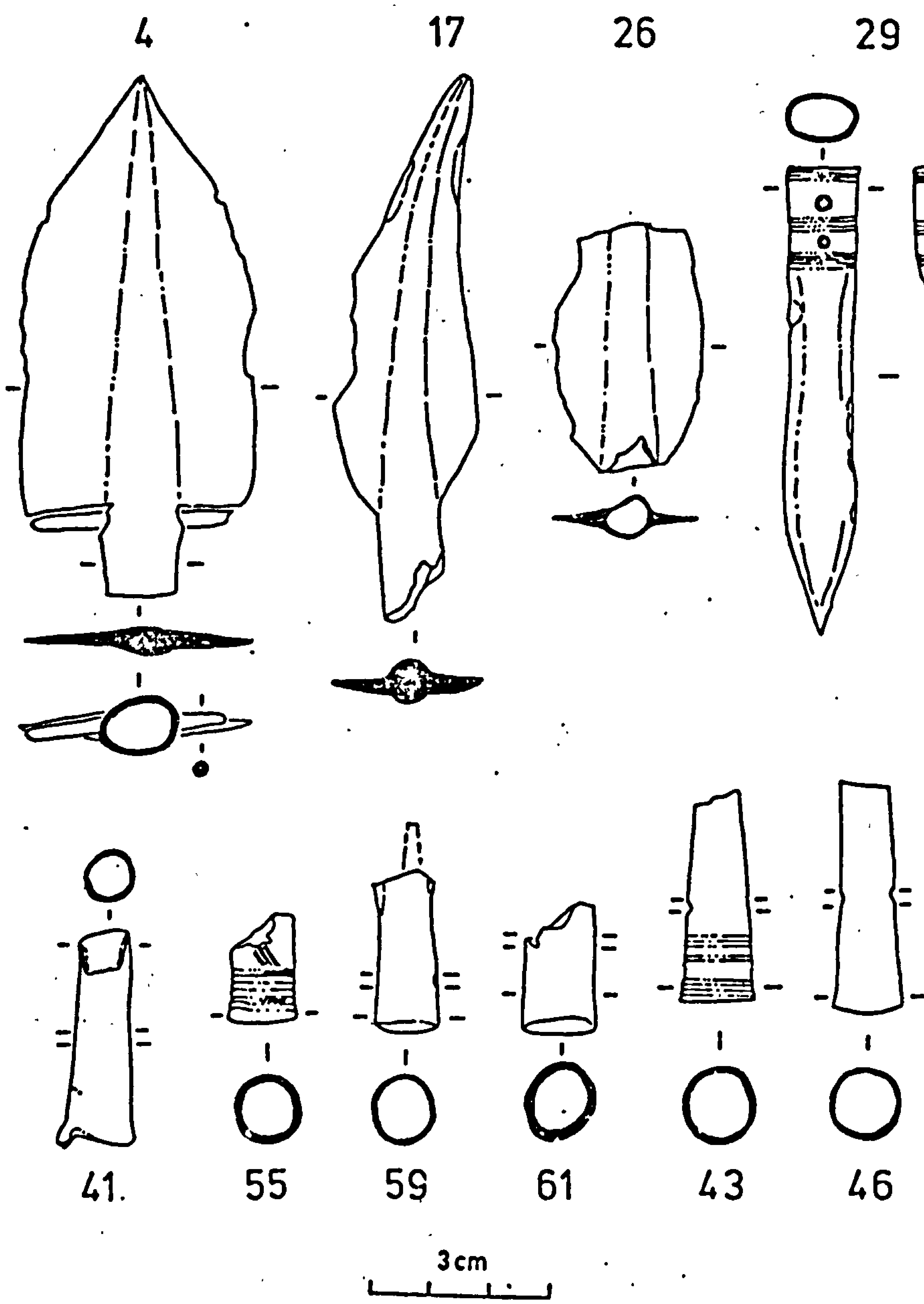

Fig III.6.2 Bronze objects from the Bramber hoard from which core material has been removed and analysed in this study (after Aldsworth et al, 1981).

been no need to scrape out all core material to fit a handle or shaft, and a small amount of clay was often left in the extremities of both Wilburton and Ewart Park implement sockets. Only at Bramber, however, have cores been found in quantity, and thus the site provides a unique opportunity to study and compare remnant clays from a range of implement forms.

III.6.2 Analytical results (see Table III.6.1)

At the time of writing, only ten core fragments have been made available for inspection. These cores were taken from a range of implement types (fig III.6.2). As many of the Bramber implements retain the remains of carbonised hafts, these had to be extracted first, before the core material could be reached. A high degree of precision is required to remove both carbonised wood and clay core, if the maximum amount of information is to be retrieved. It is hoped that the remaining cores and the crucible sherds will be available for examination and analysis in the near future.

Core material was removed from the implement sockets by Caroline Cartwright (London Institute of Archaeology) who is currently working on identification of the charcoals. Some of the ten core samples submitted to the writer are roughly cylindrical and reach a maximum size of 20mm in length and 10mm in diameter. Other samples, however (eg BMB 8, 9), could only be extracted in fragmentary condition.

In hand specimen, the ten core samples appear surprisingly homogeneous. All appear to be formed from an extremely fine clay, and all have been completely reduced to mid-grey during the casting process. The clay effervesces slightly with dilute HCl. Slaggy alteration products fringe the outer faces of the better preserved samples. Most specimens contain a scatter of carbon of indeterminate form, and discrete chalky fragments and sparse fine quartz sand are visible on cut faces. Sample BMB 7 additionally contains occasional soft, subangular, dark brown grainy inclusions.

Similarities observed in hand specimen are confirmed through thin section analysis. Anisotropic matrices are seen to be composed in the main of a mosaic of tiny irregular grains with interference colours identical to those of calcite. All samples contain a small quantity of organic material, some of which is incompletely carbonised, suggesting that the temperature reached in the centre of the core during casting was relatively low. The sparseness of organic inclusions militates against deliberate incorporation. Quartz sand is rare, poorly distributed and variable in size and shape. Large (c 1mm) rounded fragments of fossiliferous chalk are visible in BMB 2 and 3, but most samples contain a scatter of discrete smaller chalk fragments (Plate 7b). Sample BMB 10 contains a single elongate particle of fossil shell. All sections are penetrated by metallic oxides which have imparted a greenish hue to the matrix material. A thick layer of artificial slaggy minerals is visible round the perimeter of most samples and beads of metallic copper are clearly seen in sample BMB 10.

Although the matrix of BMB 7 (from a spearhead socket) is similar to that of all other samples examined, this core is distinguished in section by an even scatter of grog. Grog fragments are dark brownish-red in plain light, and contain a medium density of quartz sand to 0•08mm across. The grog fragments themselves reach 0•75mm in size, and are quite soft, indicating derivation from a low-fired ceramic artefact.

III.6.3 Discussion

It is clear from the analytical results described above, that similar raw materials were used for the production of the cores retained in the Bramber implements. Leaving aside for the moment BMB 7, these raw materials would appear to have undergone little preparation or modification prior to shaping. Inclusions of quartz, carbonate and carbon vary in size, shape and density, and are poorly distributed. It is concluded from the samples examined thus far that a single clay source was used "as dug" for core formation.

The composition of the Bramber hoard and the similarities observed in thin section between the various implement cores, highlights many problems concerning the organisation of metalworking during the bronze age. The ten cores analysed were taken from a random sample of bronze artefacts. These artefacts include two different forms of spearhead and a socketed knife interpreted as one element in a smith's tool kit. It can be predicted, on the basis of implement typology and analytical results, that the remaining Bramber core samples will exhibit similar mineralogical compositions. As the Bramber findspot is situated on the southern edge of the South Downs chalk scarp, it is reasonable to assume that all raw material observed in the archaeological samples were locally obtainable, hence local production can be hypothesised. Both the restricted implement typology (all weapons are simple spearheads) and the uniformity in core composition suggest that all the hoard objects could have been produced by a single smith group, or closely associated smith groups, operating in close proximity to Bramber if not at the site itself.

Accepting this hypothesis, it would seem logical to suppose that all implements, when broken or redundant, were collected and returned to the same weapon smith(s) for recycling. The Bramber hoard would thus represent such a collection. Why, however, did the smith only collect scrap in the form of weapons? Were several weapon smith groups, versed in a similar production technology and sharing access to a scrap metal pool, operating simultaneously in the Bramber area? In the light of associated finds, should the Bramber hoard be regarded as an element in a workshop complex associated with a prestige settlement? These questions will be broached in a broader context in Part IV of this study.

Finally, the grog-tempered core at Bramber, BMB 7, is exceptionally difficult to explain. This core was derived from an amorphous bronze socket fragment (fig III.6.2, no 61) that would seem to be typologically indeterminate. The matrix material is identical to that of the other cores examined. Further intepretation must await analysis of the remaining Bramber cores, the associated ceramic material, and a range of local raw materials.

TABLE III.6.1 BRAMBER: CONCORDANCE OF SECTIONED SHERDS

Sample no	Worthing Museum accession no	Implement type
BMB 1	81/125/4	complete spearhead, with broad, squat blade
BMB 2	81/125/26	spearhead, blade only
BMB 3	81/125/29	socketed knife, decorated
BMB 4	81/125/17	spearhead, broken and bent
BMB 5	81/125/55	decorated socket, probably spearhead
BMB 6	81/125/59	spearhead, most of blade missing
BMB 7	81/125/61	socket, probably of spearhead
BMB 8	81/125/41	socket, probably spearhead
BMB 9	81/125/43	decorated spearhead socket
BMB 10	81/125/46	socket, probably spearhead

III.7 RUNNYMEDE BRIDGE, SURREY
(TQ 018718; corpus no 17)

Runnymede Bridge, on the banks of the Thmames near Egham, has been described as "a site of specialised status belonging to a regional network of economic inter-dependence" (Needham and Longley, 1980). Salvage and controlled rescue excavation took place in 1976, 1978 and 1980, and revealed a complex settlement with a carefully constructed timber waterfront. A report on the 1976 excavations has recently been published (Longley, 1980, published August 1982). Although this report includes a detailed consideration of the bronzework (Needham, 1980b), analysis of this material and of the metallurgical finds from subsequent work is still in progress. Further extensive excavation is planned for the near future.

To date, two main areas, separated by some 80m, have been excavated. Both the radiocarbon dates and the finds recovered suggest that these areas are contemporary, and probably represent elements of a single permanent settlement complex (Needham and Longley, 1980, 402). The size of this settlement is unknown, but it is believed to extend at least 100m inland from the north-eastern waterfront.

The earliest evidence for bronze age activity at Runnymede consits of a layer of charcoal and burnt branches which have been interpreted as the results of land clearance in preparation for occupation of the area (Needham and Longley, 1980, 401). Radiocarbon dates of 740 $\pm$ 80, 770 $\pm$ 80 and 740 $\pm$ 80 bc (HAR 3114, 3115, 3120) have been obtained from this layer. At the time when the site was cleared, the Runnymede area consisted of a small peninsularof land flanked by the Thames to the north east (fig III.7.1A). Just before, or contemporary with the beginning of the major settlement period at Runnymede, the Thames broke through the isthmus, thereby creating an island (fig III.7.1B). This island appears to have survived until at least the early medieval period, and this is confirmed by an early definition of the county boundary (Needham, pers comm; fig III.7.1C). A timber river frontage was constructed c 900 BC along the northern shore of the island, perhaps to provide a wharf for the

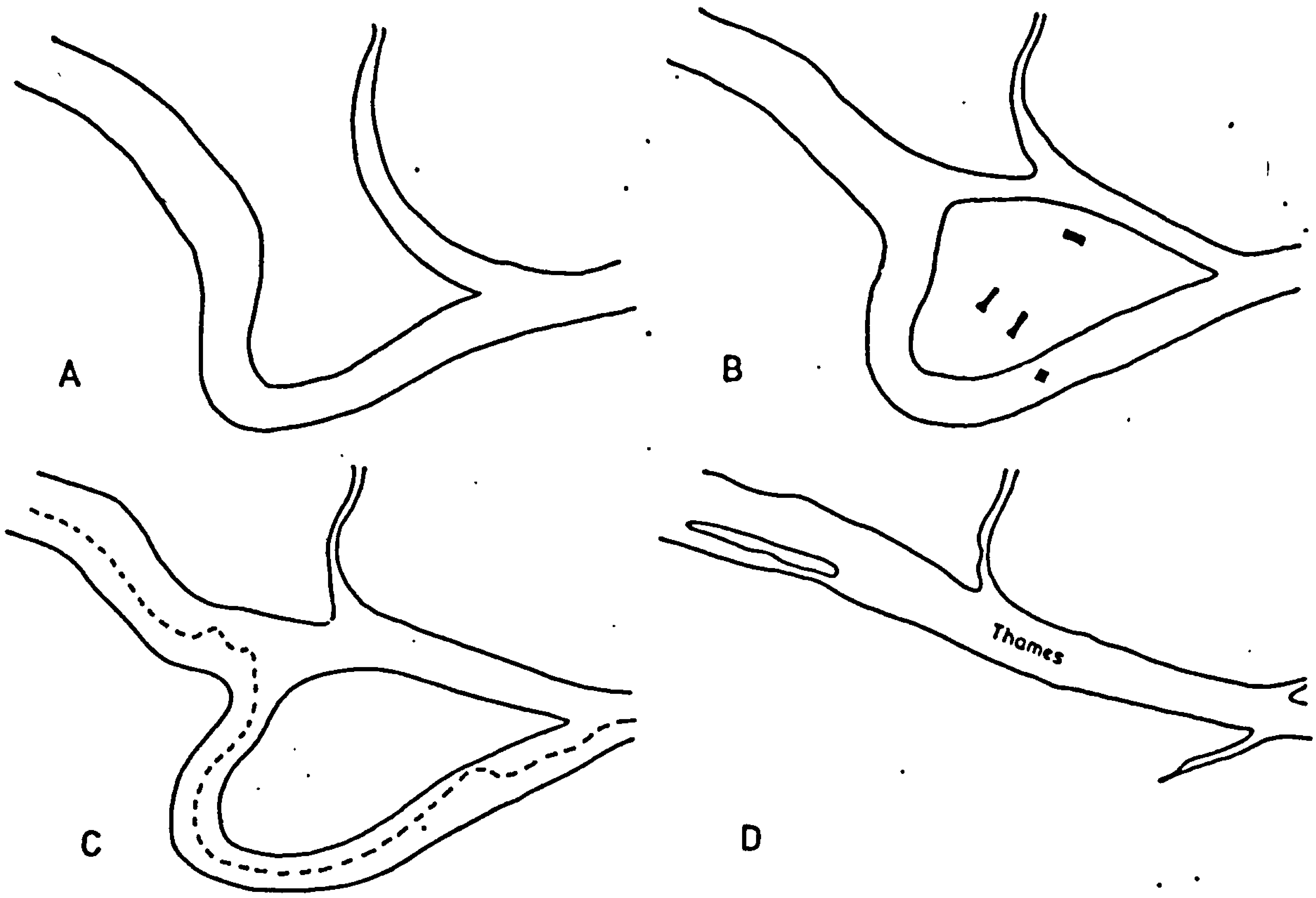

Fig III.7.1 Possible changes in river topography at Runnymede Bridge (after Needham, unpublished). A: pre-9th C BC; B: 9th century BC (with excavated areas marked); C: early medieval (with county boundary); D: present day.

mooring of craft (Needham and Longley, 1980, 418). The construction of this wharf implies that the site was involved in riverine trade. That the inhabitants may have exercised some measure of control over waterborne traffic, resources and finished products, is suggested by the location and nature of the settlement, and the wealth of finds (including many exotic items) recovered during excavation (Needham and Longley, 1980, 420).

III.7.1 The metalworking evidence

At the time of writing, only a small proportion of the finds from Runnymede have been fully processed. Obvious fragments of metalworking debris were extracted for special consideration during post-excavation work, but several boxes of anomalous fired clay await examination. The following discussion cannot, therefore, be regarded as definitive.

Clay moulds identified thus far are designed to cast a varied range of prestige objects. From Area 6, excavated in 1976, came a bivalve mould containing a miscast bifid razor (Needham, 1980b, 13; fig III.7.2). A mould for casting an ornamental plaque was also recovered during the 1976 excavations. Area 10, excavated in 1980, has produced a concentration of metallurgical debris. Moulds designed to cast spearheads, a sword, a pin and possibly a chisel have been identified. Additionally, several moulds with well preserved casting faces appear to have no parallels within the extant repertoire of metal objects (Needham, pers comm). Perhaps most interesting of all, however, is a sandy inner mould fragment, clearly recognisable as the blade portion of a late palstave or socketed axe.

A portion of a clay crucible 21•5mm thick, with a maximum diameter of 38•5mm was also recovered from Area 10. Area 6 likewise produced a ?crucible sherd (12mm thick) with bronze slag adhering to the inner surface. A portion of a hard-fired clay slab with embedded charcoal, found in Area 6, may represent part of a crucible or, more

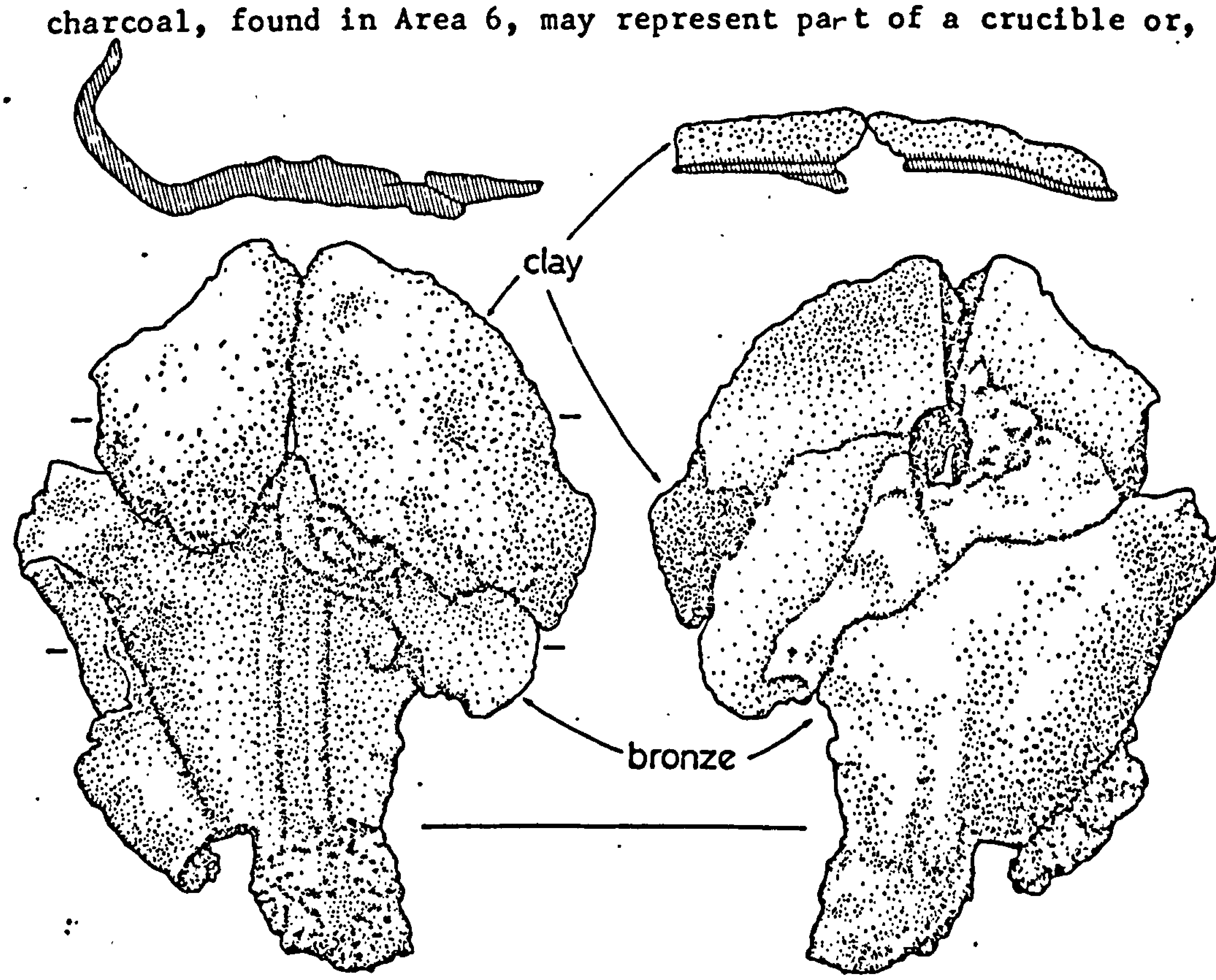

Fig III.7.2 Miscast razor in remains of clay mould (after Longley and Needham).

probably, furnace bottom.

Casting debris from the 1976 excavations included an ingot fragment, several small, nodular bronze lumps, a slab (probably a solidified pool of spilled metal) and two droplets lost during the pouring process (Needham, 1980b, 23). Similar waste was recovered in 1978 and 1980, but this awaits detailed assessment and analysis.

The quantity and range of bronze artefacts found at Runnymede is exceptional in British settlement contexts. From the c 50 sq m excavated in 1976 came some 30 bronze items in addition to the casting waste described above. These included a single spearhead fragment, several tools including a socketed knife, a hammer and a tracer (possibly components of a smith's tool kit), razors, tweezers, and a range of ornaments and attachment pieces (catalogued and illustrated by Needham, 1980b, 13-18, figs 11-13, Pls VIII, IX, X, XIII, XVII). Other than the defective razor (fig III.7.2), and a miscast pin with mould material adhering (found in 1980), it is not known which if any of these items were produced at the site. A continental notch-backed razor (Needham, 1980b, catalogue no 5), and a vase-headed pin (no 12) are certainly imports, and as such support the theory that Runnymede was a high status site involved in trade.

<u>III.7.2 Analytical results</u> (see Table III.7.1)

Although all identified refractory sherds were available for macroscopic examination, few have been fully documented and illustrated. Petrological analysis was thus confined to a very small samples of material. Further work is planned, and the results should broaden the picture of refractory production at Runnymede.

<u>The crucibles</u>

Two certain and one possible crucibles have been recognised, together with several formless sherds possibly representing bronze melting vessels. Crucibles are reduced to medium grey throughout their thickness, although a thin oxidised 'skin' is present on sample ERB 6. This exceptionally hard-fired sherd displays a laminated structure which may be indicative of relining. Slaggy material adheres to the inner face and appears to have penetrated the vessel body. Crucibles appear to have been formed from fine grade, extremely sandy clay. The slightly porous pastes are well worked, and surfaces are carefully smoothed. No crucible sherds were available for petrological analysis.

The moulds

A range of mould fabrics can be recognised in hand specimen. Most moulds are fine, sandy, generally oxidised and similar in texture and fired colour to the local sandy brickearth. Where both inner matrix and outer wrap are preserved, textural differences appear to reflect variation in preparation rather than different raw material sources. This of course requires verification by thin section analysis. Fabric of the plaque mould ERB 8 clsoely resembles that of the two crucibles, although a beige-grey fired colour suggests, perhaps, a different clay source. Fragment ERB 11, identified as a sword blade tip, the possible chisel mould (ERB 14) and the spearhead socket (ERB 19) are again sandy, but also contain a scatter of soft calcareous inclusions and a little iron oxide. The outer wrap of an unidentifiable matrix (ERB 20) is varicoloured and banded, suggesting the local Reading Beds as a possible raw material source.

The fabric of ?axe mould (ERB 9) is strikingly different in texture from all other moulds from the site. This sherd, hard-fired and grey-black in colour appears to consist almost entirely of rounded and subangular flinty sand. Quartz grains averaging 0·1mm, and flint fragments generally to 0·2mm but rarely to 0·5mm, appear on the surface. Very little binding clay seems to be present. A fine slip (c 0·5mm thick), perhaps of levigated clay, has been applied to the inner, casting face. No trace of outer wrap is preserved.

Again different from the remainder of the Runnymede moulds is that encasing the miscast razor (ERB 1). Identifiable as a two layer, bivalve structure, this friable mould appears to have been prepared from fine, slightly calcareous silt. Save for a single shell fragment visible on the inner matrix, and a little carbonised organic material in the outer wrap, the buff-green fabric is apparently inclusionless. Under the microscope, the anisotropic inner layer is seen to be extensively penetrated with molten bronze. No inclusions are present save for a very sparse scatter of quartz (only six grains can be seen in the section), and a fragment of shell. The outer wrap has been roughly formed from the same material and contains rare carbon and a single quartz grain. The fabric is excessively porous, non-refractory, and would not have withstood the impact of molten bronze. The penetration of the metal into the matrix and the failure of the casting can be unhesitatingly attributed to the use of unsuitable raw materials for mould preparation.

The clay slab

The heavy, laminated clay slab from Area 6 (ERB 5) is exceptionally hard-fired and dark grey throughout its thickness. Fragments of charcoal are clearly visible on both surfaces. Although the form is more likely to derive from furnace than crucible, the sherd was tested by thin section analysis. Under the microscope, the calcareous anisotropic clay matrix is seen to contain a scatter of poorly sorted quartz grains of varying angularity, fragments of shell and a little crystalline limestone with distinctive intersecting cleavage planes. No charcoal is identifiable in section although frequent voids may represent the burning out of organic material. Inclusions are poorly distributed, indicative of minimal care in clay preparation. Both form and fabric dictate that this sherd be rejected as crucible. However, the hard-fired paste and presence of surface charcoal suggest that it may well be derived from a furnace or hearth.

III.7.3 Resource ecology and raw material analysis

Three clay samples from archaeological layers (kindly provided by the excavator) were analysed to provide a preliminary assessment of raw materials available on the site (Table III.7.2). Only one of these, ERB 3 (C) remained stable after firing to 850°C. Despite careful preparation, sample ERB 1 and 2 (C) both shattered during slow cooling. Samples ERB 1 and 2 (C) both contain abundant shell and limestone fragments (some fossiliferous) and a sparse scatter of quartz. ERB 3 (C) is lime-free, very sandy and contains considerable iron oxide. An extensive clay sampling programme in the Runnymede area (see fig III.7.3

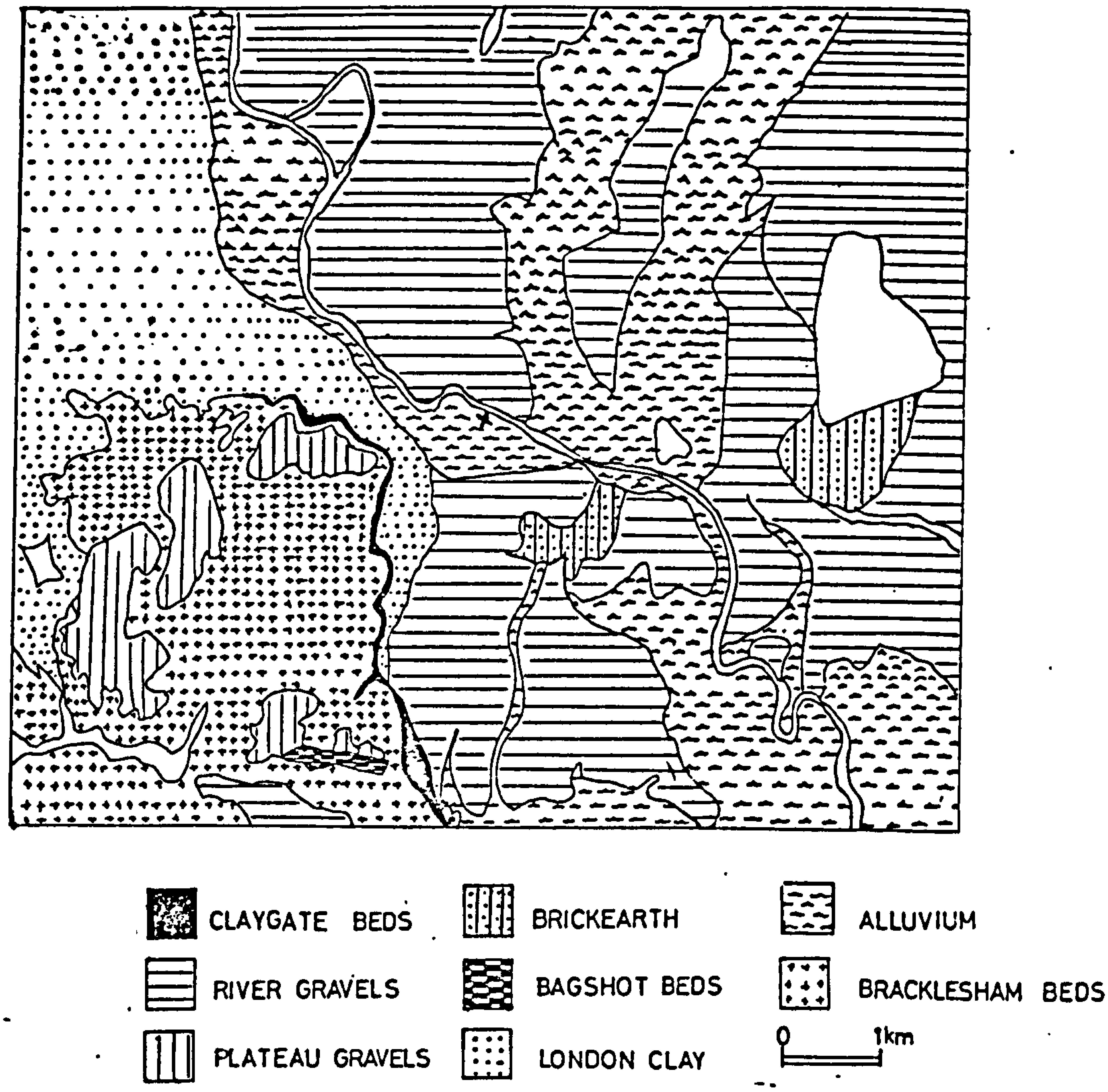

Fig III.7.3 Geology around Runnymede

for potential resources) will take place when problems of refractory material sources have been more precisely defined.

III.7.4 Discussion

Although the full extent of metalworking is not yet known, currently available evidence suggests a complex craft organisation at Runnymede. Crucibles of different forms were found in different areas of the site. Despite limited excavation, at least fourteen well-preserved mould sherds have been recognised, representing a wide range of prestige artefacts and a minimum of five distinct pastes. Aside from the failed razor mould, the Runnymede refractories reflect a sophisticated level of casting technology, exploiting a range of (probably) local raw materials.

The use of silt for the manufacture of the razor mould was probably expedient or experimental. The smith, perhaps lacking sufficient prepared refractory mixture to complete a batch of moulds for a single casting, may have attempted to substitute locally available river silt. Alternatively, suitable raw material supplies may have been interrupted, and the smith, suddenly commissioned to make a razor, may have used whatever was nearest to hand on the island. It is also possible that the fabric represents not untreated river silt, but rather a levigated locally available clay, perhaps that obtained as samples ERB 1 and 2 (C). Levigated clay may have been used in an attempt to improve the definition of the casting face. Experimental work is necessary to test this possibility. However, whatever the reasons for the use of fine silt, the results were certainly disastrous and it is unlikely the experiment would have been repeated. The smith's exasperation is clearly evident from the razor itself which as been deliberately twisted and smashed in its mould, and no attempt has been made to retrieve the metal for recycling.

The clay axe mould from Runnymede is one of only four such moulds recognised thus far, south of the Scottish border. Unfortunately, insufficient remains of this particular example to allow identification of the axe or palstave type produced. The distinctive, exceptionally hard fabric and lack of any outer wrap, suggests the possibility that the mould was imported to the site, and may even, perhaps, have been reusable. If so, it is the only example of a reusable clay mould recovered to date. Analysis of the fabric and surface slip is required to test this hypothesis. The recovery of a clay axe mould at Runnymede is especially interesting in the light of a recent find at the nearby late bronze age site at Petters Sports Field (TQ 016715). Here, a stone mould for the production of Stogursey axes was recovered (Needham, 1981, 9-10), and this may be contemporary with the axe mould at Runnymede. Assuming general contemporaneity, it is clear that two smiths, each versed in a different casting technology, were active within one km of each other during the late bronze age.

The remaining mould fragments, together with the metalwork from the site, are indicative of prestige production and acquisition. The general nature of bronzework from settlements and from hoard deposits has been discussed elsewhere (Needham, 1980b, 24). At Runnymede, as at most other settlements producing bronze artefacts, the assemblage is limited to small items, particularly ornaments. It is suggested that such minor pieces would not have been of sufficient value to merit accumulation and recycling, and instead, found their way when redundant into domestic refuse deposits. Large items such as tools and weapons, on the other hand, would have been collected by the smith and remelted. It is significant that despite the presence of clay moulds for the production of spearheads, swords and axes at Runnymede, but a single weapon fragment figures among the bronze assemblage.

Despite the small area excavated, an extremely informative collection of bronzework and refractory debris has been found at this site. Many questions have been posed, and it is hoped that analytical work and future excavation can provide some solutions.

TABLE III.7.1 RUNNYMEDE BRIDGE: CONCORDANCE OF INSPECTED SHERDS

Sample no	Excavation number	Identification
ERB 1	76.A6	razor mould, inner + outer
ERB 2	78.A6.L7.10N, 10E (27)	spindle whorl
ERB 3	78.A6.L4.8N, 13E (33)	spindlewhorl
ERB 4	78.A6.F17.5·26N, 12·69E (77)	spindlewhorl
ERB 5	78.A6.L40	fired clay slab, with charcoal embedded
ERB 6 *	78.A6.L14.10N, 12E (67)	? crucible
ERB 7	78.A6.F1.L3	loomweight
ERB 8 *	76.F24.L4	mould for ornamental plaque, inner + outer
ERB 9 *	80.A10.010.1804 (35)	mould, ? axe, inner only
ERB 10 *	80.A10.018.1201 (15)	mould, socket terminal, inner + outer
ERB 11 *	80.A10.007.0504 (11)	mould, sword blade tip, inner + outer
ERB 12 *	80.A10.007.1902 (25)	mould, flat fargment with pronounced rib, inner + ? outer
ERB 13 *	80.A10.023.1104 (3)	mould, socket, inner + outer
ERB 14 *	80.A10.023.1002 (11)	mould, ? chisel edge, inner
ERB 15 *	80.A10.010.1004 (34)	bronze pin with mould attached
ERB 16 *	80.A10.007.1104 (20)	mould, spearhead, inner + outer
ERB 17 *	80.A10.010.0704 (30)	mould, unidentified, outer
ERB 18 *	80.A10.028.0401	mould, unidentified, inner + ? outer
ERB 19 *	80.A10. .0301 (11)	crucible
ERB 20 *	80.A10.006.0804	mould, unidentified, inner + outer
ERB 21 *	80.A10	crucible

* = sherds thin sectioned

TABLE III.7.2 RAW MATERIAL SAMPLES: RUNNYMEDE BRIDGE

Sample no	Grid ref	Geological notes
ERB 1 (C)	TQ 018718	clay underlying late bronze age occupation level
ERB 2 (C)	TQ 018718	clay underlying neolithic levels
ERB 3 (C)	TQ 018718	clay from late bronze age occupation level A10 (not in situ)

note all samples are from archaeological excavations

III.8 MUCKING, ESSEX
(TQ 673803; corpus nos 15/66)

The multi-period site of Mucking is strategically located on a 30ft (10m) flint gravel terrace overlooking the north bank of the river Thames (fig III.8.1). Patches of brickearth overlie the gravel, providing a potential source of ceramic raw material. Substantial late bronze age occupation is represented by two earthworks and various pits and postholes across this vast site (Jones and Bond, 1980). Mucking South Rings (excavated in the late 1960s) comprises a circular enclosure some 43m in diameter surrounded by two ditches, eleven m apart. The overall size of the earthwork is c 83m (fig III.8.2). A single recut ditch surrounds North Ring which is smaller overall (c 48m) than the approximately contemporary site located 1km away. The central areas of both earthworks, however, are similar in size, that at North Ring measuring c 39m in diameter (fig III.8.2). Whereas three substantial roundhouses and other smaller structures have been recognised within North Ring, South Rings is dominated by an annular ditch, and structural evidence is lacking. Furthermore, whilst South Rings appears to have been occupied continuously through a single phase, two periods of activity are attested at North Ring, structural modifications indicating perhaps a change of functional emphasis at this site (Jones and Bond, 1980, 480). However, broadly contemporary occupation in the 8th-7th centuries BC at the two sites is strongly suggested by the radiocarbon dates (Table III.8.1) and by almost identical groups of finds. Both sites produced quantities of late bronze age pottery of similar forms and fabrics, fired clay mould, weaving equipment, perforated ceramic slabs, salt making or transporting vessels, and small comparable flint assemblages. Features, domestic waste and industrial debris at North Ring extended beyond the immediate vicinity of the earthwork into an area now destroyed by modern gravel extraction. One of the excavators is of the opinion that Mucking North and South Rings do not represent separate 'village' sites, but rather should be considered as component parts of a large bronze age settlement complex (M U Jones, pers comm).

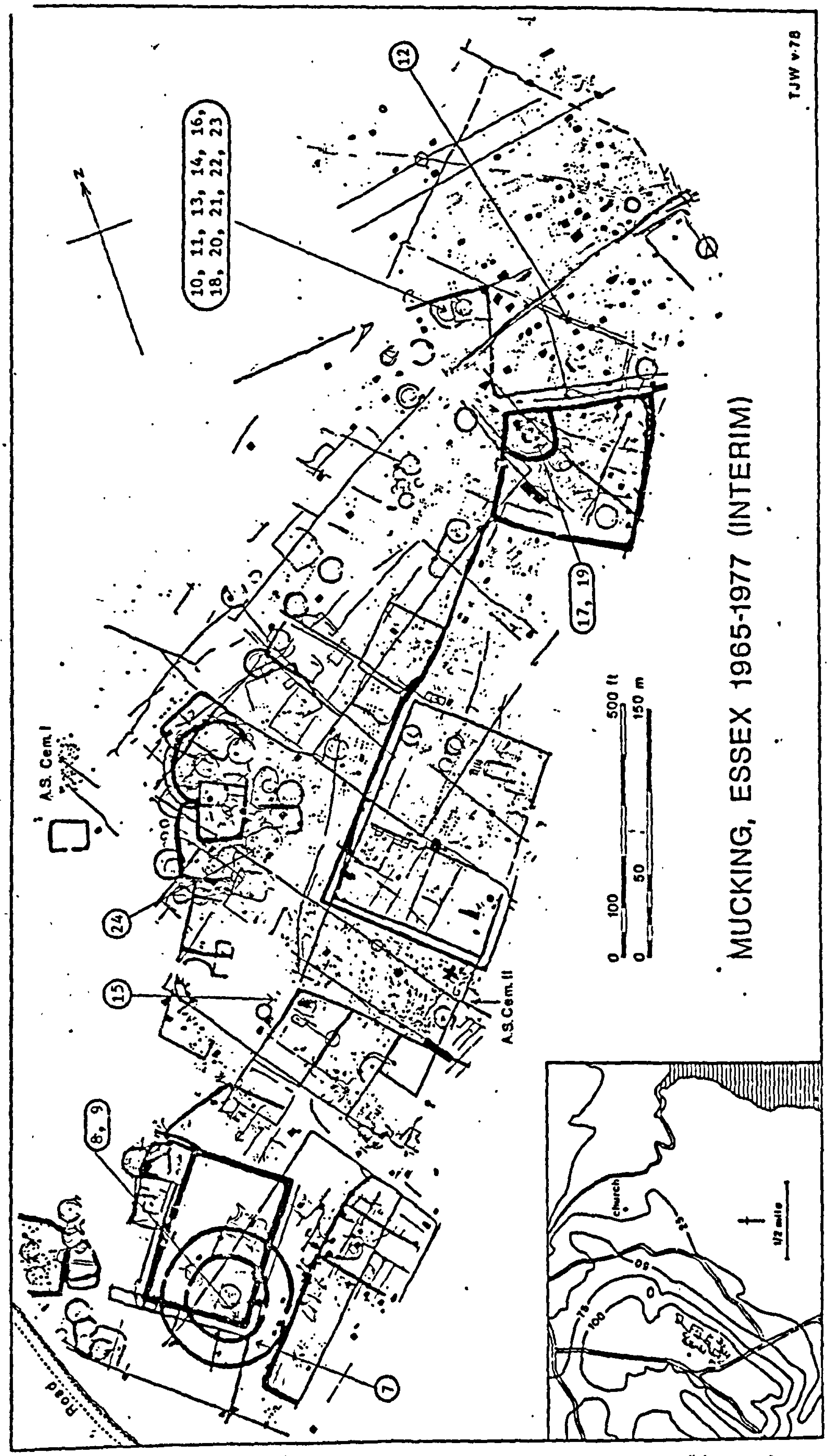

Fig III.8.1 Mucking south, all periods (after Jones).

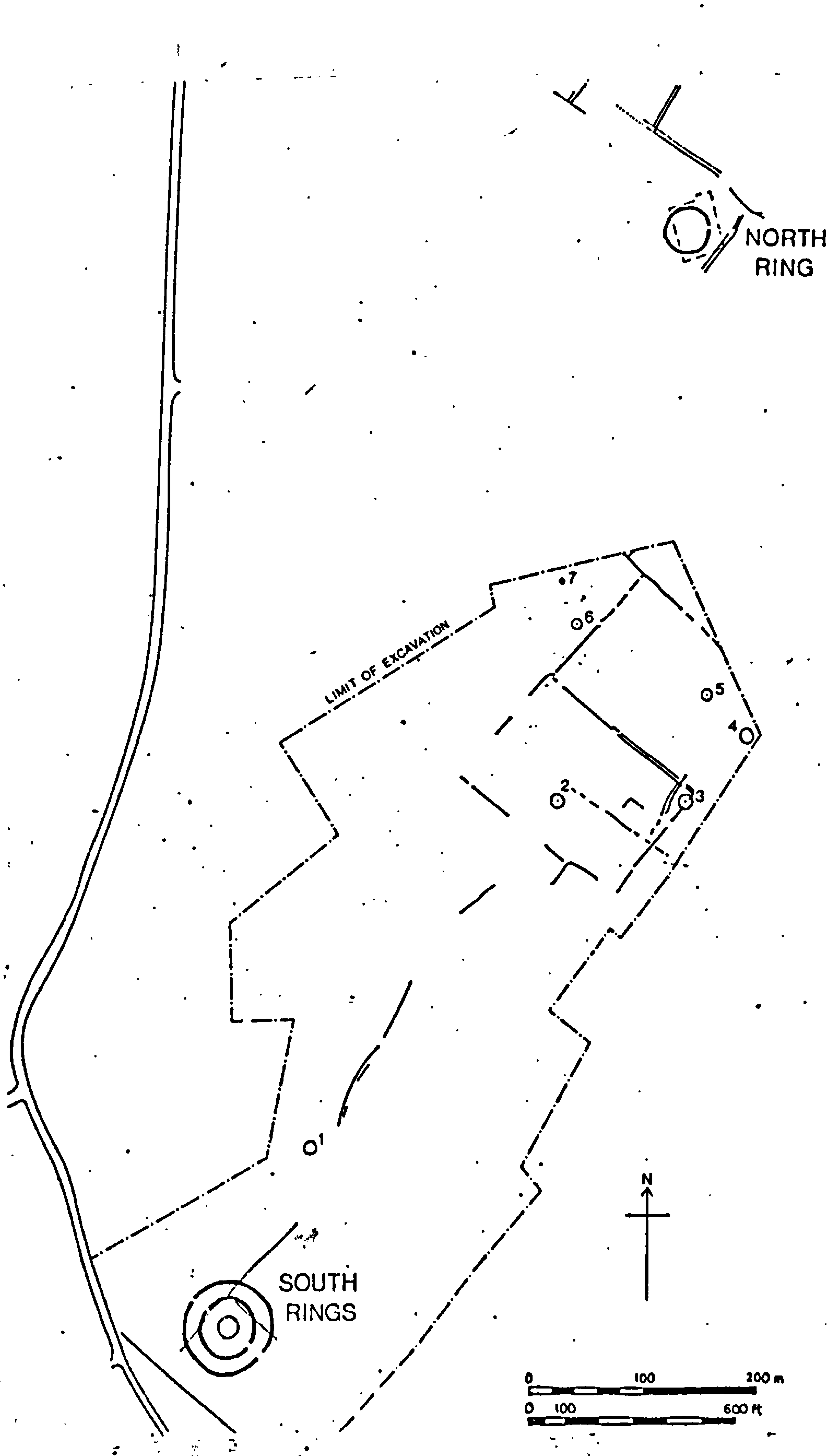

Fig III.8.2 Bronze age Mucking (after Jones)

Iron age settlement is represented by roundhouses, rectangular structures, pits, postholes and ditches across the entire excavated area of c 27ha (Jones, 1968; 1974). A concentration of circular "buildings" of middle to late iron age date was located on level ground at the top of the river terrace. These buildings were represented by drip gullies, but little structural evidence was found (Jones, 1974, 214). Many presumed iron age features at Mucking have been recut during the later Roman and Saxon occupation periods, thus precise period attribution is often difficult.

III.8.1 The metalworking evidence

Four fragments of bivalve clay mould were identified at Mucking North Rings, together with a portion of a thick-walled curcible (Bond, forthcoming). Three of the moulds (inner and outer wrap preserved) appear to have cast thin blades, perhaps sickles. The severely abraded matrix of the fourth mould is unidentifiable. A well-finished elongate sherd which was identified as the outer wrap of a fifth casting mould, was rejected after fabric analysis (fig III.8.3).

The crucible sherd found at North Ring is unique in British bronze age contexts (fig III.8.3, no 2). The rim form resembles that of Dainton vessel A, Class 1 (Needham, 1980a, fig 4; see above) but the flat base is as yet unparalleled.

Bronze objects associated with the ceramic debris include a small bar, a fragment of heavily leaded sheet metal, a small blade edge portion of a socketed axe of Ewart Park south-eastern form, and a droplet of bronze, presumably spilled from a crucible during pouring.

An immense quantity of material of all periods from bronze age to Saxon was recovered during the thirteen years of excavation at Mucking. With the exception of the finds from North Ring (excavated by D Bond in 1978), this material is still being processed by Mrs M U Jones and the Mucking Post-Excavation team. More than fifty finds positively associated with bronzeworking have been recognised, but upwards of 100kg of "fired clay" remain to be sorted and examined. It is likely that the quantity and range of metallurgical debris will be increased in the course

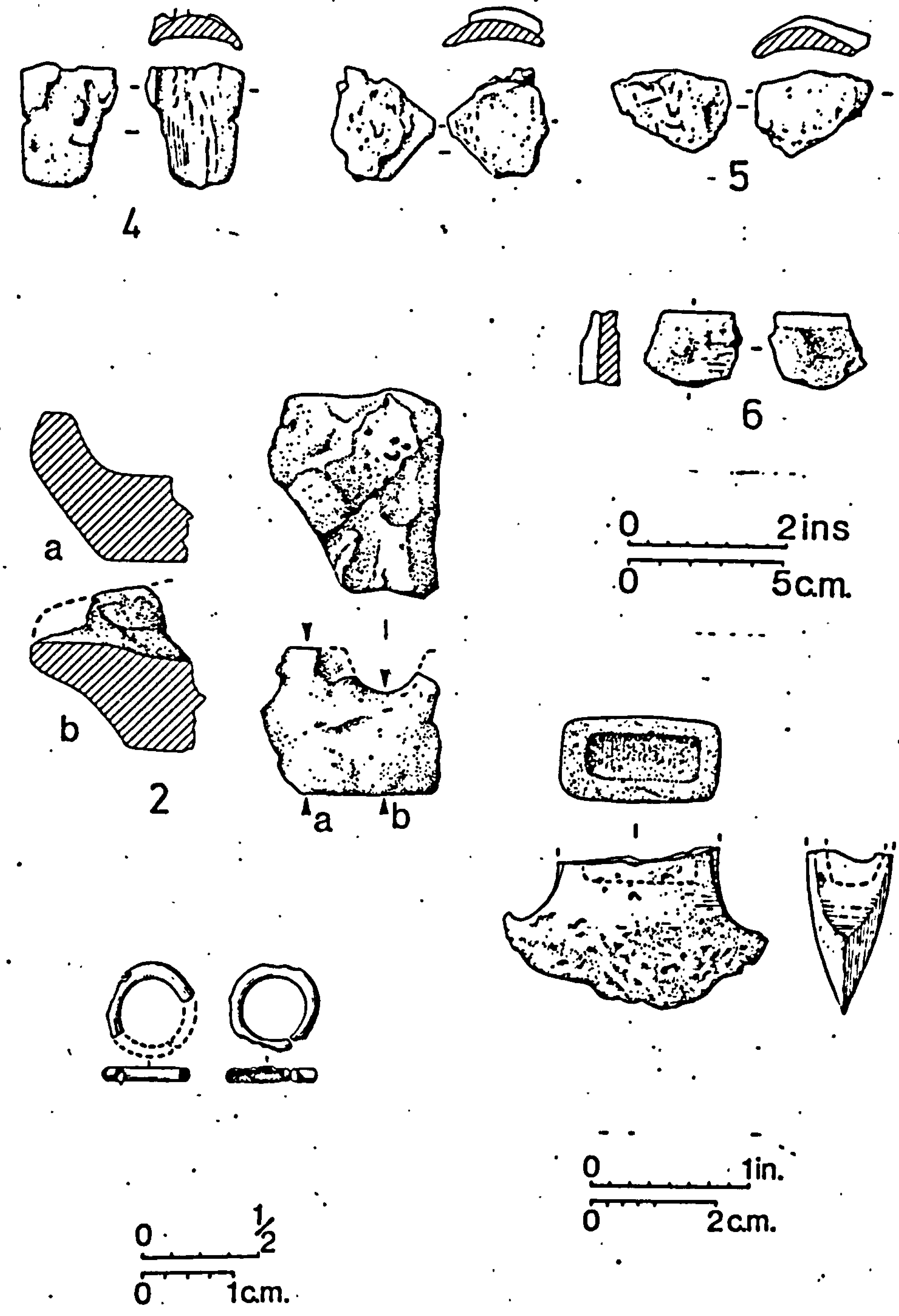

Fig III.8.3 Crucible (2) and four mould fragments, two bronze rings, a socketed axe fragment, all from North Ring, Mucking (drawing by DOE).

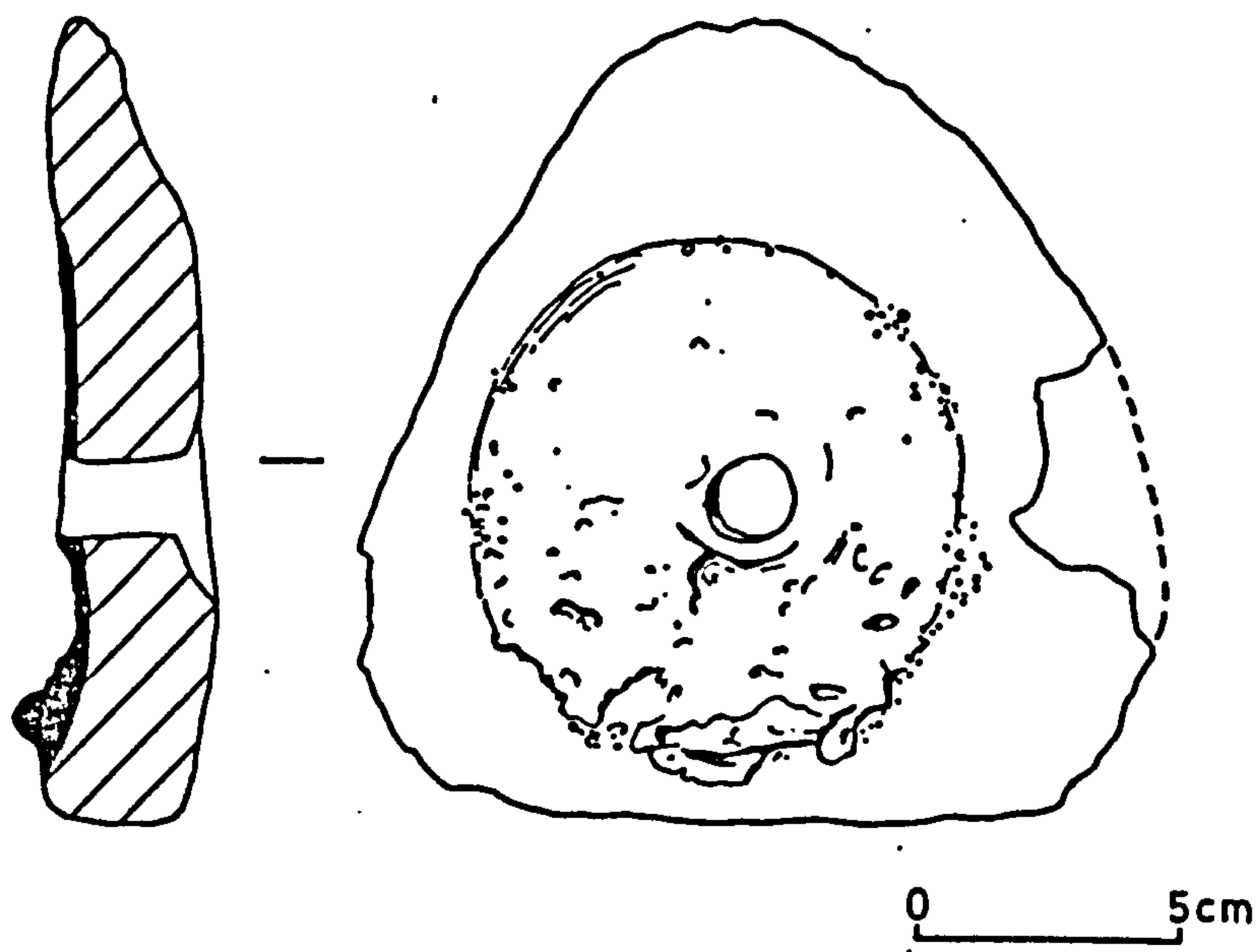

Fig III.8.4 Clay tuyère from near South Rings, Mucking (after Jones).

of this exercise.

Interpretation of much material thus far identified as possible casting waste is complicated by a high proportion of residual or intrusive material in many deposits. Small, anomalous fragments of refractory fabric in pits containing both iron age and Saxon material, for example, may belong to either period. Fortunately, metallurgical residues have been found in uncontaminated contexts, and fabric inspection of these pieces has provided a basis for interpretation of uncontexted, formless fragments. Informative pieces from mixed contexts can often be assigned on both typological and fabric grounds to a broad occupation period.

Bivalve clay moulds, probably for casting spears, sockets and swords were found in the South Rings area. Some two dozen complete and fragmentary tuyères of a form unparalleled in Britain have been identified in various late bronze age/early iron age contexts (fig III.8.4). Emission spectroscopy analysis (by J Evans, N E London Polytechnic) of the glass and clay layers from a typical tuyère mouth, confirms the association of these artefacts with bronzeworking. Copper, tin, silver and zinc were detected in the unvitrified clay body (Jones, 1982, 25).

A length of iron age ditch produced numerous crucible fragments (of typical iron age form and sandy fabric) and several remnants of ring mould similar to those found at other iron age sites described in this study. Although this ditch and peripheral features have, to date, produced the greatest concentration of metallurgical debris at the site, all represent secondary refuse, and no workshop has been located in this or any other area at Mucking.

III.8.2 Analytical results (see Table III.8.2)

All ceramic bronze casting residues (save one mould fragment which could not be located) from the North Ring excavation area were examined and analysed. All similar material identified thus far from the remainder of the site was examined, and pieces were selected for analysis on the basis of typology, fabric and, to some extent, context. Both bronze age and iron age refractories were analysed; the location of those thought to be iron age is indicated in fig III.8.1.

The crucibles

1. Fabric 1: bronze age, sand (MU 2)

This flat based sherd is reduced to mid-grey through most of its 33mm maximum thickness (this is the thickest prehistoric crucible thus far recovered). A maximum 7mm thick outer surface layer is oxidised to red (2•5YR 5/8). The inner part of the crucible is coated with a thin (c 1mm) layer of light green and reddish slaggy material. Analysis of this layer showed it to consist of copper and lead metal residues (J Bayley, pers comm). The fabric feels extremely sandy and rough to the touch. A sparse scatter of rounded voids is visible across a freshly fractured face, but only fine quartz sand and a very rare glint of mica can be seen with the aid of a 10x lens.

In thin section the crucible is seen to have been formed from a slightly micaceous clay containing, or tempered with, some 55% of subrounded quartz sand. Most of this sand is extremely fine (<0•05mm), but larger grains (to 0·6mm) are evenly scattered throughout the section (fig III.8.6). In addition to quartz, the mainly isotropic matrix contains a little finely divided carbon (perhaps accidentally incorporated), rare mica and detrital minerals typical of a glacial deposit.

2. Fabric 2: iron age, sand (MU 14, 16, 17, 18, 20)

The five samples representing this fabric group vary in maximum thickness from 7mm (MU 17) to 14mm (MU 20). Infortunately, the small size of the sherds precludes the reconstruction of profiles and estimation of capacities. Part of a pouring lip preserved on sample MU 17 suggests that this crucible at least was of typical iron age triangular form. With the exception of MU 14, all samples are reduced throughout their thickness, and outer faces are coated with a thin, pale grey-green glaze, indicative of contact with intense heat. Sample MU 16 (possibly a Saxon vessel) is almost entirely vitrified. The outer surface of sample MU14 is oxidised to brownish red (25YR 5/6) and a fine clay slip has been applied to the inner face of this vessel. All samples are porous with pin-hole voids regularly appearing in fracture, and all appear inclusionless save for rounded quartz sand. In thin section, Fabric 2 crucibles are seen to have been formed from moderately to well sorted quartz sand, mixed with a small proportion of binding clay. Matrices are invariably isotropic. Sample MU 17 contains a sparse scatter of rounded iron ore, and three angular fragments of flint are present in sample MU 14. Quartz grain size and density vary somewhat among these samples (fig III.8.5), and it is possible that several sand crucible making, and thus casting episodes are represented. The full size curve for one crucible (MU 18) appears in fig III.8.6.

3. Fabric 3: iron age, sand and carbon (MU 10, 19)

Crucible rim sherd MU 19 superficially resembles MU 17 and represents a triangular vessel. The form of MU 10 cannot be reconstructed. Both sherds are completely reduced, and MU 19 is glazed and partially vitrified on both inner and outer faces. Fabric 3 is more compact than Fabric 2 and the packing quartz appears to be of a slightly coarser grade. Brownish iron ore is visible in both samples, and both are speckled with a moderate density of soft black inclusions (all < 0•5mm), presumably carbon. MU 10 and 19 are virtually identical in section, containing moderatley abundant, well-sorted quartz sand (average c 0•2mm) set in an isotropic matrix mixed with powdered charcoal and tabular fragments of burnt organic material. Sand grains account for 66% of fabric MU 10, and 59% of MU 19. A minimum of 75% of sand is present in Fabric 2, and it would seem that a portion of sand has been deliberately replaced by carbonaçeous material for the production of Fabric 3 vessels.

The bronze age moulds

Although the bronze age moulds recovered at Mucking vary considerably in colour and firing conditions (Table III.8.3), inner matrices appear homogeneous in hand specimen. All appear to have been prepared from an exceptionally fine-textured micaceous clay. Aside from tiny reddish patches of iron oxide, inner moulds seem inclusionless. Some variation, however, is evident in the preparation of the outer wraps. In some samples, the outer mould material is virtually indistinguishable from the inner matrix, whilst in others, the outer wrap is considerably coarser and contains obvious inclusions of quartz sand and rarely sandstone and flint. Representative grain size curves for inner and outer mould appear in fig III.8.7 (and see Plate 5c).

1. Fabric 4: inner mould, but can be used for outer wrap (inner - MU 4, 8; inner matrix of MU 9, 5; inner and outer - MU 6)

Thin sectioning confirmed the macroscopic observations described above. Fine, dense quartz is set in a generally anisotropic, ferruginous and micaceous clay matrix. Detrital minerals include plagioclase felspar and epidote. MU 8 is slightly coarser than the remaining Fabric 4 samples.

2. Fabric 5: outer mould (MU 7; outer wrap of MU 5 and 9)

In thin section, quartz grains of coarser grade than those observed in Fabric 4 are seen to be set in a highly ferruginous, anisotropic clay matrix. Mica and detrital minerals are present, though

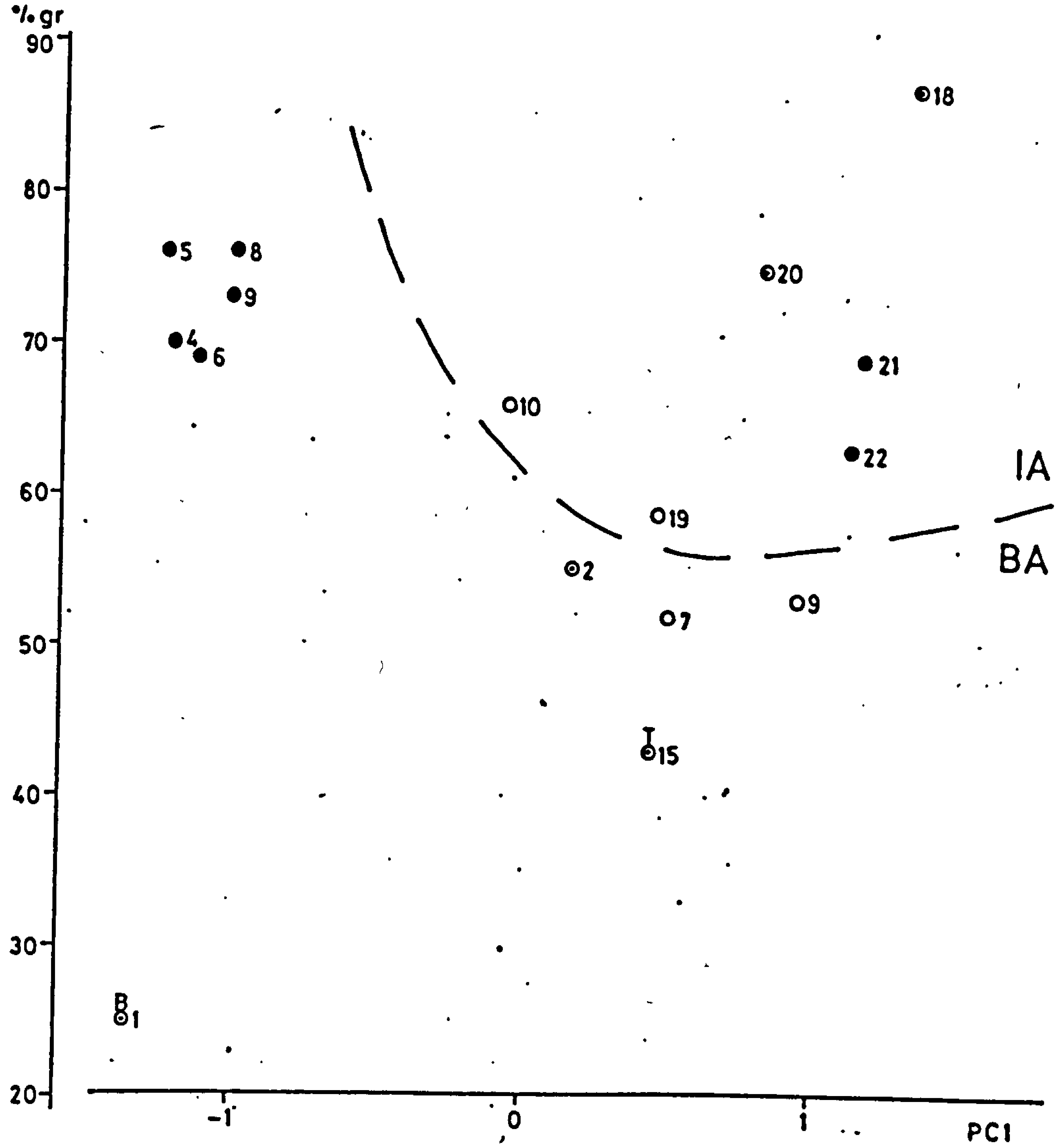

Fig III.8.5 Refractory fragments from Mucking, plotted against grain size (expressed by scores on the first principal component extracted from the Ø counts) and proportion of grains:matrix. Bronze age: ● inner mould; O outer mould; ⊙ crucible; ⊙T tuyere; ⊙B ? briquetage. Iron age: ● mould; O carbon crucible; ⊙ sand crucible.

much rarer than in Fabric 4. Although elongate impressions are visible on the outer face of MU 5, no organics or organically produced voids are present in the section. This suggests contact with fibrous material, perhaps during the drying process.

The iron age moulds

1. Fabric 6: cire perdue mould (MU 21, 22, 23)

Three fragments of ring mould were examined. In hand specimen, these fragments closely resemble iron age curcible Fabric 2, and can only be separated from the crucible sherds on the basis of typology and lack of surface slagging. In thin section, the iron age moulds are seen to contain a high tenor of well-sorted quartz (fig III.8.5 and 7) set in a partially isotropic clay matrix. No mica or other inclusions are visible. Microscopically this fabric is distinguished from crucible Fabric 2 by a lower firing/heating temperature (anisotropic zones are visible in the matrix), and by a somewhat higher clay content (fig III.8.5). It is suggested that the same or closely related sources were exploited for the production of both crucibles and moulds during the iron age at Mucking.

The tuyère

1. Fabric 7 (MU 15)

A tiny fragment was removed from tuyère mouth 754x325 (fig III.8.4) for analysis. The fine, sandy fabric is mainly oxidised to dark orange-red (2•5YR 6/8). A scatter of larger, rounded quartz inclusions, and very rare, tiny fragments of flint are visible in hand specimen. The clay appears to be slightly micaceous. Under the microscope, the tuyère fabric resembles that of the bronze age crucible MU 2. The matrix, however, is micaceous and anisotropic, and the ratio of grains to matrix differs somewhat from that recorded in the crucible sample (fig III.8.5). A few small (to 0•2mm) angular grains of brownish flint are visible, and detrital minerals include epidote, microcline and plagioclase felspar. An unidentified red mineral may be an alteration product caused by the penetration of metal oxides (Plate 9b).

Unidentified refractories, perhaps furnace

Two formless sherds, one from North Ring (MU 3), and one from an iron age context (MU 11) were tentatively identified as furnace remains. MU 3 contains exceptionally large inclusions of quartz and flint (to 3mm), and MU 11 also contains flint(to 0•5mm) and a scatter of soft dark brown and black inclusions. Both are extremely hard-fired and MU 3 appears to be totally vitrified. In thin section, although the outline of the larger inclusions can just be discerned, MU3 has completely

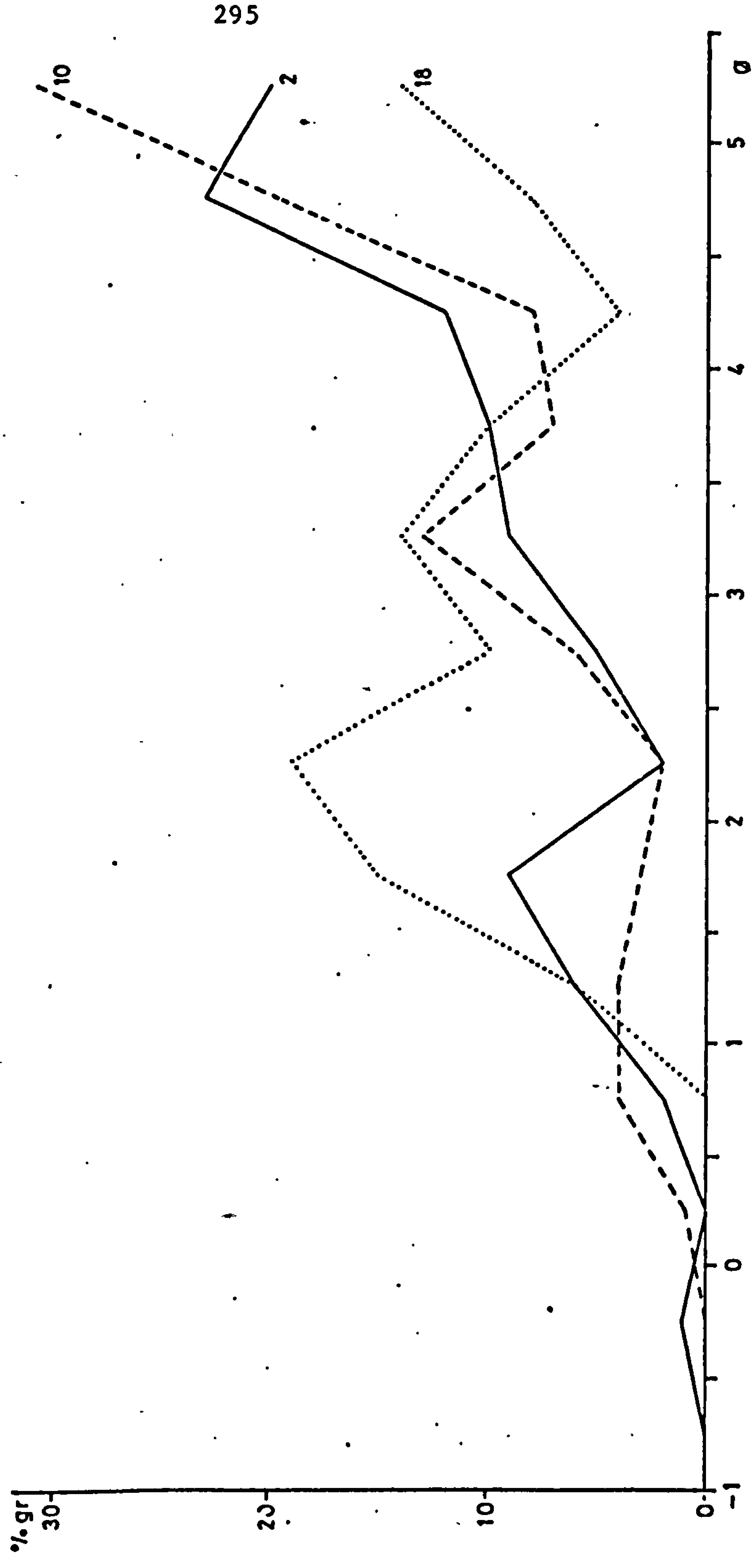

Fig III.8.6 Representative grain size curves for Mucking crucibles: bronze age (2), iron age sand and carbon fabric (10) and iron age sand fabric (18).

Fig III.8.7 Representative grain size curves for Mucking moulds: bronze age inner (9), bronze age outer (7) and iron age (22).

sintered to glass phase. The temperature at which this vitrification took place would far exceed that of the melting temperature of bronze.

Sherd MU 11 is not so highly fired although incipient vitrification is visible on one face. In thin section, the sample is seen to contain abundant fine quartz sand (few grains exceed 0•07mm) set in an isotropic, sparsely micaceous clay matrix. Large, tabular fragments of carbonised organic material are scattered throughout, but no fine carbon is present in the matrix. Sample MU 11 also contains rounded, ferruginous, micaceous clay pellets. Whilst the high-fired MU 3 would seem to have some connection with metalworking, formless MU 11 is dissimilat from all other fabrics examined, and cannot with certainty be identified as a prehistoric refractory.

III.8.3 Resource ecology and raw material sampling

Clay and sand abound in the area surrounding the Mucking site (fig III.8.8). The local London Clay is deemed "too heavy or rank" for brickmaking, although it has sometimes been used for making drainpipes. Most bricks in Essex have been made form the Claygate Beds and works were founded near major towns sited on these deposits during the 19th century. The local Brickearth has been worked to a limited extent (Dines and Edmunds, 1925, 47). Near Billericay railway station, the Bagshot Beds were dug for moulding sand. The Bagshot sand in this area is fine textured and contains considerable material other than quartz (Dines and Edmunds, 1925, 48). Samples were taken from each of these deposits save the Bagshot Beds. The old moulding sand pit is now completely built over. An additional sample was taken from the Thames alluvium, some 5km from Mucking.

Through comparison of the fired samples with the Mucking refractories, it was possible to eliminate the alluvium as a possible raw material source. The shape and size range of the quartz, and the mica/detrital content of the Brickearth sample (ESX 8) suggest that this deposit, rather than the even textured Claygate Beds, was exploited for the production of bronze age moulds. Sand (unlocated) may have been added to the slightly micaceous London Clay for bronze age crucible making. Both Brickearth and London Clay are available at or very close to Mucking.

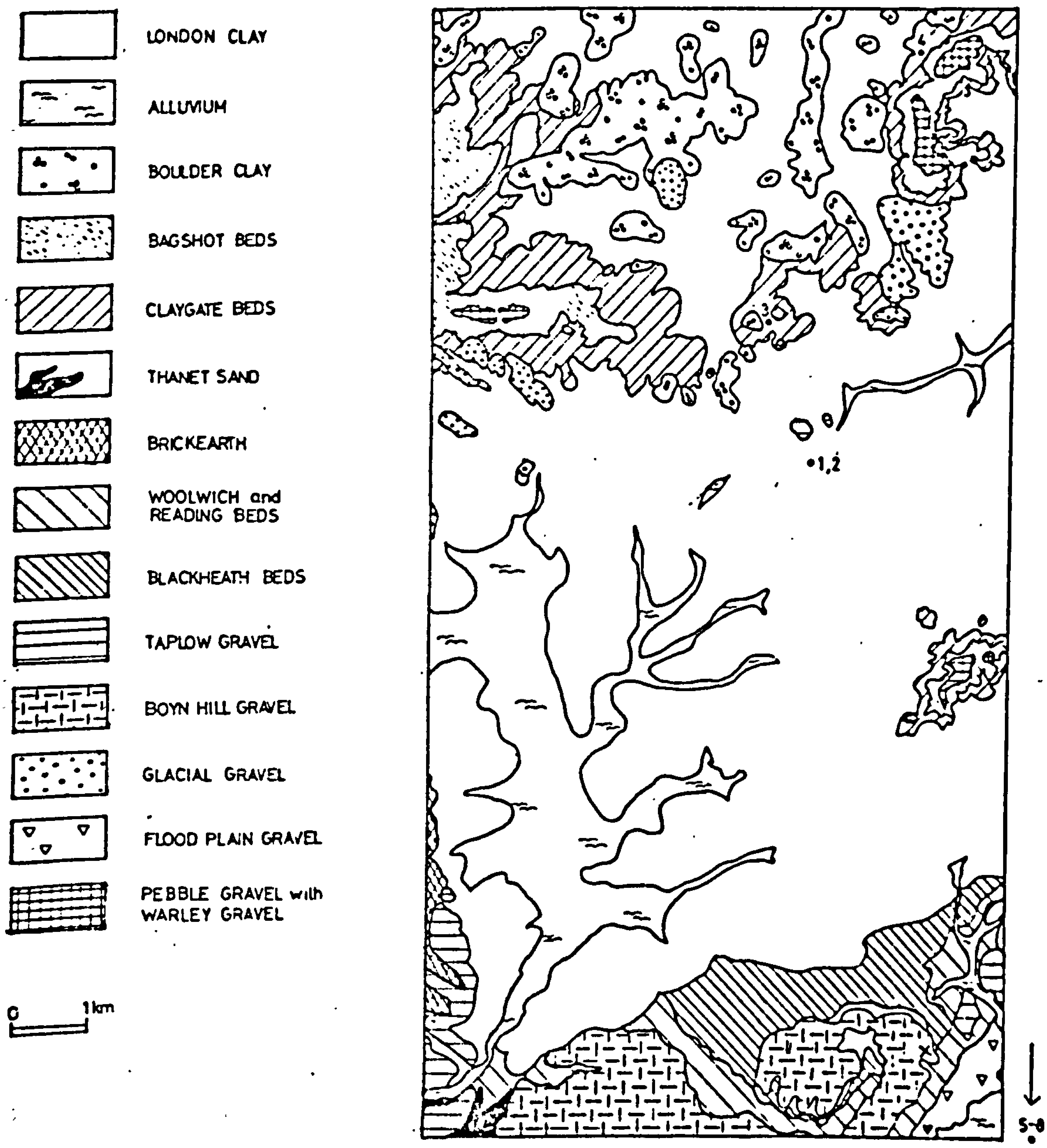

Fig III.8.8 Geology around Mucking, and location of raw material samples collected

Potential raw material sources for the sandy, non-micaceous iron age refractories were not located. Aside from the fine London Clay sample (ESX 3), all other clays collected were moderately micaceous. It is suggested that sources some distance from the site were exploited during the later occupation period at Mucking.

III.8.4 Discussion

Like the Breiddin, Mucking provides an opportunity for comparison of bronze age and iron age refractory technology. It is unfortunate that few securely contexted finds are available for examination, but the long duration of occupation at the site has inevitably resulted in repeated recutting of earlier features, and hence the mixing of material from different settlement areas. Few generalisations may be made, or interpretations offered, on the basis of results obtained to date, and attention is drawn to the 100+ kg of "fired clay" which still await processing.

Several interesting points have emerged from the current analyses, however, which merit discussion. Radiocarbon dates and the artefactual evidence obtained from both North and South Rings indicate that these sites were occupied at about the same period during the late bronze age. Contemporaneity of occupation is supported by an identical mould technology practised at both sites. Inner mould Fabric 4 and 'outer' Fabric 5 appear at both North and South Rings. Several hypotheses may be proposed to explain why bronze casting was apparently taking place at the same time in two areas separated by a mere kilometre. Thin blades, presumed to be sickles, are represented by the North Ring moulds, whilst the South Rings mould evidence attests the casting of spearheads and probably swords. Firstly, it is possible that two smith groups, versed in the same technological traditions, were each specialising by product to meet heavy demand. Secondly, North and South Rings may have been the domiciles of two high status leaders, each presiding over a limited territory (the middle bronze age barrow complex mapped in fig III.8.1, nos 2 to 7, may have served as a boundary demarcation), only one of whom 'posessed' a smith. In this case, the smith may have been 'traded' periodically to the smithless leader in return for goods or services.

Thirdly, the apparently structureless South Rings may have been in use for a very short period, the occupants moving (together with their smith) to a more appropriàte site.

In order to test the validity of these speculations, it would be necessary to know the full extent of late bronze age occupation at Mucking, the function(s) of the North and South Rings sites, and the duration of occupation. Further identifiable mould matrices would increase understanding of the full range of artefacts cast at each site. In the light of present knowledge, it is possible only to describe the Mucking bronze age refractory technology, and to note the careful and consistent (within the limited samples examined) preparation of local raw materials for inner and outer mould, and crucible production.

During the iron age different refractory formulae were in use, based on materials probably obtained some distance from the site. Cire perdue ring moulds and triangular crucibles were formed of sand bound with varying proportions (to 25% for sand crucibles and to 40% for moulds) of non-micaceous clay. A second crucible formula wherein a portion of silica was replaced by carbonaceous material attests the currency of two distinct iron age smithing traditions at Mucking. The chronological or spatial implications of these traditions are, however, unknown.

Sample MU 15 was taken from the best preserved tuyère on the site. Several such artefact have been recovered at Mucking, all from mixed bronze age/iron age contexts. Comparison with the only other large tuyère mouth from a British prehistoric context (from Glastonbury Lake Village: see below) indicates a different manufacturing tradition which may perhaps be chronologically defined. Until similar, well-stratified artefacts are recovered from other sites, however, it is not possible to suggest an industrial context for the Mucking tuyères.

TABLE III.8.1 MUCKING: RADIOCARBON DATES FROM BRONZE AGE OCCUPATION AREAS

Location	Date (bc)	Laboratory no
South Rings, outer ditch	820 ± 110	HAR 1634
South Rings, outer ditch	860 ± 70	HAR 1708
South Rings, inner ditch	840 ± 90	HAR 1630
North Ring, phase 2 ditch	680 ± 110	HAR 2893
North Ring, phase 2 ditch	750 ± 80	HAR 2911

TABLE III.8.2 MUCKING: CONCORDANCE OF "REFRACTORY" SHERDS

Sample no	Excavation number	Date of feature	Identification
MU 1	S23.C22.4509	BA	Fired ceramic, non-refractory
MU 2	S23.C387.4172	BA	crucible
MU 3	S23. C431.4253	BA	vitrified clay, ? metallurgical
MU 4	S23.C23.591	BA	mould, thin blade, ? sickle; inner + outer
MU 5	S23.C500.4216	BA	mould, knife or sickle; inner + outer
MU 6	S23.C551.4319	BA	mould, ? sickle; inner + outer
MU 7	Pit N109.E281	BA	mould, ? spearhead; outer
MU 8	Pit N159.E260	BA	mould, ? spear; inner
MU 9	Pit N159.E260	BA	mould, ? spear; inner + outer
MU 10	Ditch N2085.E680	IA	crucible
MU 11	Ditch N2085.E680	IA	? refractory
MU 12 *	Saxon hut N2061.E905	? residual BA	? mould; outer
MU 13 *	Posthole N2079.E650	IA	? refractory
MU 14	Ditch N2085.E680	IA	crucible
MU 15	Pit N754.E325	BA/IA	tuyère
MU 16	Pit N2108.E689	IA or ? Saxon	crucible
MU 17	Pit N1835.E845	IA	crucible
MU 18	Ditch N2105.E672	IA	crucible
MU 19	Pit N1835.E845	IA	crucible
MU 20	Ditch N2080.E668	IA	crucible
MU 21	Pit N2080.E668	IA	mould, ring
MU 22	Gully N2077.E651	IA	mould, ring
MU 23	Ditch N2085.E680	IA	mould, ? ingate
MU 24 *	Ditch N1055.E268	? BA	mould

* = not sectioned For location of samples 10-24, see fig III.8.1

TABLE III.8.3 MUCKING: COLOUR VARIATION IN BRONZE AGE MOULDS

Sample no	Inner valve	
MU 4	grey-black with small area 10YR 7/3	grey-black
MU 5	dark grey	variable; includes 7·5YR 5/4, 7·5YR 7/6 and 2·5YR 6/6
MU 6	mid grey	7·5YR 7/6 - 2·5YR 6/6
MU 7	-	10R 5/8 with white film on outer surface
MU 8	7·5YR 7/4 in part, but mainly mid grey	-
MU 9	mid grey	2·5YR 5/8 - 2·5YR 5/4

TABLE III.8.4 RAW MATERIAL SAMPLES: ESSEX

Sample no	Grid ref	Geological notes
ESX 1	TQ 652917	Claygate Beds
ESX 2	TQ 657896	London Clay: sandy sample
ESX 3	TQ 657896	London Clay: fine sample
ESX 4	TQ 673955	Claygate Beds
ESX 5 (S)	TQ 684777	Thanet Beds; sandpit
ESX 6	TQ 690767	Thames alluvium
ESX 7	TQ 657779	Thanet Sand
ESX 8	TQ 657779	Sandy brickearth over Thanet Sand

S = sand others = clay

DATE	OBJECT	SLIDE	% GR: MAT	NO. OF GRAINS	PHI -1 TO -.5	PHI -.5 TO 0	PHI 0 TO .5	PHI .5 TO 1	PHI 1 TO 1.5	PHI 1.5 TO 2	PHI 2 TO 2.5	PHI 2.5 TO 3	PHI 3 TO 3.5	PHI 3.5 TO 4	PHI 4 TO 4.5	PHI 4.5 TO 5	PHI 5 TO 5.5	MEAN GRAIN SIZE MM.	STD DEV
BA	CRUCIBLE																		
		2	55	99	0	1	0	2	6	9	2	5	9	10	12	23	20	.1170	3.30
	N SLIDES			1															
	N GRAINS			99															
	TUYERE																		
		15	43	84	0	0	0	1	5	5	6	12	12	12	15	15	17	.1069	1.89
	N SLIDES			1															
	N GRAINS			84															
	IN MOULD																		
		4	70	78	0	0	0	0	1	0	1	4	0	8	13	33	40	.0430	.340
		5	76	83	0	0	0	0	0	2	0	1	2	7	12	31	43	.0390	.262
		6	69	77	0	0	0	0	0	1	1	0	4	10	13	31	39	.0410	.246
		8	76	93	0	0	1	0	1	2	2	3	3	4	10	19	54	.0531	1.01
		9IN	73	82	0	0	0	0	2	1	2	1	5	5	5	29	49	.0463	.533
	N SLIDES			5															
	N GRAINS			413															
	OU MOULD																		
		1	25	84	0	0	0	0	1	0	1	0	1	6	8	35	48	.0361	.260
		7	52	92	0	0	0	3	3	3	11	11	12	15	7	10	25	.1108	2.18
		9OU	53	76	0	0	0	1	3	11	9	7	17	20	18	11	4	.1238	2.12
	N SLIDES			3															
	N GRAINS			252															
N				10															
N				848															
IA	MOULD																		
		21	69	101	0	0	0	0	2	9	21	20	17	5	2	8	17	.1335	2.16
		22	63	102	0	0	0	0	6	7	15	19	10	15	5	13	12	.1325	2.30
	N SLIDES			2															
	N GRAINS			203															
	CRUCIBLE																		
		10	66	98	0	0	1	4	4	3	2	6	13	7	8	20	31	.1026	2.69
		18	67	100	0	0	0	0	6	15	19	10	14	10	4	8	14	.1482	2.81
		19	59	97	0	0	0	0	3	10	18	11	6	6	8	11	26	.1157	1.99
		20	75	100	0	0	0	1	1	7	15	17	16	8	4	10	20	.1185	1.92
	N SLIDES			4															
	N GRAINS			395															
N				6															
N				598															
				16															
				1446															

Table III.8.5 Mucking: grain size statistics.

III.9 THE BREIDDIN, POWYS
(SJ 292144; corpus nos 4/33)

The striking, steep-sided mass of the Breiddin Hills rises some 366m from the south bank of the river Severn, 19km west of Shrewsbury. The hillfort consists of three linear banks cutting off some 30ha of rocky terrain to the south east of near vertical cliffs (fig III.9.1). Two fragments of late bronze age metalwork were recovered during early excavations at the site (O'Neil, 1937). Recent rescue excavations have demonstrated a sequence of settlement beginning in the eighth or ninth centuries BC and continuing, perhaps intermittently, throughout most of the iron age. The fort was reoccupied in the Roman period (Musson, 1970; 1972; 1976). Two radiocarbon determinations from the first of a series of ramparts (828 ± 71 bc - BM 879; 800 ± 41 bc - BM 878), and two further dates from interior features (710 ± 80 bc - HAR 1223; 610 ± 90 bc - HAE 1224) clearly identify the Breiddin as one of an emerging series of bronze age hillforts. Amongst the finds associated with the bronze age occupation phase were some 2000 sherds of coarse pottery, a scatter of metalworking debris, including crucibles and clay moulds, and several bronze objects. From one of these, a complete socketed axe with its carbonised shaft still intact, a C14 date of 754 ± 50 bc (BM 798) was obtained.

Two phases of iron age occupation have been detected, one represented by circular buildings set in shallow foundation trenches, and the other by rectangular structures built against the rear revetment. Charcoal from a burnt roundhouse produced a C14 date of 479 ± 55 bc (BM 881), whilst a sample dated to 238 ± 70 bc (BM 884) was derived from iron age contexts include material identified as 'VCP' or briquetage.

III.9.1 The metalworking evidence

At the north east corner of excavated Area B, lay a series of pits, furnaces and 'working hollows' (fig III.9.2). A date of 710 ± 80 bc (HAR 1223) was obtained from pit B5161, the largest of these features.

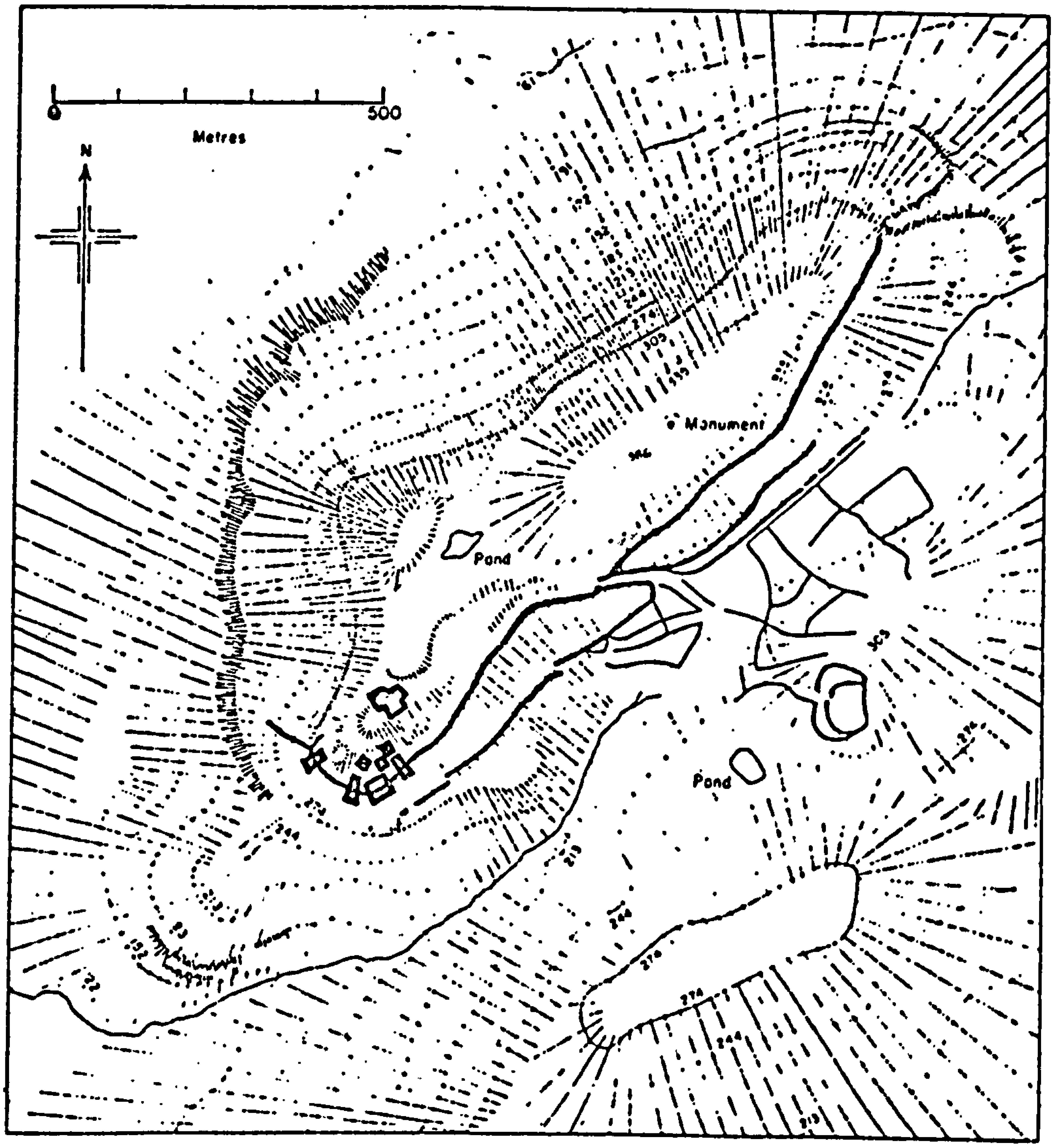

Fig III.9.1 The Breiddin: general site plan, with the recent excavations at the southern tip of the hill (after Musson, 1976)

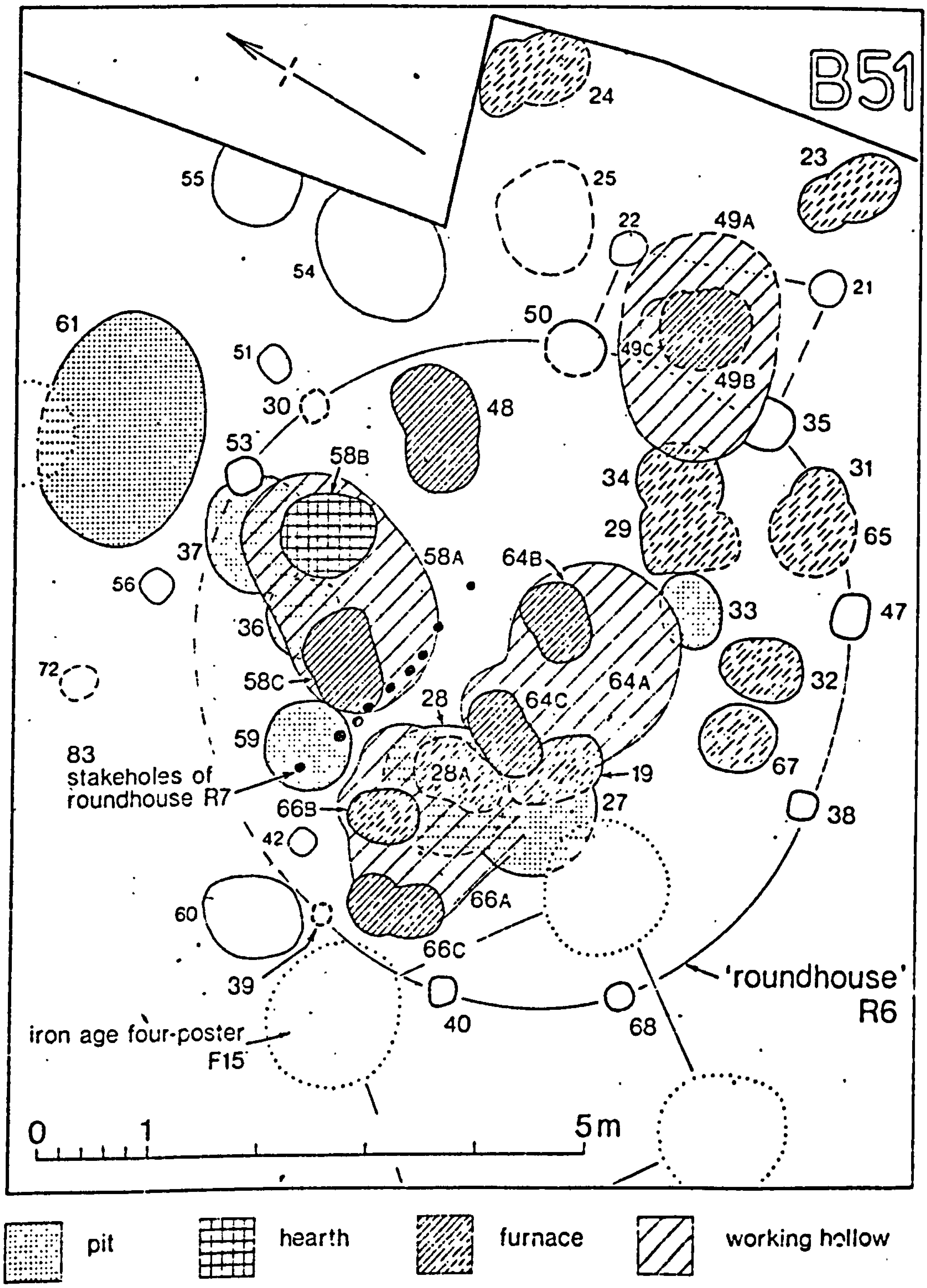

Fig III.9.2 Furnace area at the Breiddin, with bronze age features shaded (drawing supplied by C Musson). See fig III.9.4 for location.

Seven bowl shaped pits were identified, all of which (with the exception of B5161) were cut by small furnaces or shallow working hollows. Twelve certain or probable furnaces, varying in dimensions, were located within the excavated area (fig III.9.3). A combined charcoal sample from the fill of several of these features produced a radiocarbon date of 610 ± 90 bc (HAR 1224). Copper and iron-based slags in quantities consistent with the melting and purification of ingot or scrap metal have been identified from within the furnaces, and samples from the lining of furnace B5164 have yielded molecular traces of both copper and iron. This evidence, together with the recovery of several fragments of crucible and bivalve clay moulds from furnace fills, 'working hollows' and pit B1561, strongly suggest that these features be interpreted together as an industrial quarter where one or more epsiodes of bronze age casting activity took place (Musson, pers comm).

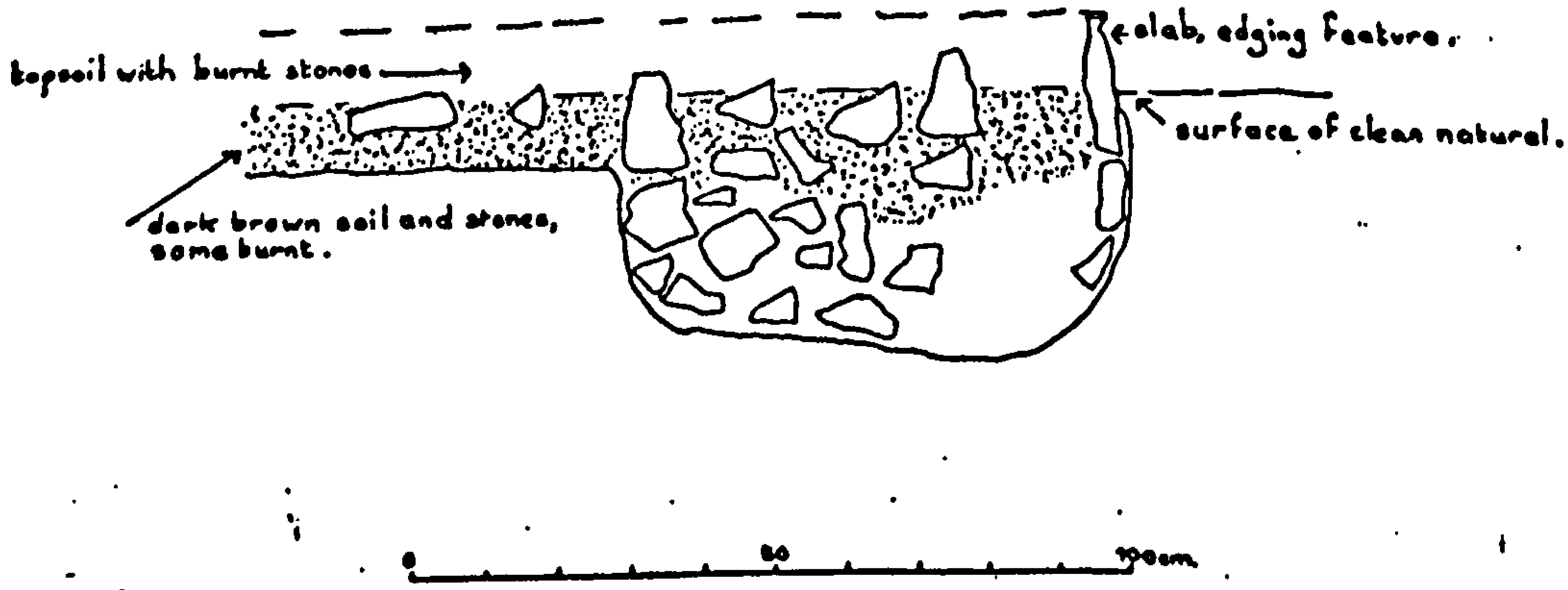

Fig III.9.3 Bronze age "furnace feature" B5164 NW, the Breiddin (after Musson).

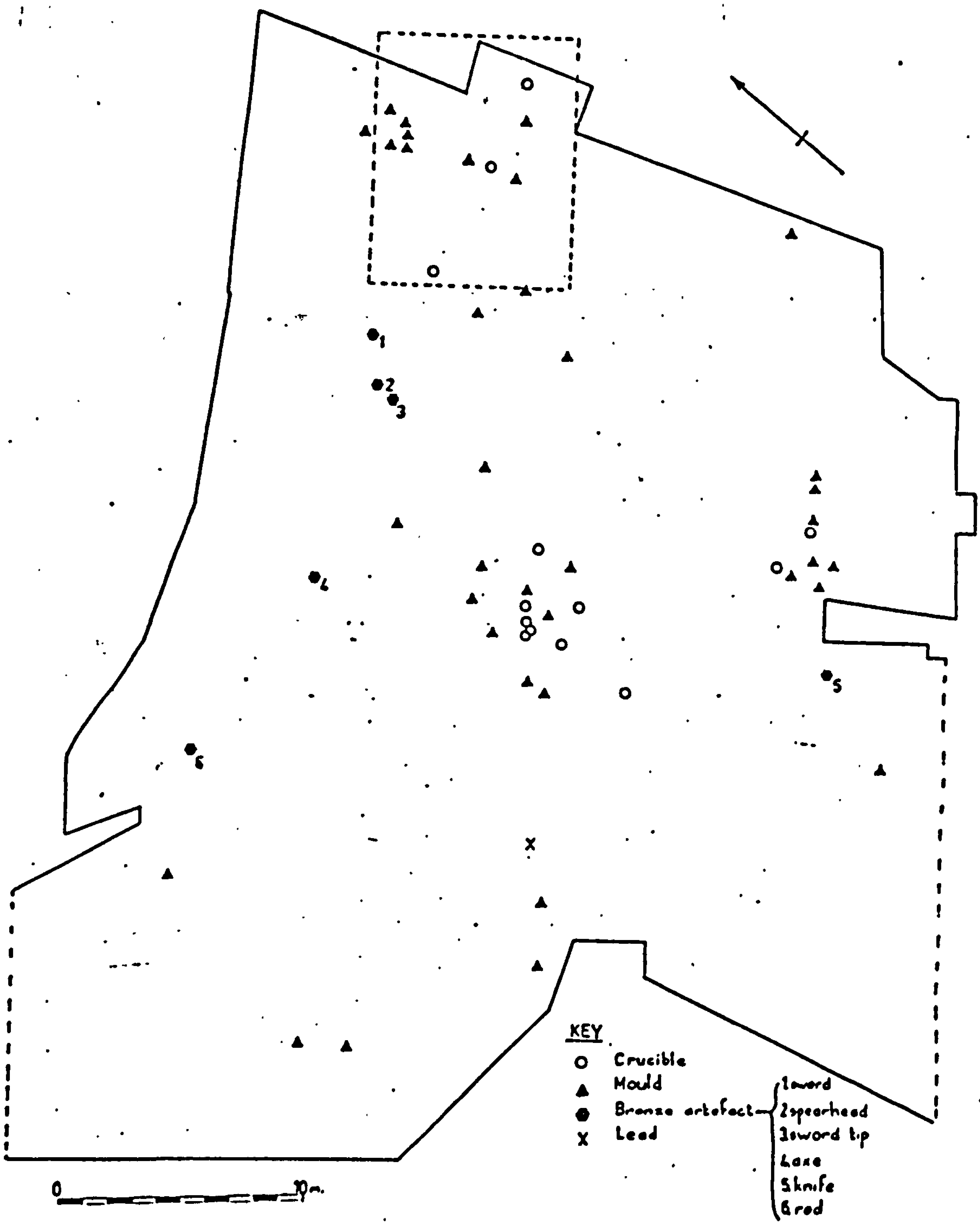

Fig III.9.4 Distribution of smithing debris in Area B3-4-5, The Breiddin. Rectangle at top is detailed in fig III.9.2 (after Musson)

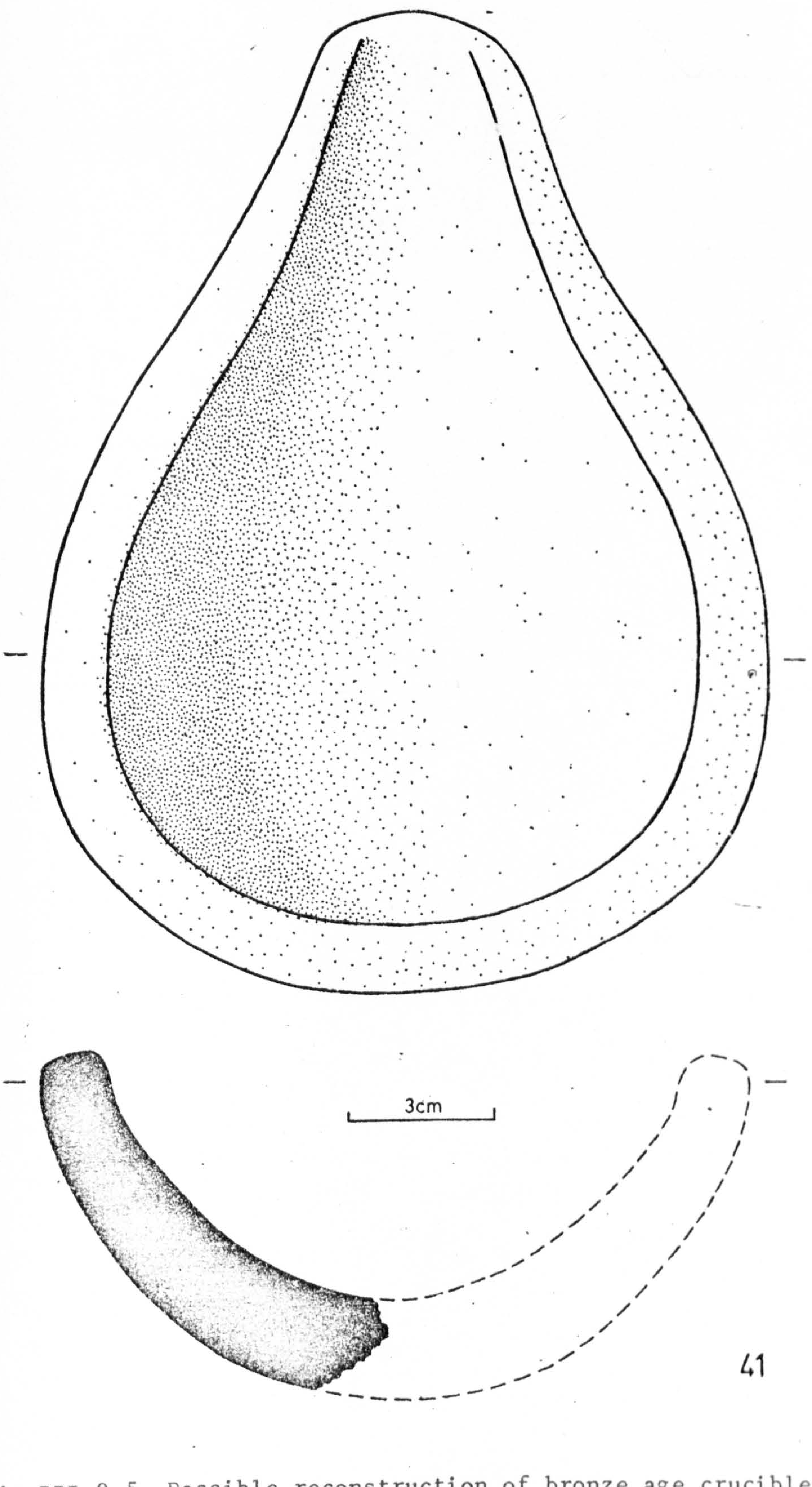

Fig III.9.5 Possible reconstruction of bronze age crucible BR 41 (after Musson).

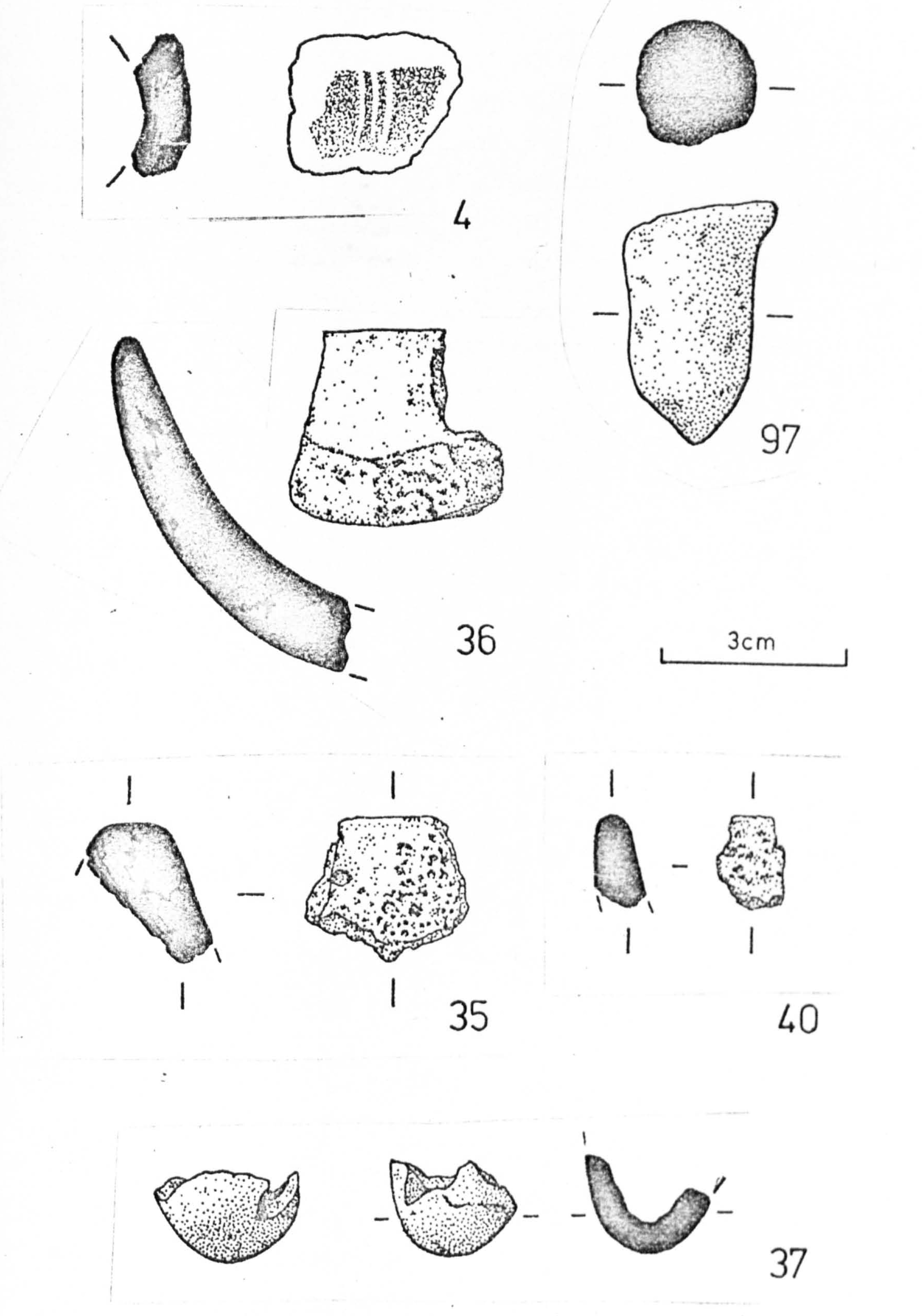

Fig III.9.6 Refractory sherds from the Breiddin:
Inner mould, probably spearhead socket (4);
crucible of possible bronze age/iron age transitional date (36); core from socketed sickle or knife (97);
iron age crucible sherds (35, 40); lost wax mould (37).

In addition to the refractory debris from the furnace quarter, crucible, mould and probable tuyère sherds were found widely spread across much of the excavated area (fig III.9.4). Parts of a large pear-shaped crucible (BR 41; fig III.9.5) were found some 20m west of the furnaces in shallow scoop B3705, and additional sherds which may derive from the same vessel were scattered around this feature. Other crucible fragments, dissimilar in form and fabric from BR 41 (a typical bronze age example) were unstratified in diverse areas of the site (fig III.9.4). Most of the bivalve mould sherds recovered are extremely abraded, and in only four cases is it possible to suggest the type of object cast. One fragment (BR 4; fig III.9.6) has been identified as part of a socketed spearhead mould, whilst the remaining definable matrices were probably for casting pins (BR 2), a socketed knife or spearhead (BR 67) and a sword (BR 85). A cylindrical clay object (BR 97; fig III.9.6) has been identified as the casting core from a socketed knife or razor (I am grateful to Stuart Needham for this identification). As such, it is unique in British prehistoric contexts.

Metal finds include a complete socketed axe, a Thornden type knife with repairs to the socket, and fragments of sword and spearhead. A folded wedge of lead was found in an iron age posthole (for location of metal finds, see fig III.9.4).

III.9.2 Analytical results (see Table III.9.1[1])

The crucibles

1. Fabric 1 (BR 23, 24, 27, 28, 32, 33, 34, 41a, 41b)

This coarse, gritty fabric has been carefully mixed and prepared. Outer surface colour varies from 7•5YR 6/4 (light brown) to 2•5YR 6/4 (light reddish brown). The inner surface is completely reduced. Well distributed angular inclusions of igneous rock, to 1mm across, are clearly visible on the surface and in fresh fracture. Although similar in oxidised colour to the mould fragments, crucible Fabric 1 sherds are

1. Table III.9.1 lists all refractory and possible refractory sherds from the site. Sectioned sherds only are referred to in the descriptions here.

easily distinguished by their coarser texture and abundance and relative size of inclusions.

Nine Fabric 1 sherds were examined in thin section. Both the rim and body of the large, most complete crucible (BR 41a and 41b; cf fig III.9.5) were sectioned to determine whether forming processes had resulted in a different distribution of mineral inclusions, and whether differential heating or contact with the molten metal had resulted in varied alteration products within the same vessel.

Under the microscope, the partially isotropic clay matrix is seen to contain a moderately high tenor of subangular quartz grains (generally to 0•08mm) and occasional grains of altered plagioclase felspar of similar size. Scattered throughout the matrix are abundant angular fragments of basic igneous rock (varying in size to about 1•0mm) composed of laths of altered plagioclase felspar, small quantities of potash felspar, a little ? epidote and relict augite, and rarely analcime. Further determination of the constituent minerals is not possible as all fragments present are heavily masked by alteration products of ferromagnesian minerals including iddingsite, occasional deep red grains of which occur within the matrix. The rock fragments are identified as dolerite (Plate 6b). Although generally similar, the nine Fabric 1 samples analysed display slight textural and mineralogical differences suggesting that they derive from more than one vessel (fig III.9.7). No differences were observed between the rim (BR 41a) and the body (BR 41b) of the large bronze age crucible.

2. Fabric 2 (BR 35, 36)

The distinctive, sharp-topped rim sherd BR 36 is derived from a well-made and smoothed crucible of unknown capacity. The fabric is reduced to mid-grey throughout, and abundant medium hard white and grey inclusions are visible on the surface and in fracture. The small, thick rim sherd BR 35 is heavily vitrified and slagged. The vesicular nature of this fabric and considerable slag penetration precludes the visual identification of any inclusions. A thin band of slaggy material appears, at one point, to penetrate the entire wall of the crucible, and the sherd was thin sectioned to test the hypothesis that the vessel had

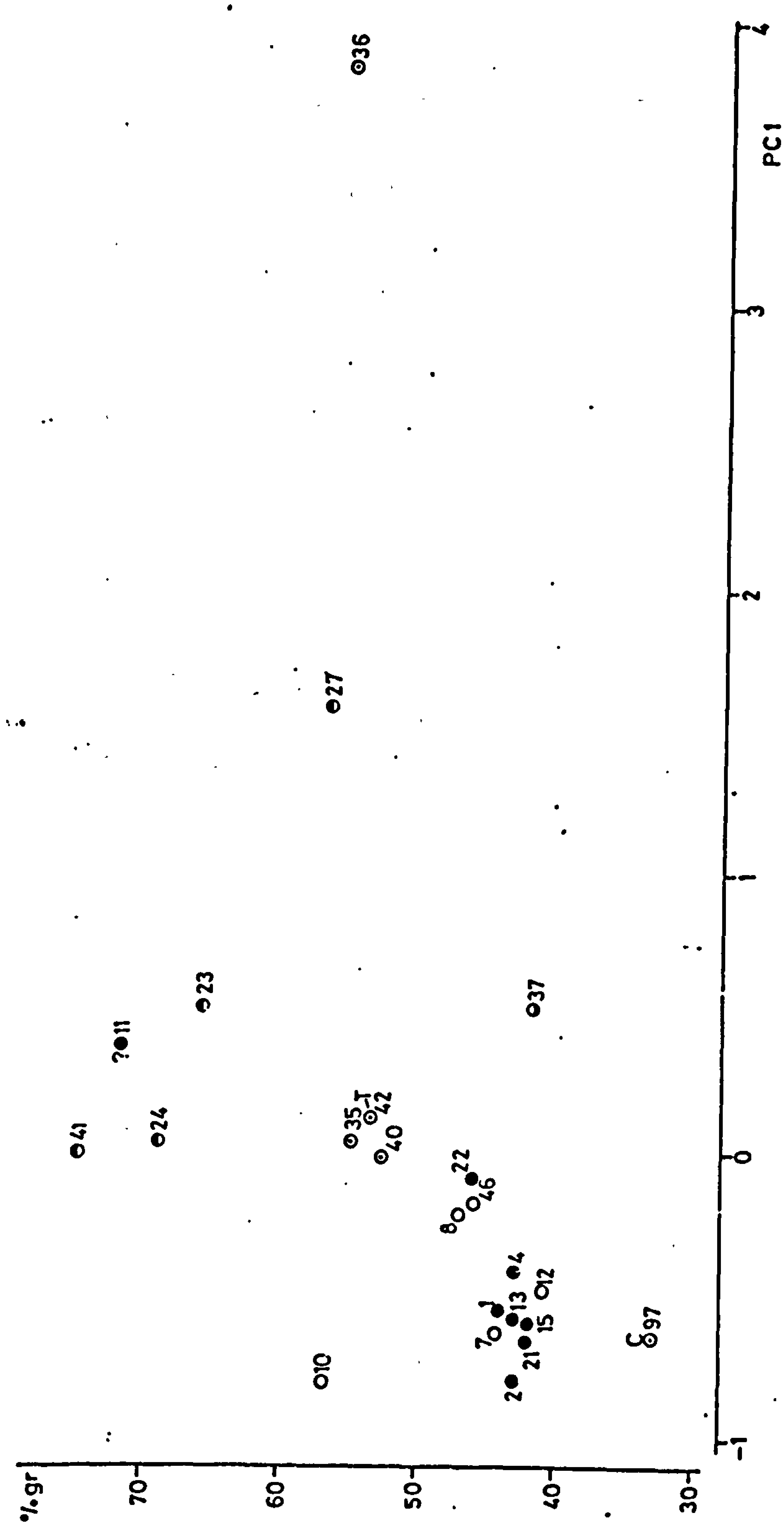

Fig III.9.7 Refractory sherds from the Breiddin, plotted against grain size (expressed by scores on the first principal component extracted from the Ø counts) and proportion of grains:matrix. BA: inner mould (●), outer mould (O), crucible (◉), core (◉C). IA: mould (⊖), crucible (⊖). Undated: tuyere (◉T).

been relined.

In thin section, the isotropic matrix of BR 36 is seen to contain frequent fine and medium grained siliceous sandstones (0•4-0•6mm) and a scatter of rounded and subangular quartz grains (to 0•3mm), some of which are heat crazed. Despite the heavy slagging visible in sample BR 35, a similar range of sandstone inclusions (although of generally smaller size) may be detected in thin section, suggesting the utilisation of the same or closely related raw materials. Under the microscope, crucible 35 shows positive evidence of relining. A distinct 1•0mm band of red slaggy material has been covered with a new layer of clay prior to the vessel's reuse (Plate 9a).

3. Fabric 3 (BR 37, 39, 38a)

This group consists of two abraded sherds from crucibles of indeterminate form, both recovered from iron age occupation soil behind the rampart, and a tiny sherd, tentatively identified as the base of a small (10-20mm high) crucible from Romano-British occupation levels. The form of this sherd (BR 37), fine fabric, and lack of slagging suggest it may, instead, perhaps represent the residue from *cire perdue* casting. All three sherds are extremely sandy and reduced to medium or dark grey throughout.

In thin section, the paste is characterised by a medium tenor (42% overall density) of fine quartz silt (to 0•08mm) and occasional larger quartz grains (to 0•5mm) which generally show signs of heat cracking. Two rounded, medium-grained sandstones are visible in BR 37, perhaps suggesting a source related to that of Fabric 2. Slag residues have permeated the bodies of both BR 37 and 39.

4. Fabric 4 (BR 40)

This tiny, lightly slagged rim sherd was found unstratified in the interior of the hillfort. The fabric is slightly vesicular and reduced throughout. Occasional medium-hard white inclusions are visible in fresh fracture, togethr with abundant finely divided carbon. In thin section, fine elongate fragments of charcoal predominate. A scatter of rounded quartz sand and occasional grains of siliceous sandstone are visible under the microscope.

The moulds

Two fabric variants were identified, representing the inner valves and outer wraps of bronze age bivalve moulds. Unfortunately, in only four cases (BR 2, 4, 67, 85) is it possible to identify the implement cast. Mould fabrics are noticeably finer than those of the various crucibles. Inner valves and outer wraps are recognised not by mineralogical differences, but by distinct methods of raw material preparation.

1. Fabric 5a: inner mould (BR 1, 2, 4, ?11, 13, 14, 15, 18, 20, 21, 22, 72, 93)

Inner valves are invariably fine, well-worked and smoothed, and appear inclusionless save for a scatter of tiny ferruginous clay pellets and the occasional glint of mica. These fragments are generally reduced to pale grey throughout most of their thickness, with outer faces sometimes remaining oxidised. Oxidised colours usually range from 7•5YR 7/4 to 7•5YR 6/4 (light brown) although light red (2•5YR 6/6) and light reddish brown (5YR 6/6) examples are occasionally recognised. Patches of these brighter colours sometimes occur on the more usual 7•5YR range, suggesting that variations result from inconsistent firing conditions as opposed to the use of different raw materials.

Thin section analysis reveals an optically anisotropic clay matrix containing a high density of fine angular and subangular quartz silt (particles rarely exceeding 0•05mm), occasional threads of white mica and rare fragments of plagioclase and potash felspar and epidote. Red-brown silty mudstones or shales (to 0•7mm) occur in the slightly coarser samples. Rounded grains of slightly micaceous snadstone all showing some degree of metamorphism are present in most sections. These sandstones are unlike those tempering crucibles BR 35 and 36. Dolerite, similar in texture and composition to that observed in the crucible sections, appears as single, tiny fragments in some inner moulds (Plate 6b). Variations in inclusion size range and packing density within Fabric 5a are described in fig III.9.7.

2. Fabric 5b: outer mould (BR 3, 5, 6, 7, 8, 9, 10, 12, 26, 46, 63, 95)

Outer mould fragments are coarser and more open textured than inner valves, and scatterd larger inclusions (to 1•5mm) usually dark or pinkish in colour are present in most samples. Clay pellets or mudstones abound, often standing proud from the abdraded outer surfaces. Voids, sometimes 'grain-shaped', and sometimes elongate indicating the burning out of residual carbon, serve to identify outer moulds. Fabric 5b fragments are almost invariably oxidised throughout to the same colour range as outer surfaces of inner valves. Colour variation across a single sherd is a common feature of outer moulds. BR 7, for example, is generally oxidised to 7;5YR 6/4, but also exhibits two brighter patches (5YR 6/4), whilst BR 8 varies from 2•5YR 6/6, to almost black on the inner surface.

Thin section analysis confirms that similar raw materials were used in the preparation of both inner and outer moulds. However, angular grains of dolerite tend to be large and more frequent in Fabric 5b than those observed in the inner valve sections (fig III.9.7). Inclusions are generally not so well distributed, and considerable banding is apparent, indicative of poor working of the clay. Rounded, ferruginous mudstones of varying size (to 2•0mm in some instances) are scattered throughout most sections. Although a little carbon is visible in some samples, this indicates improper cleaning of the clay rather than the deliberate addition of organic material.

3. Fabric 6: core (BR 97)

The knife or razor core from the Breiddin appears inclusionless in hand specimen. It has been formed from an exceptionally fine, perhaps levigated clay, which has turned pinkish-buff to orange (7•5YR 7/4 - 5YR 6/8) during the firing and casting process. In thin section, the Breiddin core is seen to contain a sparse-medium scatter of fine quartz sand set in a well worked anisotropic clay matrix. Overall, the fabric is finer that that of any other refractories from the site (fig III.9.7).

A few flecks of ? charcoal and abundant tiny grains of iron ore are well distributed throughout the section. Mica is present though rare. The core section contains two elongate fragments of an unidentified material, presumed to be organic. This material is yellow-orange in plain light, and the entire surface is pitted. In polarised light the fragments extinguish at approximately 40^{o} to the long axis (no cleavage is apparent), and any interference colours are masked by the colour of the constituent material. The presence of these unusual inclusions further distinguishes the core from the rest of the Breiddin assemblage (Plate 7a).

Tuyère/hearth: Fabric 7 (BR 38b, 43a, 44)

Four fragments of red-firing (2·5YR 6/8) powdery clay have been tentatively identified as hearth lining, or more probably tuyère. Two are from secure bronze age contexts whilst two (BR 38b and 42) are less securely stratified. These fragments (BR 42 and 44 are heavily slagged) are easily distinguished by their unusual fineness, powdery texture and bright red fired colour. A scatter of rounded, pinkish inclusions is just visible in hand specimen. In thin section, these sherds are characterised by a quartz-rich, slightly micaceous, silty matrix and sparse ragged and subrounded grains of argillaceous shadstone. Rare laths of plagioclase felspar are also present.

Pottery from bronze age contexts: Fabric 8 (BR 48-58)

Eleven bronze age pot sherds were examined macroscopically and in thin section for comparison with the refractory debris. Pottery fabrics are distinguished in hand specimen by generally much larger, angular stone temper, and by a fairly consistent dark brown to black surface colour. Thin sections are dominated by extremely large (some in excess of 3mm) fragments of dolerite set in an anisotropic, mica-free clay matrix. Free laths of plagioclase felspar and anhedral grains of epidote, presumably derived from the dolerite, constitute the only other inclusions common to all samples. Pottery matrices contain consistently less quartz than do any of the refractories examined (Plate 6c).

III.9.3 Resource ecology and raw material analysis

The Breiddin Hill itself is an intrusion of dolerite, and forms part of an Ordovician inlier some 10km long and 2•5km wide. Moel y Golfa immediately to the south is of andesite, whilst Upper Volcanic siliceous tuffs and coarse conglomerates form Middletown and Bulthy Hills to the south west (fig III.9.8). The entire inlier is limited on the north west by a fault under the Severn alluvium, and is overlain by Silurian rocks to the south east (Earp and Hains, 1971, 47). Clay and rock samples were taken from the Breiddin Hill and from all the different geological deposits within a c 15km radius of the site (fig III.9.8). The Buckbean pond area of the Breiddin which produced some of the refractory debris has been quarried away, but a sample of basal deposit from the pond had been retained for soil analysis., The sample was examined by Dr S Limbrey (University of Birmingham) who suggested a predominantly loessic component on the basis of high silt and low sand content (Limbrey, pers comm). The residue of the Buckbean pond sample was passed to the writer for petrological analysis (BRC 23).

Very little clay was available on the remains of the dolerite of the Breiddin Hill. A few small pockets of clay were located in the present quarry face, but these pockets were limited, and soon ran out into sand or rock. A sample (BRC 3) was taken from one of these pockets, and two further samples of similar material were collected from quarry spoil heaps (BRC 4 and 6). Samples BRC 1 and 2 were taken from New Pieces, the shoulder area between Breiddin Hill and Moel y Golfa, and geologically represent the junction between the dolerite and lower shales. The final sample from the Breiddin Hill was BRC 23, from the now disappeared Buckbean Pond.

All these samples contain abundant, large, sub-rounded fragments of dolerite, similar in composition to that observed in the archaeological material. Finer grained andesite, presumably derived from Moel y Golfa is visible in BRC 1 which also contains mudstone or fine shale. The matrices of these samples are extremely silty, and it is conceivable that any or all of these clays could have been used for bronze age refractory production. The presence of mudstone or shale in several of the mould fragments, points to a source in the direction of Moel y Golfa. The doleritic clays form the quarry face and from Buckbean Pond contain only igneous rocks.

In contrast to the Breiddin hilltop, good plastic clays are prolific along the banks of the Severn to the north of the site. Three closely located samples of slightly different appearance were taken from SJ 299167, south east of Llandinio Bridge (BRC 7, 8, 9). Samples BRC 7 and 8 are similar in fired colour and superficial appearance. However, whereas BRC 7 is inclusionless save for scattered fine-medium quartz and iron ore, BRC 8 additionally contains tiny fragments of dolerite, a little plagioclase felspar and sandstone with ferruginous cement. Sample BRC 9 is totally inclusionless save for a few ragged grains of iron oxide.

It is conceivable that one of these materials, perhaps BRC 7, may have served as the base clay for the Breiddin bronze age pottery. It is further conceivable that BRC 8 may have been used for mould production with the addition of a little sand to increase porosity and thermal shock resistance. The advantages of using the Severn alluvial clays lie in their abundance (limitless supplies are readily accessible), and the ease with which mould fabrics could be prepared without prior removal of rock and other inclusions. This is a lengthy process, requiring both skill and patience. The disadvantage lies in the physical relationship between the alluvial deposits and the hill-top site. It would have been no mean task to have carried quantities of clay from the valley floor up the 366m high Breiddin Hill.

Although it is possible that clays could have been brought to the site from other outcrops sampled in the course of this study, and modified (in the bronze age) by the addition of crushed igneous rock, the results obtained from analyses of both Breiddin Hill clays and Severn alluvium suggest that this was most unlikely.

Unfortunately, none of the samples examined contains the distinctive sandstones and high tenor of quartz sand present in crucible Fabrics 2 and 3. Pending further sampling and experimentation, it is suggested that siliceos materials were brought to the site form an area at present unlocated, and mixed with a fine alluvial clay (perhaps

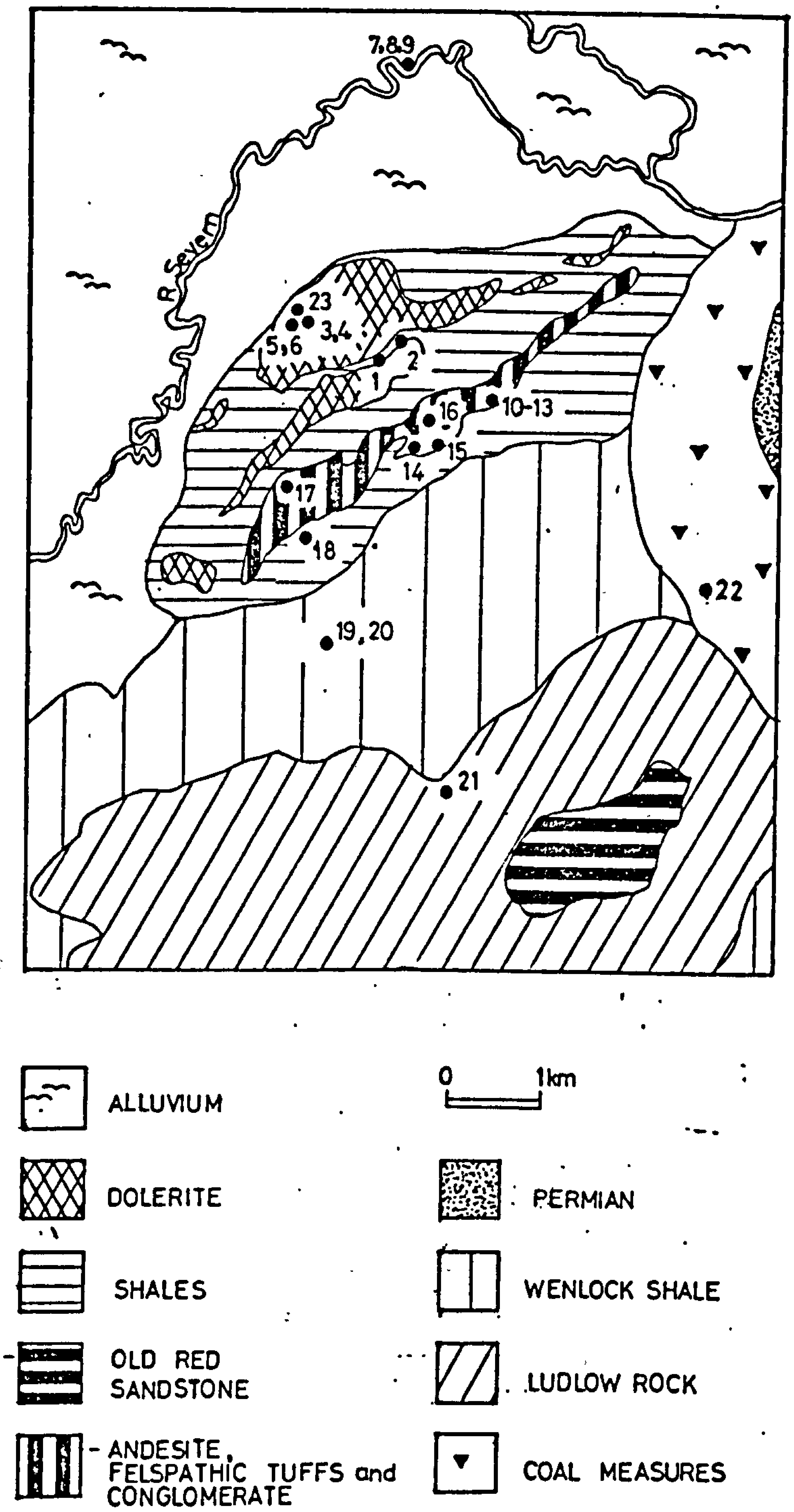

Fig III.9.8 Geology around the Breiddin (the source of sample number 23) and raw material samples

BRC 9?) for the production of these vessels.

III.9.4 Discussion

The Breiddin ceramics examined in the course of this study may be divided into two broad groups on the basis of fabric analysis. One group encompasses the large, pear-shaped crucible and related crucible sherds, the bivalve moulds (both inner valves and outer wraps) and the bronze age pottery. This group is distinguished by inclusions of dolerite rock and minerals derived from this rock. The second group includes the remaining curcibles from the site, the possible fragment of cire perdue casting mould and the tuyères or furnace fragments. This group is characterised by the lack of igneous inclusions and the presence of abundant sand and/or sandstone.

Stratigraphic data, typological information and fabric assessment allow group 1 material to be assigned with confidence to the late bronze age occupation period. Unfortunately, among the group 2 crucible sherds, only those representing Fabric 3 are securely stratified. Samples BR 38a and 39 were found in iron age occupation soil, whilst the possible mould fragment BR 37 came from a Roman deposit above prehistoric occupation layers. However, the careful selection of siliceous materials for the production of all group 2 crucibles suggests an overall iron age rather than bronze age date. Results obtained from all sites included in this study show that aside from rare examples of carbon pastes, iron age metalworkers invariably chose quartz sand (sometimes with additional quartzite or sandstone with siliceous cement) for crucible production, in preference to other potentially suitable raw materials. Typologically, the small crucibles represented by Fabrics 3 and 4, and sample BR 35 in Fabric 2 are appropriately assigned to the iron age. Less molten metal is required to cast ornaments and horse-gear than to cast weapons and implements. Iron age crucibles are thus smaller than those of the earlier period.

It is difficult, however, to suggest a date for sample BR 36.

Although the profile cannot be reconstructed, this sherd would seem to be derived from a well-finished, deep vessel of some considerable size. It is tempting to propose that this large crucible in siliceous fabric represents a transitional bronze age-iron age technology. This technology remains elusive, and relevant comparative material is all but absent. It is thus especially unfortunate that sample BE 36 was unstratified. Nevertheless, the form and fabric of this sherd do suggest that a transitional context may be appropriate.

During the bronze age occupation period at the Breiddin it is clear that similar raw materials were used for the manufacture of a wide range of ceramic products. However, distinct variations between mould, crucible and pottery fabrics show that different (though probably closely related) clay and temper sources and methods of paste preparation were deliberately selected to comply with the functional requirements of each artefact category (see Plate 6). These differences are reflected in quantity and size of igneous rock inclusions and matrix silt. It is clear from the results of textural analysis that rock fragments are more variable in size in outer than in inner moulds, and tend to occur more frequently. Crushed dolerite in the crucible sherds is larger and more frequent than that present in the moulds (see fig III.9.7), indicating different paste preparation methods. Dolerite used to temper the Breiddin bronze age pottery frequently exceeds 3mm across, and the small size of the sherds made textural analysis unfeasible. Again, however, similar raw materials were exploited and prepared in a manner different from that seen in refractory production.

Clay and rock analyses have shown that the materials used to produce all bronze age ceramic artefacts at the Breiddin were obtained on, or in close proximity to the site. It is suggested from inspection of both artefacts and raw materials that: (a) either dolerite and other obvious inclusions were removed from the stony local clay for mould making, or that alluvial clay with a little added sand constituted the paste for this artefact category; (b) crucibles were produced from local clays, but the size of the naturally included dolerite was reduced and made uniform by careful crushing; (c) crushed dolerite was added to a less silty clay for pottery making (all clay samples obtained in the Breiddin Hills are siltier than the pottery matrices). These different methods of preparation of closely located materials would seem to be functionally determined.

At some point during the history of the site a technological change took place and this change is manifest in the selection of completely different raw materials for refractory production. These new materials were collected from somewhat further afield, though the precise origin has not been located. The reasons for this change are not known, but it would seem that the silica tempered Breiddin crucibles are representative of a broader change in refractory technology which took place at about the time iron became economically viable in Britain (see Part IV, below).

The identification of permanent furnace features and associated working hollows at the Breiddin is unique in bronze age contexts. Indeed workshops and metalworking areas remain elusive for the whole of British prehistory. The Breiddin furnaces appear to have been located at the extremity of the settled area and have been recut several times, implying a lengthy period of use. Although a portion of the refractory debris was recovered in the furnace area, much similar material was widely spread across the site. If the furnace features had not been found, it would not have been possible, from the distribution of refractory debris, to predict where metalworking had taken place within the excavated areas at the Breiddin. The presence of carefully constructed furnaces indicates that a smith, or more probably a smith group, expert in the exploitation of local resources, was resident at the site for some period during the bronze age. With the single exception of pit/furnace 5149, which contains a sherd of salt-working debris and may have been in use during the iron age, all furnace features would seem to be securely dated to the late bronze age. There is no evidence to suggest that metalworking took place in the same industrial area during the later periods of occupation at the site.

TABLE III.9.1 THE BREIDDIN: CONCORDANCE OF EXAMINED CERAMIC DEBRIS

Sample number	Excavation number	Context date	Identification
BR 1 *	361401		inner mould
BR 2 *	140201	? BA	pin mould, inner
BR 3 *	377906	? BA	outer mould
BR 4 *	360106		inner mould; ? spearhead
BR 5 *	516144	710 bc	mould, ? outer
BR 6 *	520403		mould, ? outer
BR 7 *	510704		mould, ? outer
BR 8 *	049103	IA	mould, ? outer
BR 9 *	049176	IA	mould, outer
BR 10 *	045323	? BA	mould, outer
BR 11 *	045320	? BA	mould, ? inner
BR 12 *	040821	IA	mould, outer
BR 13 *	370305		mould, inner
BR 14 *	370201		mould, inner
BR 15 *	370202		mould, inner
BR 16	510205		? pottery
BR 17	514801		not metallurgical, unless furnace or outer mould
BR 18 *	514905		mould, inner (overfired)
BR 19	514932		no firm identification
BR 20 *	516117	BA	mould, inner
BR 21 *	516201	IA	mould, inner
BR 22 *	520306		mould, inner
BR 23 *	520307		crucible
BR 24 *	3701B		crucible
BR 25	370306		crucible
BR 26 *	370320		? outer mould
BR 27 *	363722		crucible
BR 28 *	370501-04	BA	crucible fabric, but smooth
BR 29	520202		mould, outer
BR 30	520305		mould, inner
BR 31	520304		mould, inner
BR 32 *	520310		crucible
BR 33 *	3701A		crucible
BR 34 *	370304		(? crucible)
BR 35 *	709701		crucible (relined)
BR 36 *	040722		crucible
BR 37 *	144503	Roman	crucible, or cire perdue mould
BR 38b *	105320	IA	tuyere/furnace end ?
BR 38a *	105320	IA	crucible
BR 39 *	145908	IA	crucible
BR 40	510807		crucible
BR 41 *	370501	BA	crucible
BR 42	115901	BA	tuyere/furnace end ?
BR 43a *	118001	BA	? tuyere
BR 43b	118001	BA	? pottery
BR 44 *	118002	BA	tuyere/hearth
BR 45	516603		? domestic
BR 46 *	520312		mould, outer
BR 47	510528		crucible (or mould, outer)
BR 48-58 *	various	BA	late bronze age pottery
BR 59	040406		crucible
BR 60	041450	BA	outer mould or sprue cup
BR 61	140727	BA	mould, ? outer
BR 62	140729	BA	mould, ? inner
BR 63 *	167801	BA	mould, inner + ? outer

BR 64	321033	? BA	not metallurgical ? (white clay)
BR 65	3705	BA	mould, inner
BR 66	506804	IA	mould, inner
BR 67	506902		mould, inner (knife or spearhead ?)
BR 68	510501	BA	not metallurgical ?
BR 69	515806	BA	domestic
BR 70	516114	BA	mould, outer (+ inner ?)
BR 71	516122	BA	mould, inner (refired)
BR 72 *	516160	BA	mould, outer or inner
BR 73	516411	? BA	not metallurgical ?
BR 74	516414	? BA	mould, outer
BR 75	516905	IA	mould, inner (abraded)
BR 76	507901	IA	mould, inner
BR 77	520304		mould, ? outer
BR 78	140730	BA	mould, outer
BR 79	041408	BA	domestic
BR 80	321413	? BA	mould, outer; luting at gate (thong marks ?)
BR 81	520315(2)		mould, inner; plus uncertain
BR 82	350902	IA	mould, inner + ? outer
BR 83	370411	IA	mould, ? outer (thong marks ?)
BR 84	410434		mould, inner
BR 85	156008	Roman	mould, inner (? sword)
BR 86	154607	IA	inner mould fabric (? end of gate)
BR 87	365510		not metallurgical
BR 88	370322		mould, inner
BR 89	149110	IA	? mould, ? outer (or domestic ?)
BR 90	350106		mould, ? outer
BR 91	520407		mould, inner
BR 92	022802		mould, inner
BR 93 *	047301	IA	mould, outer + ? inner
BR 94	400342		mould, ? outer
BR 95 *	410113		mould, ? outer
BR 96	023603	? BA	domestic
BR 97	329802	BA	core

* = sectioned sherds

TABLE III.9.2 RAW MATERIAL SAMPLES: WELSH BORDERLAND

Sample no	Grid ref	Geological notes
BRC 1	SJ 296139	junction of dolerite and Lower Shales; sparse clay
BRC 2	SJ 298144	Lower Shales; sparse clay
BRC 3	SJ 292143	Dolerite; sparse clay interbedded with sand
BRC 4	SJ 292143	Dolerite; clay pocket in quarry face
BRR 5	SJ 292144	Dolerite; samples showing textural variations
BRC 6	SJ 292144	Dolerite; outwashed clay from spoilheap
BRC 7-9	SJ 299167	Severn alluvium; variable textured and coloured clays
BRR 10	SJ 299130	Barytes seam in conglomerate
BRR 11	SJ 299130	Linear quarry; andesite and conglomerate
BRR 12	SJ 299130	Linear quarry; barytes, andesite and "felsite"
BRC 13	SJ 299130	Linear quarry; clay pocket between barytes and conglomerate
BRC 14	SJ 300127	clay pocket in volcanic tuffs and conglomerates with shale seams
BRC 15	SJ 300128	solid geology as BRC 14; clay pocket on shale
BRR 16	SJ 301131	andesitic conglomerate with "bomb" inclusions
BRR 17	SJ 292127	andesite
BRC 18	SJ 289118	clay on shale; Llandovery Series, Silurian
BRC 19-20	SJ 293109	alluvial stream clay
BRC 21	SJ 310095	
BRC 22	SJ 346108	
BRC 23	SJ 292144	sample taken during archaeological excavations

BRC = clay BRR = rock

DA TE	OBJECT	SLIDE	% GR MAT	NO. OF GRAINS	PHI -1 TO -.5	PHI -.5 TO 0	PHI 0 TO .5	PHI .5 TO 1	PHI 1 TO 1.5	PHI 1.5 TO 2	PHI 2 TO 2.5	PHI 2.5 TO 3	PHI 3 TO 3.5	PHI 3.5 TO 4	PHI 4 TO 4.5	PHI 4.5 TO 5	PHI 5 TO 5.5	MEAN GRAIN SIZE MM.	STD DEV
BA	CRUCIBLE																		
		23	66	130	0	2	2	5	4	3	2	2	2	2	4	27	46	.1191	5.38
		24	69	58	0	2	3	2	5	0	2	0	0	3	7	31	45	.1044	5.01
		27	57	129	2	1	5	8	6	4	4	4	0	3	2	17	61	.2096	11.9
		41	75	60	3	5	5	0	2	0	0	2	0	5	8	28	42	.1701	13.1
	N SLIDES			4															
	N GRAINS			377															
	TUYERE																		
		42	54	78	0	0	1	0	0	5	0	3	1	3	5	18	64	.0492	.978
	N SLIDES			1															
	N GRAINS			78															
	CORE																		
		57	33	78	1	0	0	0	1	0	0	0	0	3	6	24	64	.0421	1.80
	N SLIDES			1															
	N GRAINS			78															
	IN MOULD																		
		1	44	79	0	0	0	0	0	0	0	0	1	7	11	18	63	.0291	.092
		11	72	86	0	0	0	2	2	3	3	2	1	1	5	15	64	.0568	1.19
		13	43	52	0	0	0	0	0	0	0	1	1	5	10	24	59	.0299	.103
		15	42	80	0	0	0	0	0	0	0	1	3	7	7	32	50	.0333	.130
		2	43	71	0	0	0	0	0	0	0	0	0	1	7	22	70	.0239	.051
		21	42	72	0	0	0	0	0	0	0	0	0	4	9	18	69	.0257	.065
		22	46	81	0	0	0	0	0	0	1	4	4	6	13	28	44	.0408	.233
		4	43	75	0	0	0	0	0	0	1	2	5	3	6	30	53	.0352	.180
	N SLIDES			8															
	N GRAINS			626															
	OU MOULD																		
		10	57	78	0	0	0	0	0	0	0	0	1	1	9	26	63	.0263	.067
		12	41	87	0	0	0	1	0	1	1	0	2	7	9	33	46	.0418	.474
		46	46	53	0	0	0	0	0	0	0	2	6	6	24	28	34	.0421	.202
		7	44	80	0	1	0	0	0	1	0	0	1	3	8	24	63	.0403	1.19
		8	47	71	0	3	0	1	0	0	1	3	1	1	14	28	46	.0717	3.58
	N SLIDES			5															
	N GRAINS			366															
N				19															
N				1525															
IA	MOULD																		
		37	42	67	0	0	1	0	0	2	3	3	6	11	9	17	46	.0571	.970
	N SLIDES			1															
	N GRAINS			67															
	CRUCIBLE																		
		35	55	86	0	0	1	1	1	0	1	2	5	12	8	22	47	.0565	1.15
		36	56	94	0	0	0	0	11	11	13	11	2	6	11	10	30	.1311	2.80
		40	53	79	0	0	0	0	1	1	3	1	0	1	5	24	63	.0367	.368
	N SLIDES			3															
	N GRAINS			259															
N				4															
N				346															
				23															
				1871															

Table III.9. The Breiddin: grain size statistics.